Vol. 14, No. 03, pp. 1728-1753, 2024 DOI: 10.23960/jpp.v14.i3.2024118

Jurnal Pendidikan Progresif

e-ISSN: 2550-1313 | p-ISSN: 2087-9849

http://jurnal.fkip.unila.ac.id/index.php/jpp/

Understanding Students' Struggles in Solving Mathematical Problems: A Systematic Literature Review Using Polya's Framework

Abdul Wahab A[1*], Yaya S Kusuma[1*], Dadang Juandi , Turmudi[1], Buhaerah[2], & Syaiful[3]

[1]Department of Mathematics Education, Universitas Pendidikan Indonesia, Indonesia

[2]Department of Mathematics Education, Institut Agama Islam Negeri Parepare, Indonesia

[3]School of Education, The University of Adelaide, Australia

*Corresponding email: yskusumah@upi.edu

Received: 18 November 2024 Accepted: 05 December 2024 Published: 17 December 2024

Abstract: Understanding Students' Struggles in Solving Mathematical Problems: A Systematic Literature Review Using Polya's Framework. Objective: This study aims to identify the specific challenges faced by students in solving mathematical problems at each stage of Polya's problem-solving framework: understanding the problem, devising a plan, carrying out the plan, and looking back. **Methods:** The research focuses on the context of mathematics education in Indonesia, using a systematic literature review (SLR) methodology. A total of 48 articles published in accredited journals (2019–2023) were systematically analyzed, based on inclusion criteria that involved Polya's framework, the education levels of elementary to high school, and mathematical problem-solving contexts. **Findings:** Challenges at the understanding the problem stage include low motivation, lack of concentration, poor reading literacy, weak mathematical communication, conceptual misunderstandings, and reasoning deficiencies. In the devising a plan stage, students struggle with cognitive gaps, misconceptions, weak connections between mathematical concepts, difficulties in mathematical modeling, and lack of organizational skills. At the carrying out the plan stage, procedural errors, misconceptions, and inaccuracy are the primary obstacles. Finally, at the looking back stage, motivational issues, inadequate evaluation, errors in interpreting results, and lack of thoroughness persist. **Conclusion:** This research highlights the need for targeted teaching strategies, such as strengthening students' reading literacy, addressing misconceptions, and fostering deeper conceptual understanding through collaborative and problem-based learning. Furthermore, the study emphasizes designing interventions tailored to each stage of Polya's framework to enhance students' problem-solving abilities in mathematics education.

Keywords: systematic literature review, mathematical problem solving, polya framework, student challenges.

To cite this article:

Wahab, A. A., Kusuma, Y. S., Juandi, D., Turmudi, Buhaerah, & Syaiful. (2024). Understanding Students' Struggles in Solving Mathematical Problems: A Systematic Literature Review Using Polya's Framework. *Jurnal Pendidikan Progresif*, *14*(3), 1728-1753. doi: 10.23960/jpp.v14.i3.2024118.

INTRODUCTION

The challenges faced by students in solving mathematical problems have become one of the main focuses in mathematics education research (Klang et al., 2021; Tambychik & Meerah, 2010). The study of problem solving skills is essential for students, because it not only improves their mathematical understanding, but also develops critical thinking skills (Varveris et al., 2023). In addition, this ability also involves the use of analytical thinking skills that help students to understand problems in depth, plan effective solutions, and evaluate results, which are part of these skills essential in almost all academic and professional fields (Chand et al., 2021).

Moreover, the framework (Polya, 1978), which outlines four steps in problem solving—understanding the problem, planning a solution, implementing the plan, and looking back—has been widely adopted in the analysis of student problem solving. Research results (Malikah, 2023; Perkasa & Astuti, 2022; Wahab, 2022) showed that only students with high ability are able to complete each stage of Polya, while students with low ability almost all fail at each stage of Polya. Other research (M. K. Wardhani & Nduru, 2023) suggests that the stage is most often forgotten as a result of which errors often occur in both the results of the solution and the formula used, whereas in research (Rachmawati & Adirakasiwi, 2021) the percentage of student achievement at the problem understanding stage is the lowest. Furthermore (Prastiyo et al., 2023) in their study stated that many students did not make a solution plan and immediately wrote the results of their answers. This shows that the findings present different information in each study he examined.

Primarily, students' inability at the problem solving stage shows that there are some challenges that students face when solving problems (Wahab A et al., 2023). In the process of student errors in solving problems can be caused by problematic parts of the cognitive structure, either because they are disorganized, disconnected or have cognitive holes (Buhaerah et al., 2023). For example, (Hartuti & Firmansyah, 2023) found that challenging students' knowledge of the required material is very important in students' mathematical problem solving abilities, which play a role in a unified and interconnected student cognitive structure (Wahab A et al., 2022). A study conducted (Ramadhani et al., 2024) suggests that literacy skills are also a challenge for students in understanding and planning solutions to mathematical problems. His research notes that students with good literacy may be more likely to understand complex problems. Besides, the findings (Sen, 2022) suggest that students' ability to solve mathematics problems is greatly influenced by their motivation to learn, achievement, self-confidence and their emotional state about mathematics. Meanwhile, lack of understanding of questions, forgetting concepts, not mastering the steps in solving problems, not being used to writing conclusions, and not being able to translate questions into mathematical models (Chand et al., 2021) low quality of teaching, and lack of effective teaching methods can be a factor in the lack problem solving abilities.

Previous research has identified several common challenges faced by students in solving mathematical problems. While the Polya framework has been widely applied, a systematic review is still needed to synthesize the existing literature and identify the specific difficulties that students encounter at each stage. This research aims to fill this gap by conducting a systematic literature review (SLR) to synthesize information on the challenges students face in solving mathematics problems based on Polya's framework. The review focuses on studies conducted in elementary, middle, and high schools in Indonesia, with the goal of providing a comprehensive understanding of these challenges.

Overall, this research addresses a critical need in mathematics education by systematically reviewing and synthesizing literature on student problem-solving challenges based on the Polya framework. It is hoped that this study will provide a deeper understanding of these difficulties and offer practical recommendations for improving mathematics education in Indonesian schools. Based on the aforementioned description, the research aims to answer the following research questions:

1. RQ1: What are the trends in student problem-solving studies based on the Polya framework?
2. RQ2: What factors contribute to students' problem-solving difficulties at the Understanding the Problem stage?
3. RQ3: What factors contribute to students' problem-solving difficulties at the Devising a Plan stage?
4. RQ4: What factors contribute to students' problem-solving difficulties at the Carrying Out the Plan stage?
5. RQ5: What factors contribute to students' problem-solving difficulties at the Looking Back stage?

METHOD

This article is a systematic literature review (SLR) which aims to synthesize information in the field related to students' challenges in solving mathematics problems at school based on the Polya framework. This analysis can help map or recommend future problem-solving research priorities. Analysis of various publications will be able to answer questions regarding research problems and provide recommendations for further research (Dang & Nguyen, 2024). Before starting the review, a study protocol was established, circulated to all authors, and discussed until consensus was reached. The systematic literature review process adopts guidelines from the Cochrane Handbook for Systematic Review Guidelines and Reporting (Higgins & Green, 2023). The following paragraphs describe the process in more detail.

Eligibility and Selection Criteria

Eligibility criteria include (i) studies that focus on analyzing students' difficulties in solving mathematical problems based on the Polya theoretical framework (ii) Studies conducted in schools at the Indonesian Elementary School, Middle School and High School levels. (iii) Published in a SINTA-accredited journal from the Ministry of Education and Culture of the Republic of Indonesia or indexed by Scopus, (vi) between 2019 and 2023. These eligibility criteria are determined through abstract review and then proceed to detailed full text. We excluded theoretical articles due to the absence of empirical data and results, in addition to protocols, non-peer reviewed conference papers, opinion pieces, news articles, informal reporting on students' mathematical problem solving based on Polya theory.

Data Source and Search Strategy

Researchers conducted a comprehensive literature search using the electronic database Publish or Perish 8 (Windows GUI edition). We use the title words: "Analisis Pemecahan Masalah Matematika" and "Mathematical Problem Solving Analysis" then the keywords "Teori Polya" and "Polya Theory" to cover all articles published in Indonesian and English.

Data Management

Next, the RIS file from Perish Software is downloaded and then imported into the Covidence software management. This software facilitates the systematic review process with an intuitive interface, online team collaboration, and supports important steps such as reference screening and effective conflict resolution (Babineau, 2014). All steps of the data management process are carried out with Covidence, the results of which are extracted into a more systematic Excel spreadsheet. Covidence has sought to ensure researchers conduct systematic literature reviews in a more efficient and organized manner (Cleo et al., 2019).

Study Selection

The process used for study selection is detailed in the Preferred Reporting Items for Systematic Reviews [PRISMA] flow diagram.

All searches imported from Perish are processed selectively including filtering the title, and if necessary, the abstract, to determine relevance. The remaining papers were further filtered based on detailed inclusion/exclusion criteria developed to guide the second step of the screening process through covidence management. Each item was screened by reviewers to determine eligibility against inclusion criteria. Any conflicts were resolved through discussion among the authors until consensus was reached. In a small number of cases, a third author wa consulted to intervene.

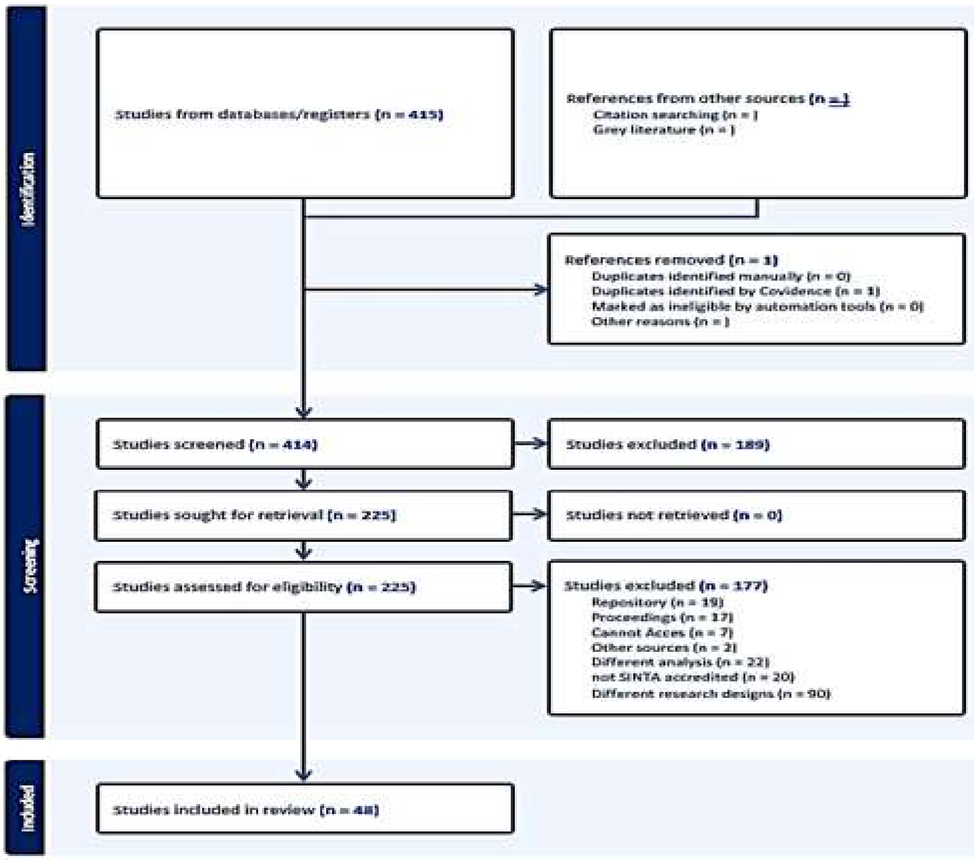

Figure 1. PRISMA flow diagram from covidence

Based on Figure 1, in total, 415 references have been identified and 1 was excluded because it was a duplicate of another reference. Furthermore, 189 of the 414 references identified were deleted because they did not match the inclusion criteria at the title screening stage. This process resulted in 225 items for further examination. After accessing the full text of the references, another 177 items were removed. The reasons for this were no access (n = 7), not in accordance with the research design (n = 90), different analysis methods (n = 22), and published only in the repository (n = 19), published in proceedings (n =17), and published in other database sources that are not indexed by Sinta or Scopus (n=2). The final synthesis and analysis included forty-eight (n = 48) peer-reviewed journal article references.

Data Extraction and Analysis

Although data extraction would ideally be performed by two independent reviewers, time and resource constraints require that data extraction be mostly performed by one author. However, it is in accordance with stringent Cochrane systematic review guidelines (Higgins & Green, 2023) to have at least two independent reviewers extract at least the reported outcome data. In cases where the results differed, discussion followed until consensus was reached. Study characteristics were identified by conceptually weighing the included studies for the following components: publication year, education level, location, difficulty factors. Data were analyzed thematically.

Quality Assessment

The quality of the included studies was assessed based on the indicator criteria of the JBI Critical Appraisal Checklist for Systematic Reviews and Research Syntheses (Aromataris E, Fernandez R, Godfrey C, Holly C, Kahlil H, 2017). This includes clear and explicit information regarding the review question, appropriateness of inclusion criteria, appropriate search strategy, accuracy of resources used, appropriateness of study assessment criteria, critical assessment by two or more reviewers independently, methods to minimize errors in data extraction, suitability methods for combining studies, evaluation of possible publication bias, support of policy and/or practice recommendations by reported data, and specific directions for new research. All of these indicators are important to ensure that the systematic review conducted is of good quality and can be trusted. All authors were involved in quality assessment and the results were compared and discussed until consensus was reached.

RESULT AND DISCUSSION

The main characteristics of 48 studies on student problem solving in solving mathematics problems based on Polya's theory, which were included in the systematic literature review are as follows:

RQ1. What are the trends in student problem-solving studies based on the Polya framework?

RQ1.1. Study Based on Research Location

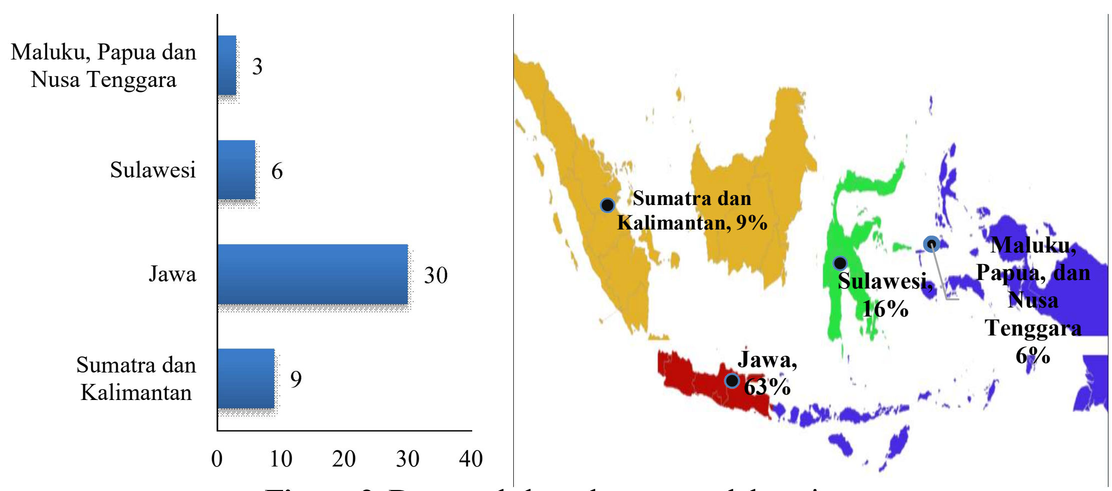

Figure 2. Data study based on research location

Based on the data presented in Figure 2, there is a striking imbalance in the distribution of research on student errors in problem-solving across various regions in Indonesia. Java emerges as the primary research center, with 30 studies representing 63% of the total research analyzed. This dominance reflects the concentration of educational resources and academic institutions in Java, making it the main focus for research on mathematical problem-solving. In contrast, Sumatra and Kalimantan together contribute 9 studies (19% of the total), indicating a significant but much smaller contribution. Sulawesi recorded 6 studies (16%), while the regions of Maluku, Papua, and Nusa Tenggara collectively contributed only 3 studies (6%).

This geographic imbalance highlights the need to expand research efforts to less represente regions. For example, a study by (Perkasa & Astuti, 2022) conducted in Java explored high school students' challenges with trigonometry, particularly in understanding and planning solutions. Meanwhile, research in Sulawesi, such as that by (Buhaerah et al., 2023), revealed cognitive errors made by students in solving mathematical problems, reflecting the unique context and challenges faced outside of Java. However, regions like Maluku, Papua, and Nusa Tenggara remain severely underrepresented in this research. The concentration of research in Java risks overlooking the diverse educational contexts and challenges faced by students in other areas. Bridging this gap is crucial to developing a more comprehensive understanding of students' problem-solving abilities throughout Indonesia. Future research should prioritize exploring the unique cultural, educational, and socio-economic factors that influence students in less studied regions, thus supporting a more equitable and inclusive educational insight.

RQ1.2 Studies by Year of Publication

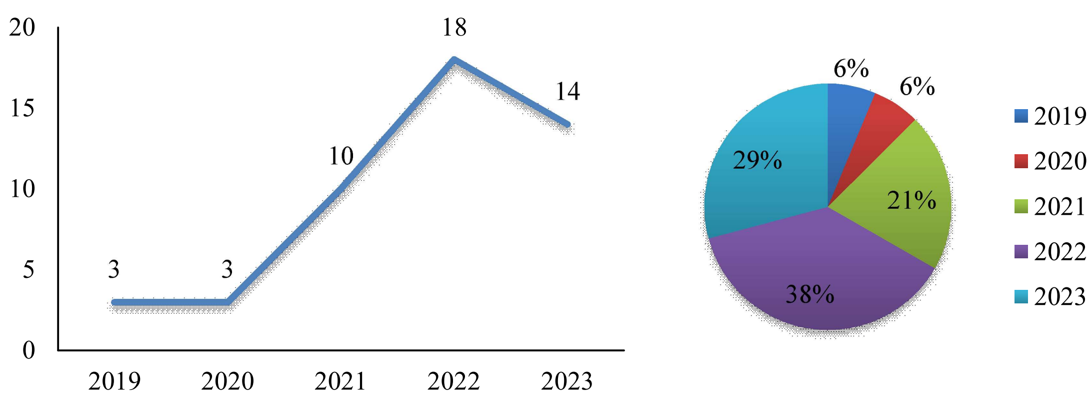

Figure 3. Data studies by year of publication

Based on the data presented in Figure 3, the trend in research publications shows a significant increase from 2019 to 2023. In 2019 and 2020, the number of studies published was relatively low, with only 3 studies each, accounting for around 6% of the total research. However, there was a notable surge in 2021, with 10 studies published (21%), peaking in 2022 with 18 studies (38%). In 2023, the number of studies slightly decreased to 14 studies (29%), though it remained higher compared to previous years. Overall, these data indicate a significant rise in research interest regarding the analysis of students' errors in solving mathematical problems, particularly in the last two years. Despite the slight decline in 2023, the consistent increase in publications during 2021 and 2022 highlights a growing focus on this area of research.

The decrease in publication numbers in 2023 (29%) could be attributed to several factors, such as the annual publication cycle or a shift in research interests among scholars, who may have started exploring new topics or alternative approaches to mathematical problem-solving. For instance, research by (Malikah, 2023) on arithmetic sequences demonstrates a shift in focus towards analysis based on the Polya framework, which had previously been applied to other topics. Thus, while there was a slight decline, the sustained interest in analyzing errors in problem-solving remains strong and relevant in the context of mathematics education.

RQ1.3 Study by Education Level

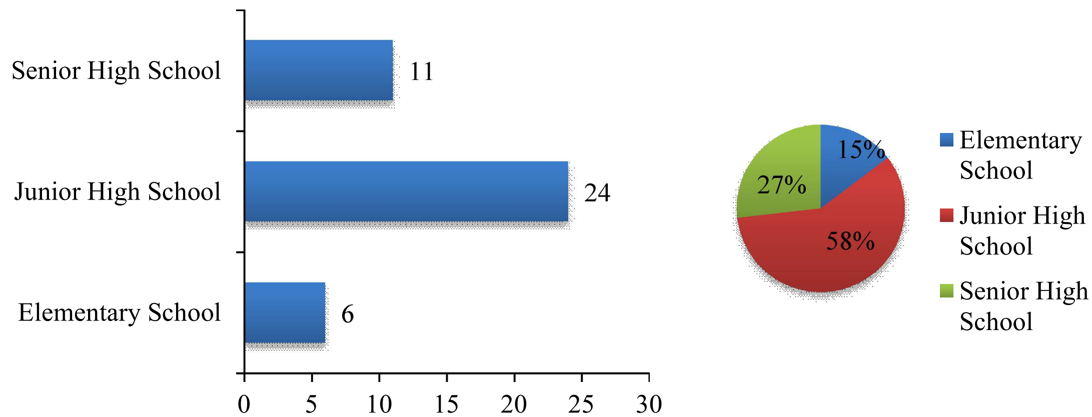

Figure 4. Data study by education level

Based on the data shown in Figure 4, research on student errors in problem-solving predominantly focuses on secondary education levels. Specifically, 24 studies (58% of the total studies) were conducted at the junior high school level, indicating a strong emphasis on this age group. The senior high school level accounts for 11 studies (27%), while the elementary school level is represented by only 6 studies (15%). These figures demonstrate a clear trend of more research being conducted on middle school students, followed by high school students, with the least focus on elementary school students. This distribution may reflect the unique challenges faced by middle school students, particularly in terms of developing problem-solving skills and foundational knowledge. Additionally, it highlights the need for more targeted interventions at this educational stage to address these challenges.

The prevalence of research focused on junior high school students suggests that they encounter significant obstacles in problem-solving, particularly at the initial stages. For example, (Rachmawati & Adirakasiwi, 2021) found that the Understanding the Problem stage was the most difficult for junior high school students, especially due to difficulties in reading literacy and grasping basic concepts. This may be because students at this stage are transitioning from concrete to more abstract mathematical thinking, making it harder for them to comprehend complex problems. In contrast, only 15% of the research targeted elementary school students, even though studies like (Hartuti & Firmansyah, 2023) emphasize the importance of mastering basic concepts at this level. Mastery of these foundational skills in elementary school is crucial for students' future problem-solving abilities, as it lays the groundwork for more advanced mathematical thinking in higher education levels.

RQ1.4 Study Based on Mathematics Topic

Based on the data presented in Figure 5, the distribution of studies reveals that algebra is the most frequently researched topic, particularly at the junior high school level, followed by high school, with only a small proportion of studies focused on elementary school students. The topic of numbers is also widely explored at the middle school level, with notable contributions from elementary school research, while high school studies on this topic are relatively few. Geometry and measurement topics are fairly evenly distributed between middle and high school levels, with only a minimal focus at the elementary school level. The study of calculus appears exclusively at the high school level, reflecting its relevance to more advanced mathematical education. Data analysis and probability are more commonly explored at the middle and high school levels, with a limited amount of research at the elementary school level.

Overall, these findings indicate that the majority of research focuses on algebra and number topics at the middle school level, while geometry and measurement also receive significant attention. In contrast, advanced topics such as calculus and data analysis are less frequently studied and are primarily addressed in higher education contexts. For example, (Chand et al., 2021) highlight the dominance of algebra as a key research topic at the junior high school level. However, areas such as calculus and data analysis are often underexplored, despite their importance for high school students. Further studies are needed to investigate the interconnections between these topics and their collective contribution to the development of problem-solving skills in mathematics. Expanding research on these advanced topics may provide valuable insights into how to better support students' mathematical development as they progress through their education.

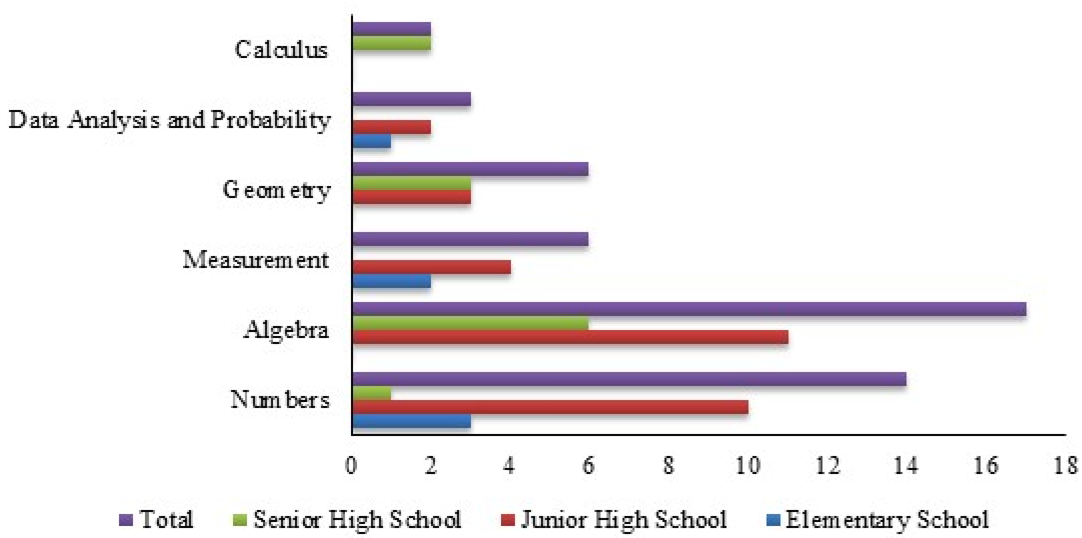

Figure 5. Data study based on mathematics topic

RQ2. What factors contribute to students' problem solving difficulties at the Understanding the Problem (UP) stage?

The stage of understanding students' problems is an initial stage that requires students to understand the problem statement well, identify known and asked information, as well as other important information (Anggo, 2011; Polya, 1978). Students are considered capable at this stage if they are able to compile instructions for the problem by entering the information that has been given and the questions asked in the problem accurately (Sinaga et al., 2023). This research shows that the challenges in the understanding the problem stage are very complex and involve various aspects as shown in figure 6 such as motivation, concentration, reading literacy, mathematical communication, conceptual understanding, and reasoning. The following are the key findings identified through citation analysis of related articles:

UP-Motivation and Enthusiasm

Several studies show that quite a few students view mathematics as a very difficult subject, which makes them feel defeated before starting to learn. Students often consider mathematics questions to be difficult, which reduces their enthusiasm for trying to understand the problem. Apart from that, the lack of motivation causes students to quickly give up before trying to solve the problem (Asdamayanti et al., 2023). Bad mood and low motivation have a negative effect on students' attention and responsiveness to questions (Mangarin & Caballes, 2024). Some students showed reluctance to try to understand the question text in its entirety, which could be seen from errors in interpreting the problem due to thinking the question was too difficult (Lilisantika & Roesdiana, 2023).

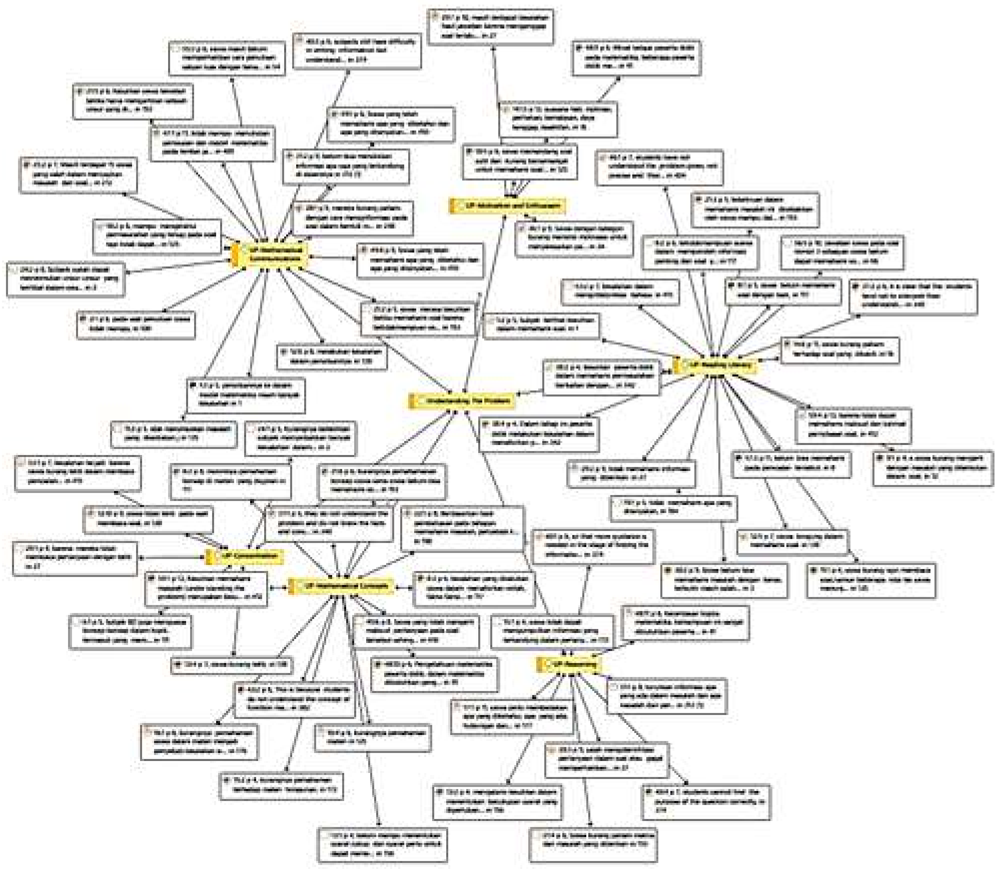

Figure 6. Selective results of problem solving coding at the understanding the problem stage

UP-Concentration and Meticulousness

In the studies reviewed, many students were often not careful when reading the questions, which caused errors in writing down the mathematical model of the question information. This lack of accuracy is often triggered by a lack of habit of recording what is known and what is asked before solving a problem (Martin & Kadarisma, 2020). Even though they master basic concepts, some students still have to be more careful in understanding the sentences in the questions to avoid mistakes.

UP-Reading Literacy

These studies also show that many students still have difficulty understanding complex question texts. They are often unable to obtain important information from the questions given, which causes their answers to be inaccurate. The inability to understand what is being asked and what is known in the question often causes students to be confused (Nanda Muliawati & Sutirna, 2022). Some students are able to read the problem but do not know what problem to work on, which shows a lack of understanding of the information provided (Syavira & Novtiar, 2021). This study also shows that errors in interpreting the language of the questions often occur, especially in story questions which require a deeper understanding of the narrative and questions given (Ade et al., 2021).

UP-Mathematical Communications

This study shows that many findings show that students often experience difficulty in writing mathematical models of story problems. They often know the problem presented but cannot describe what information they know and ask in mathematical form (Djawa et al., 2019; Taneo & Kusumah, 2021). Some students who already understand the problem are still unable to write or express the general form of the required equation or inequality correctly (Martin & Kadarisma, 2020). For example, writing mathematical examples, units, set notation and so on.

UP-Mathematical Concepts

Lack of understanding of the mathematical concepts underlying the material being tested causes students to be unable to interpret terms, facts, concepts and principles correctly (Nanda Muliawati & Sutirna, 2022). This is often the main cause of errors in the problem understanding stage. Some students show a weak understanding of certain materials such as sets, which causes errors in solving questions related to that material (Anggraeni & Kadarisma, 2020; Fitriyana & Sutirna, 2022). Symptoms of pseudo-thinking were also found, namely that students often had difficulty understanding problems because the format of the questions was not as usual in class, such as mathematical problem solving story questions followed by questions after the story was finished (Wahab, 2022).

UP-Reasoning

Students often have difficulty determining the conditions needed to solve problems (Debora Simbolon et al., 2022). They cannot gather the information contained in the question and have difficulty describing statements of known facts (Fitriyana & Sutirna, 2022). Students often misidentify the question in the question or fail to pay attention to important elements in the question, resulting in an inability to understand the meaning of the question correctly (Rohmah et al., 2023). Many students need additional guidance to find the necessary information in a problem and understand the meaning of a given problem.

This study highlights that students face various challenges in understanding mathematical problems, influenced by factors such as motivation, concentration, reading literacy, mathematical communication, conceptual understanding, and reasoning. Motivation and engagement play a critical role in students' ability to interact with and comprehend mathematical tasks. For instance, a study in Ningbo, China, found that many students exhibit avoidance behaviors, driven by the perceived difficulty of mathematics and its lack of relevance to real-life contexts (Mengyao et al., 2024). Similarly, (Cahyani et al., 2024) revealed that 50% of students reported low motivation levels, underscoring the need for effective motivational strategies to enhance learning outcomes. Without sufficient motivation, students are less likely to invest the effort needed to interpret and solve mathematical problems effectively.

Low motivation often compounds with anxiety, which poses significant cognitive barriers to learning mathematics. Research by (Avita Salsabila et al., 2024) suggests that this anxiety often stems from a belief that mathematics is inherently difficult, further discouraging students from engaging deeply with problems. These factors collectively hinder students' ability to concentrate, extract essential information from texts, and apply logical reasoning to solve problems. Reading literacy is another crucial factor affecting students' understanding of mathematical problems. Poor literacy skills hinder students from effectively interpreting problem texts, making it difficult to identify key information. This aligns with findings by (Tambychik & Meerah, 2010) and (Eysenck & Keane, 2015), which emphasize that students with limited literacy skills struggle to comprehend problem contexts, thereby impairing their problem-solving abilities. On the other hand, students with strong literacy skills, as shown by (Chand et al., 2021) and (Perkasa & Astuti, 2022), are better equipped to process mathematical problems, enabling them to achieve higher levels of performance.

To address these challenges, it is essential to create a supportive learning environment that fosters motivation, reduces anxiety, and strengthens students' literacy skills. Teaching methods that connect mathematics to real-life contexts can enhance students' engagement, while confidence-building activities and relaxation techniques help alleviate math-related anxiety. Encouraging mathematical communication—such as rewriting and analyzing key problem clues—combined with a focus on conceptual understanding and reasoning, equips students with essential tools for effective problem-solving. Beyond individual factors like motivation and literacy, systemic issues such as curriculum complexity and testing pressures must also be addressed to ensure a balanced approach that promotes both foundational skills and students' comprehensive development.

RQ3. What factors contribute to students' problem solving difficulties at the Devising A Plan stage?

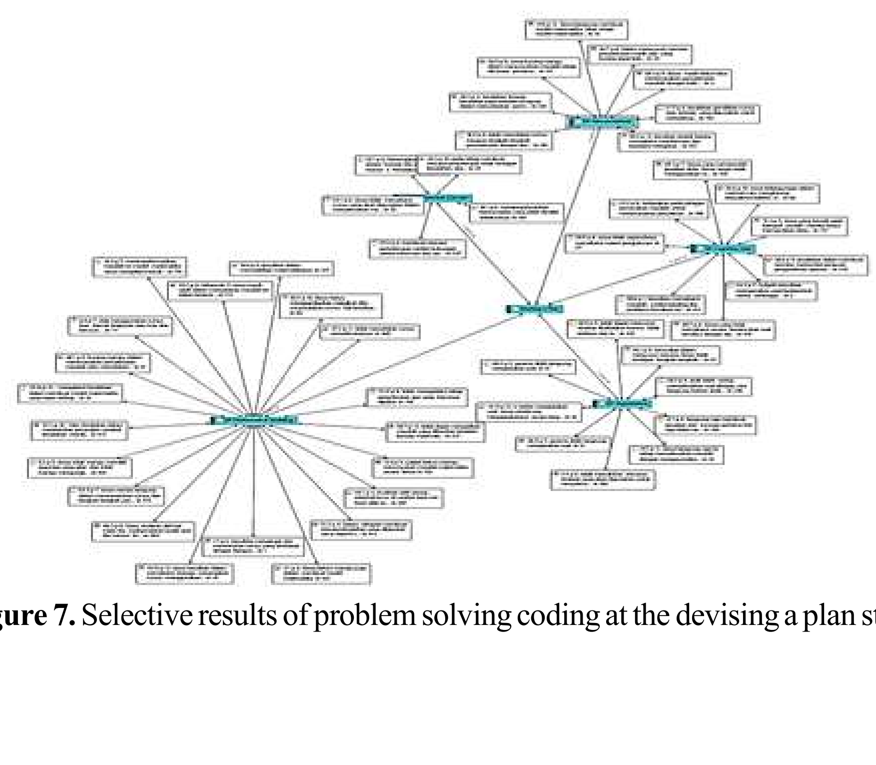

Figure 7. Selective results of problem solving coding at the devising a plan stage

After thoroughly understanding the problem, students must transition to the devising a plan stage (Suharti et al., 2021)). With information about what is being asked and what is known, students need to think about strategies, methods, formulas and procedures that they will use to overcome the problem (Purba & Lubis, 2021; Ramadhani et al., 2024). The studies reviewed show that the challenges in the planning stage of problem solving are very diverse and involve various aspects as seen in figure 7 such as understanding concepts, connections between concepts, mathematical modeling, and strategic organization. The following are the key findings identified through citatioanalysis of related articles:

DP-Cognitive Holes

This study showed that students who do not fully understand the basic operating concepts of mathematics lead to wrong decisions and ineffective planning (Suharti et al., 2021; Wahab, 2022). Students still often have difficulty remembering and determining formulas related to material that they have not fully understood even though it is already material that they have gone through (Nurhayati & Zanthy, 2019; Rahmawati & Warmi, 2022). This shows that there is a hole in the understanding of basic mathematical concepts. Another sign found is that students are often only able to make part of the solution plan but not the complete one. In researching existing studies, it turns out that this is due to prerequisite mathematical knowledge that is not fully understood, causing ignorance about the steps that must be taken next (Fitriyah & Haerudin, 2021).

DP-Misconceptions

Beside the cognitive holes, misconceptions also often occur when students devise a plan and misunderstand the concept of the material (Suharti et al., 2021). For example, when students directly create mathematical models which are often inaccurate because they do not write down the constants or values for each equation, they make mistakes in choosing the formula or concept used (Lilisantika & Roesdiana, 2023; Syavira & Novtiar, 2021). Conceptual errors cause students to misinterpret the solution plan. For example, students mistakenly consider an arbitrary triangle to be an equilateral triangle, which causes errors in planning calculations (Wahab A et al., 2023).

DP-Connection of Mathematical Concepts

Students often fail to relate the various necessary concepts (Asdamayanti et al., 2023), they often have difficulty identifying the right method to use, resulting in an incorrect or inefficient approach (Putri et al., 2022). For example, while students understand how to solve linear equations and basic geometric concepts separately, when faced with problems that combine these two concepts, they often do not know how to connect geometric formulas with linear equations to find solutions (Wahab, 2022). This can cause them to choose irrelevant steps or skip important steps in solving the problem.

DP-Mathematical Modeling

Students have difficulty creating appropriate mathematical models, which results in the solution procedure not obtaining correct results (Fitrianingsih & Budiman, 2022; Khadijah & Munandar, 2022). They are also often unable to formulate mathematical problems correctly (Debora Simbolon et al., 2022). Students have difficulty analyzing the facts contained in the questions and relating them to relevant mathematical concepts (Mutmainah et al., 2023). For example, they cannot relate a given problem to the concepts they have learned to create a three-variable linear equation. They are often confused in determining the formulas and steps to be used in solving problems because they are not yet able to model cases in the form of mathematical equations (Ade et al., 2021).

DP-Organization

Students often go straight to problem solving without writing down a plan or strategy to be used. They tend to work on questions directly without planning the solution first (Lastin et al., 2023; Martin & Kadarisma, 2020). In systems of linear equations, for example, students tend to often use a trial and error approach by assuming a problem and adding up the known information without using appropriate elimination or substitution methods (Lilisantika & Roesdiana, 2023). Students are not used to developing strategies first before solving problems. They often start working on questions without planning the necessary steps (Martin & Kadarisma, 2020).

The difficulties students face in designing a plan for solving mathematical problems are rooted in cognitive gaps, misconceptions, and challenges in connecting mathematical concepts. These issues often stem from a lack of deep understanding of fundamental mathematical principles, which significantly impacts their ability to develop effective solution plans. Research indicates that many students struggle to recall relevant formulas, especially for topics they have not fully understood, resulting in incomplete or incorrect plans (Kurniawati, 2024; Samosir et al., 2024). Misconceptions further complicate the process, as students may misapply formulas or misinterpret concepts such as geometric properties, leading to errors in their mathematical models (S. I. Ani & Rosyidi, 2021; Tririnika et al., 2024). Additionally, difficulties in connecting mathematical concepts present a major obstacle, particularly when solving complex problems that require integrating various approaches. For instance, the inability to link linear equations with geometric concepts may lead to missing or irrelevant steps in the problem-solving process (Cohen & Cohen, 2024; Kurniawati, 2024).

These cognitive challenges highlight the importance of establishing strong connections between mathematical concepts and modeling skills, as identified in research by (Klang et al., 2021). Their findings suggest that the ability to connect different concepts is crucial for effective problem-solving since misconceptions and cognitive gaps hinder students' ability to plan solutions. Studies by (Buhaerah et al., 2023) and (Perkasa & Astuti, 2022) further support this notion, emphasizing that misconceptions are a primary barrier to successful problem-solving. Moreover, findings by (NCTM, 2020) reveals that a lack of deep understanding of mathematical concepts is a significant factor contributing to students' struggles in devising solutions. On the other hand, students with a solid understanding of fundamental mathematical concepts are better equipped to plan and implement effective solutions (Mutawah et al., 2019).

To support students in this process, the ability to organize and structure plans is equally essential. This skill is critical because it allows students to approach problem-solving systematically and logically (Polya, 1978). Therefore, a combination of organizational skills, a solid understanding of mathematical concepts, and the ability to connect these concepts plays a pivotal role in enhancing students' ability to develop effective solution plans for mathematical problems.

RQ4. What factors contribute to students' problem solving difficulties at the Carrying Out The Plan (CP) stage?

After preparing the plan, the next stage is carrying out the plan that was formulated in the previous step (Khairunnisa & Ramlah, 2021). They start solving problems by using correctly selected strategies, methods and procedures (Pradana & Murtiyasa, 2020). Figure 8 shows that the challenges in the implementation stage of the plan are very varied and involve various aspects such as understanding concepts, misconceptions, algorithms or calculation procedures, and accuracy. The following are the key findings identified through citation analysis of related articles:

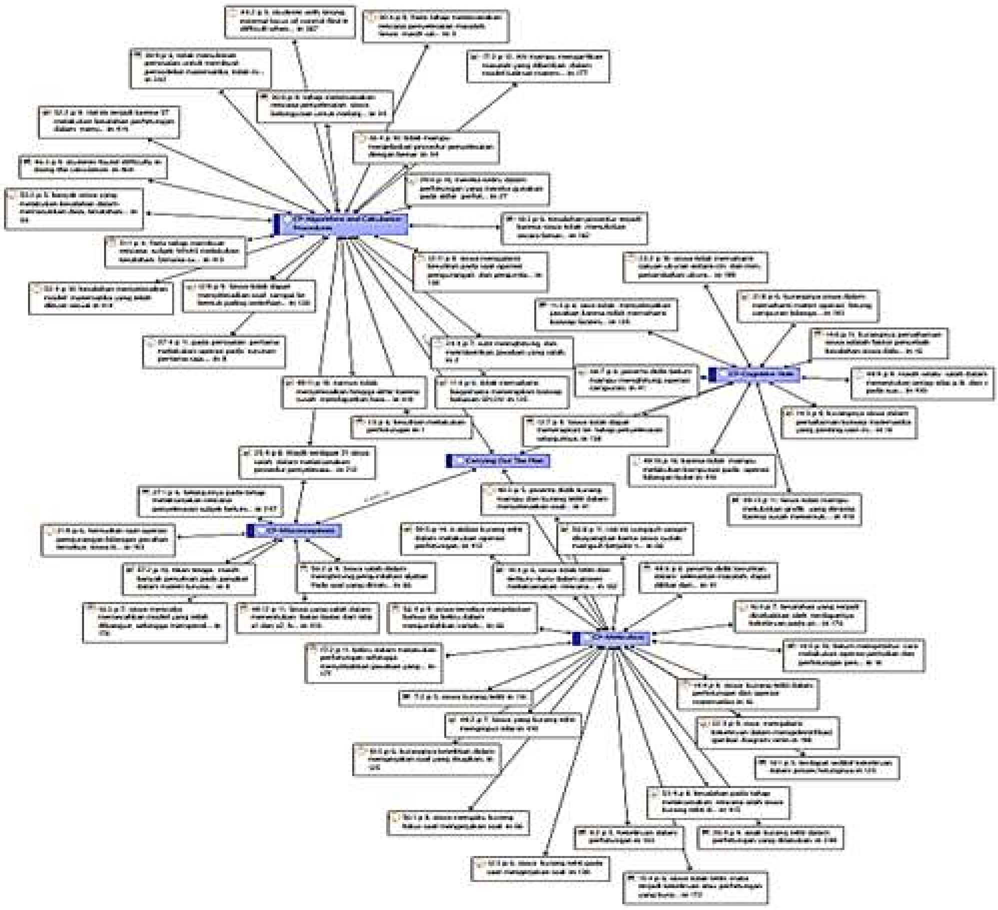

Figure 8. Selective results of problem solving coding at the Carrying Out the Plan (CP) stage

CP-Cognitive Holes

Almost the same as at the DV stage, cognitive holes influence students in executing the solution plans that have been made. For example, students who have a poor understanding of basic operations such as addition, subtraction, multiplication, or division, they have difficulty making plans involving these operations (Sumartini et al., 2023). The rules relating to arithmetic operations involving mixed whole numbers and fractions, or units of measurement, which should have been mastered because they are fundamental, still cannot be fulfilled. This results in incorrect or incomplete final answers.

CP-Misconceptions

Several studies show that students often try to solve mathematical models incorrectly from the start, such as not balancing the denominators in fraction operations, incorrectly determining value limits, and errors in calculating algebraic additions. Errors in selecting and using the correct formula, such as errors in writing power formulas in derivative material or determining larger fraction values (Sholekah et al., 2017; Utami & Hakim, 2023). This shows that misconceptions are still an obstacle at this stage.

CP-Algorithms or Calculation Procedures

Other studies show that students also often make mistakes in applying the System of Linear Equations (SLE) concept (Puspita et al., 2022). Often this happens when students fail to execute the correct steps or procedures in working on questions, which causes algorithm and calculation procedure errors (Martin &

Kadarisma, 2020). For example, errors in entering data or calculation errors in carrying out plans that have been made (Debora Simbolon et al., 2022). Students are often confused about continuing to solve problems after starting calculations, especially when they do not write mathematical examples or models correctly.

CP-Meticulousness

In several studies, almost all of them stated that the thoroughness factor was an obstacle to student success at this stage. Students are often less careful when working on questions, which causes errors in calculations. This inaccuracy is caused by haste and lack of focus when working on questions (Rachmawati & Adirakasiwi, 2021). Errors in the calculation process often occur in mathematical operations. Students who are less careful often make mistakes in adding variables or identifying Venn diagram images (Anggraeni & Kadarisma, 2020; Fitriyah & Haerudin, 2021). This lack of precision causes students who are otherwise capable of higher level thinking to be sloppy in their calculations, which is unfortunate because they do not reach the correct answer.

This study found that understanding algorithms and calculation procedures, as well as maintaining accuracy, were significant obstacles to student success at this stage. This aligns with research by (Chand et al., 2021), which highlights that students' inability to execute algorithms and follow calculation procedures often impedes their problem-solving abilities. Such difficulties are commonly attributed to gaps in conceptual understanding or misconceptions, as supported by (Hartuti & Firmansyah, 2023), who found that students struggle to apply basic concepts they have learned effectively. Similarly, the (National Research Council, 2001) emphasizes that students who lack a strong grasp of calculation procedures are prone to making mistakes when carrying out their solutions.

In addition, research by (Altbawi et al., 2023) and (Dörner & Funke, 2017) reveals that insufficient thoroughness in applying plans is often the result of limited practice and experience in solving complex problems. The challenges students face in mastering algorithms and calculation procedures are crucial barriers to their problem-solving performance. These challenges are compounded by misconceptions and cognitive gaps, which hinder students from successfully applying learned concepts, as reflected in various studies emphasizing the importance of a strong understanding of algorithms for effective problem-solving.

Misconceptions related to algorithms can lead to significant errors in problem-solving. For example, (Danielsiek et al., 2012) analyzed 400 exams and identified common areas where students misunderstood algorithmic procedures. A lack of thoroughness in implementing algorithms is often linked to inadequate practice, as seen in studies examining the challenges faced in algorithmic MOOCs (Babori, 2020). Effective problem-solving requires not only an understanding of algorithms but also the ability to apply them systematically. This skill can be developed through collaborative efforts and hands-on experience, as discussed by (Nursania Simbolon & Yahfizham Yahfizham, 2023)

While understanding algorithms is essential, some argue that an overemphasis on procedural knowledge may detract from fostering creativity and critical thinking in problem-solving. This perspective advocates for a more balanced approach in educational settings that encourages both technical proficiency and creative problem-solving skills.

RQ5. What factors contribute to students' problem solving difficulties at the Looking Back (LB) stage?

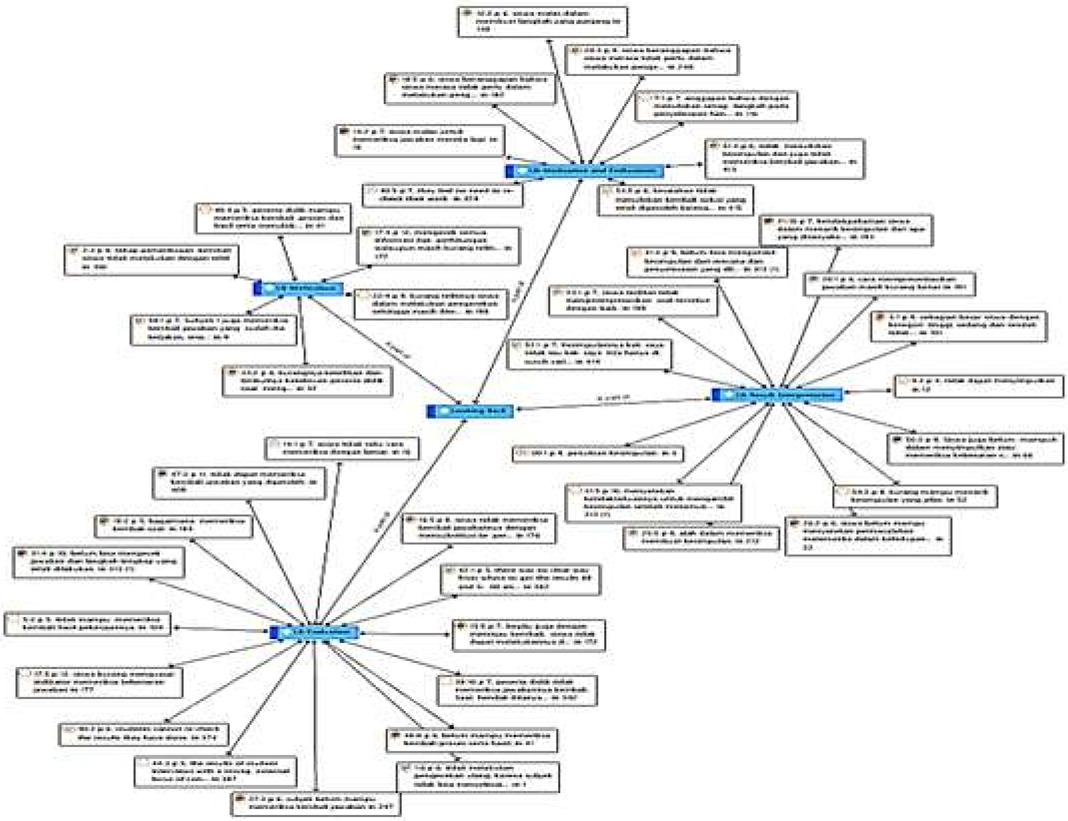

Figure 9. Selective results of problem solving coding at the Looking Back (LB) stage

The final stage is the looking back in which students review their answers to ensure the steps taken are correct (E. U. Ani & Rahayu, 2018). If differences are found, they can revise the solution. This stage is very important because it teaches students to be thorough and careful in their work (Schoenfeld, 1985). Based on Figure 9, this research shows that the challenges in the looking back stage are very varied and involve various aspects such as motivation, evaluation, interpretation of results, and accuracy. The following are the key findings identified through citation analysis of related articles:

LB-Motivation and Enthusiasm

Motivational issues significantly hinder students during the Looking Back stage. Many students perceive reviewing their answers as unnecessary or time-consuming, often relying on misplaced confidence in their initial responses (Rachmawati & Adirakasiwi, 2021; A. K. Wardhani et al., 2022). This reluctance to revisit their work results in undetected errors, as they fail to verify their solutions (Lilisantika & Roesdiana, 2023). For instance, research by (Martin & Kadarisma, 2020) notes that students often omit writing conclusions or conducting re-evaluations because they underestimate the importance of these steps. To address this, educators should emphasize the value of reflection as an integral part of problem-solving and provide structured guidelines to help students develop this habit.

LB-Evaluation

A common challenge in this stage is students' inability to effectively evaluate their work. They often lack the skills to systematically check their answers, such as substituting their solutions back into the original equation or verifying whether their results align with the problem's requirements (Mutmainah et al., 2023). This aligns with findings by (Halawati, 2023; Putri et al., 2022), hich reveal that many students complete problem-solving tasks without confirming the validity of their results. Addressing this requires explicit teaching of evaluation techniques, including error-checking methods, and their incorporation into regular practice. This approach not only reinforces students' evaluative abilities but also promotes critical thinking and systematic assessment skills, as highlighted by (Leviton et al., 1998) and (Elmgrab, 2016)

LB-Result Interpretation

Students frequently struggle with interpreting and articulating their results. Many fail to write clear conclusions, misrepresent their answers, or overlook the problem's requirement (Siregar et al., 2021; Syavira & Novtiar, 2021). They also face difficulties in translating mathematical findings into everyday language, which often leads to incomplete or incorrect responses (Utami & Hakim, 2023). For example, research by (Syavira & Novtiar, 2021; A. K. Wardhani et al., 2022) indicates that a lack of clarity in interpreting and representing results is a recurring issue in mathematical problem-solving. Educators can mitigate this by encouraging students to verbalize their thought processes and conclusions, fostering better mathematical communication skills.

LB-Meticulousness

At this stage, students often fail to carefully recheck their calculations and results, which leads to errors in their final answers. This lack of accuracy is frequently caused by rushing or insufficient practice in the review process (Yusupova & Tokhtasinova, 2022). Errors in the checking process typically occur when students overlook small mistakes in their calculations or reasoning. These errors could have been avoided with more thorough checking (Yustiara et al., 2021). Inadequate attention to detail during the looking back stage often results in missed errors, whether in calculations or logical reasoning. This lack of precision is often linked to hastiness and limited practice in identifying and correcting mistakes. Studies, such as those by (Wahyuni et al., 2022; Yustiara et al., 2021), show that even skilled students may fail to catch minor errors due to carelessness. To address this, it is essential to develop the habit of carefully reviewing work, supported by strategies like checklists, which can help guide students through the review process step by step.

This study shows that motivation, evaluation, result interpretation, and meticulousness are the main factors that hinder students at this stage. Motivation is a key determinant of student performance in mathematics, as demonstrated by (Lishchynska et al., 2023), who found that motivated students perform better in mathematics service modules. A lack of motivation can cause students to neglect re-checking their answers, leading to recurring mistakes (Fuji Amanda et al., 2024). Students often overlook the importance of evaluating their work, resulting in inaccuracies in their outcomes (Dwita & Retnawati, 2022). (Eccius-Wellmann et al., 2019) highlight that overconfidence in one's abilities can lead to performance misjudgment, which exacerbates the problem of uncontrolled errors.

Teaching students to evaluate and review their work is crucial for improving their mathematical problem-solving skills (Chang et al., 2022). Innovative teaching strategies that enhance motivation and engagement can help address these challenges (Fuji Amanda et al., 2024). On the other hand, while motivation is important, some argue that external factors, such as the quality of teaching and curriculum design, also play a significant role in student performance, indicating the need for a multifaceted approach to improving educational outcomes.

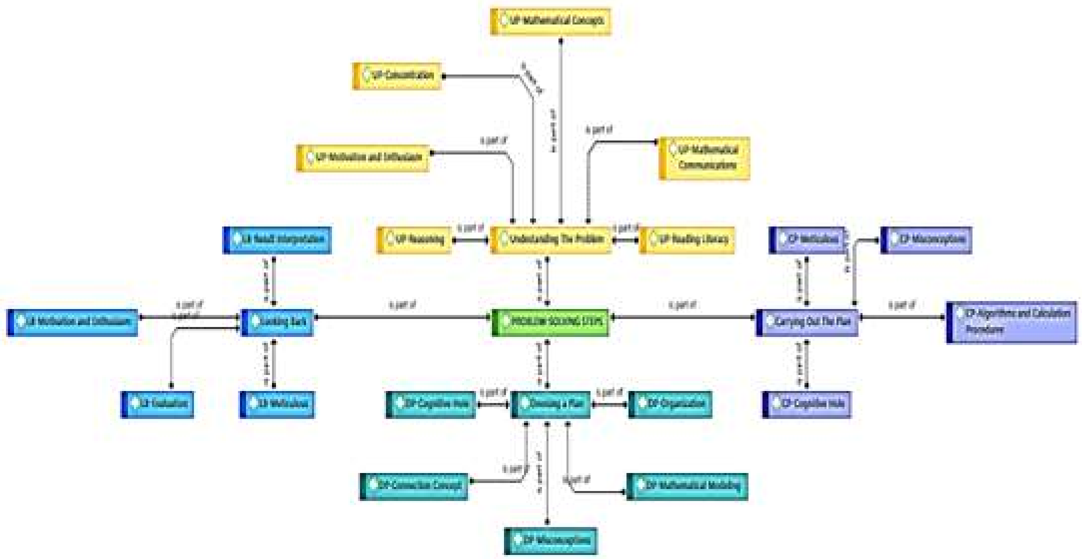

Figure 10. Selective results of problem solving coding based on Polya theory

From the findings organized based on the four main steps in the Polya framework Understanding the Problem, Planning the Solution, Implementing the Plan, and Looking Back (Figure 10)—this study has highlighted the complex challenges students face in solving mathematical problems. These findings suggest that teaching strategies need to be tailored to address the specific barriers at each stage of problem-solving.

There are several key aspects in education that need attention. First, teacher education and training should be enhanced to equip educators with the skills to identify and address the various difficulties students face in problem solving. Specifically, teaching strategies should be developed to strengthen students' understanding of mathematical concepts and improve their ability to apply them correctly in problem-solving situations. For example, at the Understanding the Problem stage, enhancing reading comprehension is crucial for helping students extract relevant information from word problems, reducing misunderstandings (Gopinath & Lertlit, 2022). Furthermore, teaching strategies should focus on contextualized problems that relate to students' everyday experiences, which can increase motivation and engagement (Simarmata & Lailin Hijriani, 2020). At the Planning the Solution stage, emphasizing the interconnections between mathematical concepts, such as algebra and geometry, can help students formulate effective plans (Siswanto & Yulaikah, 2023). Approaches like problem-based learning and collaborative learning can deepen students' understanding and reduce misconceptions (Al-Ihsan et al., 2023). Moving to the Implementing the Plan stage, techniques that guide students through step-by-step execution of strategies can help ensure accuracy and prevent oversight (Martínez-Padrón, 2021). Structured methods such as checklists can promote meticulousness during this stage (Simarmata & Lailin Hijriani, 2020). Finally, at the Looking Back stage, teaching approaches should encourage students to evaluate and reflect on their work to identify errors and improve accuracy (Siswanto & Yulaikah, 2023). Peer reviews can enhance this reflective process, fostering a collaborative learning environment (Al-Ihsan et al., 2023).

Second, curriculum development should focus on strengthening students' basic reading literacy and foundational mathematical skills. Integrating more problem-solving exercises related to real-life situations will not only make math more relevant but also increase student engagement. For instance, incorporating contextual problems related to students' everyday lives can boost their motivation and help them see the practical applications of math. Adopting diverse learning approaches, such as problem-based learning and collaborative learning, can help students better understand concepts and reduce misconceptions (Chang et al., 2022; Cheng et al., 2021). By encouraging active collaboration, students will have the opportunity to share strategies and clarify misunderstandings, which is highly beneficial during the Planning the Solution and Implementing the Plan stages.

However, this study has several limitations. The systematic literature review conducted for this study relied on the quality and availability of the studies reviewed. Limitations in these studies may have influenced the findings, especially if critical factors or insights were overlooked. Additionally, this research did not account for external factors such as family support, socio-economic conditions, and the learning environment, all of which can affect students' problem-solving abilities. Research by (Eccius-Wellmann et al., 2019) and (Dwita & Retnawati, 2022) shows that family and school support, as well as a positive learning environment, can enhance students' motivation and performance in mathematics. Therefore, further research is needed to explore these external factors more thoroughly and examine how they interact with students' cognitive and motivational processes. This could provide a more comprehensive understanding of what influences problem-solving abilities, enabling more targeted interventions across different contexts.

■ CONCLUSION

This study successfully identified several factors that hinder students in solving mathematical problems based on Polya's framework. At the Understanding the Problem stage, key obstacles include low motivation, lack of concentration, poor reading literacy, weak mathematical communication, inadequate understanding of mathematical concepts, and poor reasoning skills. At the Planning the Solution stage, cognitive gaps, misconceptions, weak connections between mathematical concepts, incorrect mathematical modeling, and inadequate data organization skills emerge as major challenges. During the Implementing the Plan stage, difficulties in correctly applying algorithms and calculation procedures, along with cognitive gaps, misconceptions, and a lack of accuracy, often result in errors. Finally, at the Looking Back stage, lack of motivation, enthusiasm, and thoroughness in reviewing work, as well as the inability to effectively interpret and evaluate results, lead to undetected errors.

The findings of this research have significant implications for teaching strategies. Educators need to enhance students' reading literacy and basic mathematical skills, as well as develop effective teaching methods to address misconceptions and cognitive gaps. The adoption of problem-based learning and collaborative approaches can help students better understand mathematical concepts and reduce misconceptions. Furthermore, teaching reflective skills is essential, enabling students to revisit their work, thereby improving their accuracy and problem-solving performance.

This study has several limitations, including reliance on the quality and availability of previous studies. External factors such as family support, socio-economic conditions, and the learning environment were not explored in depth. Therefore, further research is needed to investigate these additional factors that may influence students' problem-solving abilities in various contexts

■ REFERENCES

Ade, K., Ihwayudin, & Reny, A. P. (2021). *Analisis kesalahan siswa dalam* *menyelesaikan soal cerita segitiga berdasarkan prosedur polya. Jurnal Ilmiah IKIP Mataram*, *8*(1), 127–136. https://doi.org/10.33503/prismatika.v5i1.1942

Al-Ihsan, M. I., Wulandari, T., Prasetyo, O. D., & Yuliana, C. (2023). Implementation of polya's heuristic strategy on mathematical literacy ability. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *12*(3), 3470. https://doi.org/10.24127/ajpm.v12i3.7331

Altbawi, S. M. A., Khalid, S. B. A., Mokhtar, A. S. Bin, Shareef, H., Husain, N., Yahya, A., Haider, S. A., Moin, L., & Alsisi, R. H. (2023). An improved gradient-based optimization algorithm for solving complex optimization problems. *Processes*, *11*(2), 498. https://doi.org/10.3390/pr11020498

Anggo, M. (2011). *Pelibatan metakognisi dalam pemecahan masalah matematika. Edumatica*, *1*(1), 25–32.

Anggraeni, R., & Kadarisma, G. (2020). *Analisis kemampuan pemecahan masalah matematik siswa smp kelas vii pada materi himpunan. Jurnal Cendekia/ : Jurnal Pendidikan Matematika*, *4*(2), 1072–1082. https://doi.org/10.31004/cendekia.v4i2.334

Ani, E. U., & Rahayu, P. (2018). *Profil kemampuan pemecahan masalah matematika siswa berbentuk soal cerita materi bangun ruang. Jurnal Riset Pendidikan Dan Inovasi Pembelajaran Matematika (JRPIPM)*, *1*(1), 40. https://doi.org/10.26740/jrpipm.v1n1.p40-49

Ani, S. I., & Rosyidi, A. H. (2021). *Merencanakan pemecahan masalah kontekstual: berpandu pada rumus atau konteks? Edumatica/ : Jurnal Pendidikan Matematika*, *11*(02), 73–84. https://doi.org/10.22437/edumatica.v11i02.13344

Aromataris E, Fernandez R, Godfrey C, Holly C, Kahlil H, T. P. (2017). Checklist for systematic reviews and research syntheses. *The Joanna Briggs Institute*. http://joannabriggs.org/research/critical-appraisal-tools.htmlwww.joannabriggs.org%0Awww.joannabriggs.org

Asdamayanti, N., Nasution, E. Y. P., & Sari, M. (2023). *Analisis kemampuan pemecahan masalah matematis siswa madrasah aliyah pada materi SPLTV. Jurnal Cendekia/ : Jurnal Pendidikan Matematika*, *7*(2), 1141–1152. https://doi.org/10.31004/cendekia.v7i2.2084

Babineau, J. (2014). Product review: covidence (systematic review software). *Journal of the Canadian Health Libraries Association / Journal de l'Association Des Bibliothèques de La Santé Du Canada*, *35*(2), 68. https://doi.org/10.5596/c14-016

Babori, A. (2020). *MOOC of Algorithmic: Elaboration of Content and Difficulties Encountered by Students* (pp. 40–46). https://doi.org/10.1007/978-3-030-36778-7_5

Buhaerah, B., Prayogo, P., Ahsanul Haq, M., & Wahab, W. (2023). Decompose the cognitive mapping of the pisa question's problem solving thinking structure. *Jurnal Pendidikan MIPA*, *24*(3), 603–626. https://doi.org/10.23960/jpmipa/v24i3.pp603-626

Cahyani, A., Shalsabilia, & Novita, J. (2024). Analysis of students' motivation to learn mathematics in class XII. *Journal of Research on Mathematics Instruction (JRMI)*, *4*(2), 49–57. https://doi.org/10.33578/jrmi.v4i2.91

Chand, S., Chaudhary, K., Prasad, A., & Chand, V. (2021). Perceived causes of students' poor performance in mathematics: a case study at ba and tavua secondary schools.

Frontiers in Applied Mathematics and Statistics, *7*. https://doi.org/10.3389/fams.2021.614408

Chang, Y.-H., Yan, Y.-C., & Lu, Y.-T. (2022). Effects of combining different collaborative learning strategies with problem-based learning in a flipped classroom on program language learning. *Sustainability*, *14*(9), 5282. https://doi.org/10.3390/su14095282

Cheng, F.-F., Wu, C.-S., & Su, P.-C. (2021). The impact of collaborative learning and personality on satisfaction in innovative teaching context. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.713497

Cleo, G., Scott, A. M., Islam, F., Julien, B., & Beller, E. (2019). Usability and acceptability of four systematic review automation software packages: a mixed method design. *Systematic Reviews*, *8*(1), 145. https://doi.org/10.1186/s13643-019-1069-6

Cohen, G., & Cohen, A. (2024). Mapping educators' insights of student problem-solving difficulties while implementing video-assisted self-regulated learning training in classrooms. *European Journal of Open, Distance and E-Learning*, *26*(1), 72–86. https://doi.org/10.2478/eurodl-2024-0005

Dang, T. D., & Nguyen, M. T. (2024). Correction: Systematic review and research agenda for the tourism and hospitality sector: co-creation of customer value in the digital age. *Future Business Journal*, *10*(1), 19. https://doi.org/10.1186/s43093-023-00293-2

Danielsiek, H., Paul, W., & Vahrenhold, J. (2012). Detecting and understanding students' misconceptions related to algorithms and data structures. *Proceedings of the 43rd ACM Technical Symposium on Computer Science Education*, 21–26. https://doi.org/10.1145/2157136.2157148

Debora Simbolon, F., Harman, H., & Yarmayani, A. (2022). *Analisis kemampuan pemecahan masalah matematis siswa kelas x ipa sman 8 Kota Jambi. PHI: Jurnal Pendidikan Matematika*, *6*(1), 43. https://doi.org/10.33087/phi.v6i1.185

Djawa, Y., Asma, S., & Taher, T. (2019). *Analisis kesalahan siswa dalam menyelesaikan soal matematika pada SMA Pedesaan dan SMA Perkotaan. Al-Khwarizmi: Jurnal Pendidikan Matematika Dan Ilmu Pengetahuan Alam*, *7*(2), 135–150. https://doi.org/10.24256/jpmipa.v7i2.1276

Dörner, D., & Funke, J. (2017). Complex problem solving: what it is and what it is not. *Frontiers in Psychology*, *8*. https://doi.org/10.3389/fpsyg.2017.01153

Dwita, A., & Retnawati, H. (2022). Students' errors in solving mathematical problems. 040007. https://doi.org/10.1063/5.0107794

Eccius-Wellmann, C., Orenday, P. S., & García, F. (2019). Reasons for overconfidence in mathematics task performance of freshmen. 2956–2957. https://doi.org/10.21125/edulearn.2019.0788

Elmgrab, R. (2016). Possible criteria for evaluating students' translation errors. *International Journal of Humanities and Cultural Studies (IJHCS) ISSN 2356-5926*, *1*(3), 131–145.

Eysenck, M. W., & Keane, M. T. (2015). Cognitive psychology (7 th ed). Psychology Press. https://doi.org/10.4324/9781315778006

Fitrianingsih, I., & Budiman, I. (2022). *Analisis kemampuan pemecahan masalah matematis siswa kelas viii dalam menyelesaikan soal cerita spldv. JPMI (Jurnal Pembelajaran Matematika Inovatif)*, *5*(2), 327. https://doi.org/

10.22460/jpmi.v5i2.p327-334

Fitriyah, S. L., & Haerudin, H. (2021). *Analisis kemampuan pemecahan masalah matematis siswa smp pada materi himpunan. UNION: Jurnal Ilmiah Pendidikan Matematika*, *9*(2), 147–162. https://doi.org/10.30738/union.v9i2.9524

Fitriyana, D., & Sutirna. (2022). *Analisis kemampuan pemecahan masalah matematis siswa kelas vii pada materi himpunan. Jurnal Educatio FKIP UNMA*, *8*(2), 512–520. https://doi.org/10.31949/educatio.v8i2.1990

Fuji, A., Sahrun, N., & Ari, S. (2024). *Analisis kesulitan dalam pembelajaran matematika pada siswa sekolah dasar ditinjau dari berbagai faktor. Dewantara/ : Jurnal Pendidikan Sosial Humaniora*, *3*(2), 282–293. https://doi.org/10.30640/dewantara.v3i2.2652

Gopinath, S., & Lertlit, S. (2022). The implementation of polya's model in solving problem-questions in mathematics by grade 7 students. *Suranaree Journal of Social Science*, *11*(1), 47–59. https://doi.org/10.55766/FFNZ6417

Halawati, F. (2023). *Analisis kemampuan siswa dalam menyelesaikan soal pemecahan masalah matematis. Linear/ : Jurnal Ilmu Pendidikan*, *7*(1), 15–29. https://doi.org/10.53090/jlinear.v7i1.378

Hartuti, S. A., & Firmansyah, D. (2023). *Pada materi turunan fungsi aljabar*. *16*, 60–74.

Higgins, J. P., & Green, S. (2023). Cochrane handbook for systematic review of interventions. In S. G. Julian PT Higgins (Ed.), *IEEE International Symposium on Information Theory - Proceedings* (Version 6.). y John Wiley & Sons Ltd.

Khadijah, S., & Munandar, D. R. (2022). *Analisis kemampuan pemecahan masalah matematis siswa kelas viii pada materi SPLDV. Jurnal Ilmiah Dikdaya*, *12*(1), 7. https://doi.org/10.33087/dikdaya.v12i1.263

Khairunnisa, & Ramlah. (2021). *Aktivitas pemecahan masalah siswa dalam mengerjakan soal pisa ditinjau berdasarkan tahapan polya. Jurnal Pembelajaran Matematika Inovatif*, *4*(2), 445–452. https://doi.org/10.22460/jpmi.v4i2.445-452

Klang, N., Karlsson, N., Kilborn, W., Eriksson, P., & Karlberg, M. (2021). Mathematical problem-solving through cooperative learning the importance of peer acceptance and friendships. *Frontiers in Education*, *6*. https://doi.org/10.3389/feduc.2021.710296

Kurniawati, A. (2024). *Analisis kesulitan belajar matematika dalam menyelesaikan soal cerita siswa kelas 4 sekolah dasar. ISLAMIKA*, *6*(4), 1861–1884. https://doi.org/10.36088/islamika.v6i4.5392

Lastin, N., Wicaksono, A. G., & Prihastari, E. B. (2023). *Analisis kemampuan pemecahan masalah matematis dalam menyelesaikan soal tipe higher order thinking skill (hots) pada siswa kelas v sdn 02 plumbon tawangmangu. Jurnal Pendidikan Tambusa*, *7*(2), 18123–18130.

Leviton, L. C., Collins, C. B., Laird, B. L., & Kratt, P. P. (1998). Teaching evaluation using evaluability assessment. *Evaluation*, *4*(4), 389–409. https://doi.org/10.1177/13563899822208699

Lilisantika, & Roesdiana, L. (2023). *Analisis kemampuan pemecahan masalah matematis siswa sma dalam menyelesaikan soal cerita SPLTV. Didactical Mathematics*, *5*(2), 232–246. https://doi.org/10.31949/dm.v5i2.5480

Lishchynska, M., Palmer, C., Lacey, S., & O'Connor, D. (2023). Is motivation the key? Factors impacting performance in first year service mathematics modules. *European Journal of Science and Mathematics Education*, *11*(1), 146–166. https://doi.org/10.30935/scimath/12529

Malikah, S. (2023). *Analisis kemampuan pemecahan masalah matematis siswa pada barisan dan deret aritmetika berdasarkan teori Polya. Primatika/ : Jurnal Pendidikan Matematika*, *12*(2), 89–98. https://doi.org/10.30872/primatika.v12i2.2579

Mangarin, R. A., & Caballes, D. O. (2024). Difficulties in learning mathematics: a systematic review. *International Journal of Research and Scientific Innovation*, *XI*(IX), 401–405. https://doi.org/10.51244/IJRSI.2024.1109037

Martin, I., & Kadarisma, G. (2020). *Analisis kemampuan pemecahan masalah matematis siswa sma pada materi fungsi. Jurnal Pembelajaran Matematika Inovatif*, *3*(6), 641–652. https://doi.org/10.33387/jpgm.v1i3.3530

Martínez-Padrón, O. J. (2021). Afecto en la resolución de problemas de Matemática. *Revista Caribeña de Investigación Educativa (RECIE)*, *5*(1), 86–100. https://doi.org/10.32541/recie.2021.v5i1.pp86-100

Mengyao, H., Ismail, Z., Ismail, N., & Xueting, H. (2024). Motivation in learning mathematics among high school students in Ningbo, China. *Journal on Mathematics Education*, *15*(3), 961–978. https://doi.org/10.22342/jme.v15i3.pp961-978

Mutawah, M. A. Al, Thomas, R., Eid, A., Mahmoud, E. Y., & Fateel, M. J. (2019). Conceptual understanding, procedural knowledge and problem-solving skills in mathematics: high school graduates work analysis and standpoints. *International Journal of Education and Practice*, *7*(3), 258–273. https://doi.org/10.18488/journal.61.2019.73.258.273

Mutmainah, K. N., Kirom, A., Saifuloh, S., & Hadi, M. N. (2023). *Pentingnya metodologi pembelajaran bagi guru. Indo Green Journal*, *1*(2), 58–85. https://doi.org/10.31004/green.v1i2.10

Nanda Muliawati, F., & Sutirna, S. (2022). *Analisis kemampuan pemecahan masalah matematis siswa pada materi relasi dan fungsi. PHI: Jurnal Pendidikan Matematika*, *6*(1), 32. https://doi.org/10.33087/phi.v6i1.184

National Research Council. (2001). Adding it up: helping children learn mathematics. National academies press. https://doi.org/10.17226/9822

NCTM. (2020). Principles and standards for school mathematics. National Council of Teachers of Mathematics. https://www.nctm.org/standards

Nurhayati, & Zanthy, L. S. (2019). *Analisis kemampuan pemecahan masalah matematik siswa mts pada materi pola bilangan. Journal On Education*, *1*(02), 23–36.

Nursania, S. & Yahfizham. (2023). *Studi literartur algoritma pemograman pada pembelajaran matematika. Jurnal Elektronika Dan Teknik Informatika Terapan (JENTIK)*, *1*(4), 147–157. https://doi.org/10.59061/jentik.v1i4.510

Perkasa, A. A., & Astuti, D. (2022). Analysis of students' mathematical problem-solving ability on trigonometry. *UNION: Jurnal Ilmiah Pendidikan Matematika*, *10*(2), 179–191. https://doi.org/10.30738/union.v10i2.12476

Polya, G. (1978). How to solve it: a new aspect of mathematical method second edition. In *The Mathematical Gazette* (Vol. 30, p. 181). http://www.jstor.org/stable/

3609122?origin=crossref

Pradana, D. A. Y., & Murtiyasa, B. (2020). *Kemampuan siswa menyelesaikan masalah berbentuk soal cerita sistem persamaan linear ditinjau dari kemampuan penalaran. Pythagoras: Jurnal Pendidikan Matematika*, *15*(2), 151–164. https://doi.org/10.21831/pg.v15i2.35419

Prastiyo, A. P. P., Nugroho, A. A., Prasetyowati, D., & Nuriafuri, R. (2023). *Analisis kemampuan pemecahan masalah matematis peserta didik kelas iii materi bilangan cacah berdasarkan teori polya. Jurnal Pendidikan Tambusai*, *7*(1), 151–159. http://riset.unisma.ac.id/index.php/jp3/article/view/8400/6986

Purba, D., & Lubis, R. (2021). *Pemikiran george polya tentang pemecahan masalah. Jurnal MathEdu (Mathematic Education Journal)*, *4*(1), 25–31. http://journal.ipts.ac.id/index.php/MathEdu

Puspita, M., Gunawan, S., & Rosyana, T. (2022). *Analisis kesalahan siswa smp kelas viii dalam menyelesaikan soal pemecahan masalah matematis materi sistem persamaan linear dua variabel. Jurnal Pembelajaran Matematika Inovatif*, *5*(6), 1779–1787. https://doi.org/10.22460/jpmi.v5i6.1779-1786

Putri, N. E., Dermawan, & Febrianti. (2022). *Analisis kemampuan pemecahan masalah matematis dengan menggunakan teori polya pada siswa MTS Ddi Basseang. Peqguruang: Conference Series*, *4*(2), 856–861.

Rachmawati, A., & Adirakasiwi, A. G. (2021). *Analisis kemampuan pemecahan masalah matematis siswa SMA. Jurnal Pembelajaran Matematika Inovatif*, *4*(4), 835–845. https://doi.org/10.26877/jipmat.v6i1.8080

Rahmawati, A., & Warmi, A. (2022). *Analisis kemampuan pemecahan masalah matematis siswa smp pada materi teorema pythagoras. Jurnal Cendekia/ : Jurnal Pendidikan Matematika*, *6*(1), 365–374. https://doi.org/10.31004/cendekia.v6i1.1012

Ramadhani, S., Nurcahyo, A., Kasman, N., Hardianti, & Ahmad, J. (2024). Analysis of problem-solving skills with Polya's steps in solving numeracy problems in class VIII junior high school in terms of gender differences. 020045. https://doi.org/10.1063/5.0183389

Rohmah, Z., Fajri, A. S. N., & Riswari, L. A. (2023). *Analisis kemampuan pemecahan masalah matematis siswa kelas iv dalam menyelesaikan soal cerita pada materi pengukuran. LAPLACE/ : Jurnal Pendidikan Matematika*, *6*(2), 380–390. https://doi.org/10.35706/sjme.v6i1.5764

Samosir, C. M., Herman, T., Prabawanto, S., Melani, R., & Mefiana, S. A. (2024). Students' difficulty in understanding problems in the contextual problem-solving process. *PRISMA*, *13*(1), 20. https://doi.org/10.35194/jp.v13i1.3726

Schoenfeld, A. H. (1985). *Mathematical Problem Solving*. Academic Press. https://doi.org/10.1016/C2013-0-05012-8

Sen, E. O. (2022). Middle school students' engagement in mathematics and learning approaches: structural equation modelling. *Pedagogical Research*, *7*(2), em0124. https://doi.org/10.29333/pr/11908

Sholekah, L. M., Anggreini, D., & Waluyo, A. (2017). *Analisis kesulitan siswa dalam menyelesaikan soal matematika ditinjau dari koneksi matematis materi limit fungsi. WACANA AKADEMIKA: Majalah Ilmiah Kependidikan*, *1*(2), 151–164. https://doi.org/10.30738/wa.v1i2.1413

Simarmata, J. E., & Lailin Hijriani. (2020). Improving students' competency on financial mathematics learning by applying polyas' model heuristic strategy. *Kalamatika: Jurnal Pendidikan Matematika*, *5*(2), 143–154. https://doi.org/10.22236/KALAMATIKA.vol5no2.2020pp143-154

Sinaga, B., Sitorus, J., & Situmeang, T. (2023). The influence of students' problem-solving understanding and results of students' mathematics learning. *Frontiers in Education*, *8*. https://doi.org/10.3389/feduc.2023.1088556

Siregar, M. S., Siregar, E. Y., & Elindra, R. (2021). *Analisis kemampuan pemecahan masalah matematis di pesantren nurul falah panompuan. JURNAL. MathEdu (Mathematic Education Journal)*, *4*(1), 39–44.

Siswanto, S., & Yulaikah, Y. (2023). Implementation of cognitive learning theory in polya learning to improve mathematical problem solving ability. *Jurnal Analisa*, *9*(1), 48–58. https://doi.org/10.15575/ja.v9i1.25026

Suharti, S., Nur, F., & Alim, B. (2021). Polya steps for analyzing errors in mathematical problem solving. *AL-ISHLAH: Jurnal Pendidikan*, *13*(1), 741–748. https://doi.org/10.35445/alishlah.v13i1.570

Salsabila, A., Hasanah, R. U., Sitepu, D. F. S. B., & Hasanah, S. Z. H. (2024). *Studi literatur review: analisis kesulitan belajar mahasiswa pendidikan matematika.* Jurnal Arjuna: Publikasi Ilmu Pendidikan, Bahasa dan Matematika, 2(3), 19-27.

Sumartini, T., Rosyana, T., & Afrilianto, M. (2023). *Analisis kemampuan pemecahan masalah matematis siswa smp kelas viii pada materi aljabar. Jurnal Pembelajaran Matematika Inovatif*, *6*(1), 311–320. https://doi.org/10.46799/jst.v4i2.689

Syavira, V. F., & Novtiar, C. (2021). *Analisis kesalahan pemecahan masalah matematis siswa dalam menyelesaikan soal operasi hitung campuran bilangan cacah dan pecahan. JPMI (Jurnal Pendidikan Matematika Indonesia)*, *4*(6), 1671–1678. https://doi.org/10.22460/jpmi.v4i6.1671-1678

Tambychik, T., & Meerah, T. S. M. (2010). Students' difficulties in mathematics problem-solving: what do they say? *Procedia - Social and Behavioral Sciences*, *8*, 142–151. https://doi.org/10.1016/j.sbspro.2010.12.020

Taneo, P. N. L., & Kusumah, Y. S. (2021). Analysis of students' mathematical problem-solving ability based on category levels through polya steps. *(JIML) Journal of Innovative Mathematics Learning*, *4*(2), 87–95. https://doi.org/10.22460/jiml.v4i2.p87-95

Tririnika, Y., Suryadi, I., & Slamet, I. (2024). In-depth analysis of students' mathematical problem-solving skills: influence factors motivation and effective teaching strategies. *AL-ISHLAH: Jurnal Pendidikan*, *16*(3). https://doi.org/10.35445/alishlah.v16i3.5474

Utami, A. A. L. A., & Hakim, D. L. (2023). *Analisis kemampuan pemecahan masalah matematis siswa smp pada materi bilangan bulat dan pecahan. Didactical Mathematics*, *5*(2), 471–484. https://doi.org/10.31949/dm.v5i2.6381

Varveris, D., Saltas, V., & Tsiantos, V. (2023). Exploring the role of metacognition in measuring students' critical thinking and knowledge in mathematics: a comparative study of regression and neural networks. *Knowledge*, *3*(3), 333–348. https://doi.org/10.3390/knowledge3030023

Wahab, A. (2022). *Diagnosa kesulitan siswa dalam menyelesaikan soal spltv melalui* *pemetaan kognitif berbasis polya dan upaya mengatasi dengan scaffolding. RAINSTEK/ : Jurnal Terapan Sains & Teknologi*, *4*(1), 1–14.

Wahab A, A., Buhaerah, Ahsan, M., & Busrah, Z. (2022). Defragmenting the thinking structure of problem solving through cognitive mapping based on polya theory on pisa problems. *Journal Of Mathematics Learning Innovation (JMLI)*, *1*(1), 93–97. Https://Doi.Org/10.35905/Jmlipare.V1i1.3388

Wahab A, A., Buhaerah, B., Ahsan, M., & Busrah, Z. (2023). Mapping students' thinking structure in solving PISA-like problems: Errors and defragmentation. *Beta: Jurnal Tadris Matematika*, *16*(2). https://doi.org/10.20414/betajtm.v16i2.545

Wahyuni, N. T., Aima, Z., & Fitri, D. Y. (2022). *Analisis kesalahan siswa sma dalam menyelesaikan soal pemecahan masalah matematis. EDU-MAT: Jurnal Pendidikan Matematika*, *10*(1), 65. https://doi.org/10.20527/edumat.v10i1.10361

Wardhani, A. K., Haerudin, & Ramlah. (2022). *Jurnal didactical mathematics analisis kemampuan pemahaman matematis siswa smp dengan. Jurnal Didactical Mathematics*, *4*(2), 94–103.

Wardhani, M. K., & Nduru, M. (2023). Method of learning through play to facilitate the activeness of kindergarten students. *Jurnal Pendidikan Dasar Nusantara*, *8*(2), 250–262. https://doi.org/10.29407/jpdn.v8i2.19185

Yustiara, R. I., Siagian, T. A., & Susanto, E. (2021). *Analisis kemampuan pemecahan masalah matematis siswa kelas vii smpn 4 kaur pada materi perbandingan berdasarkan langkah penyelesaian polya. Jurnal Edukasi Matematika Dan Sains)*, *9*(2), 313–326. https://doi.org/10.25273/jems.v9i2.10420

Yusupova, A. K., & Tokhtasinova, N. I. (2022). Typical mistakes of students in analytical geometry and diagnostics of the causes of errors. *Current Research Journal Of Pedagogics*, *03*(01), 1–8. https://doi.org/10.37547/pedagogics-crjp-03-01-01