ISSN 2502-5872 (Print)
ISSN 2622-3627 (Elektronik)

Volume 10 Number 1, February 2025, 271-285

ANALYSIS OF PROCEDURAL ERRORS IN ARITHMETIC PROBLEM-SOLVING THROUGH POLYA STEPS

Dini Wardani Maulida[1], Mutiara Hisda Mahmudah[2], Miftachul Hidayati[3], Yulia Maftuhah Hidayati[4*]

[1, 2, 3, 4]Magister Departemen of Mathematics Education, Universitas Muhammadiyah Surakarta, Central Java, 57162, Indonesia

*Correspondence: ymh284@ums.ac.id

ABSTRACT

Difficulty is the cause of errors, math errors refer to actions or results that do not follow the correct steps or procedures in solving math problems. Therefore, the purpose of this study is to describe procedural errors in solving social arithmetic problems using Polya's steps. In this context, procedural errors refer to mistakes made by students while following the systematic steps recommended by Polya, which include understanding the problem, planning a solution strategy, carrying out the plan, and reviewing the results. This study aims to identify where and how errors occur at each of these stages, as well as to provide a deeper understanding of the challenges faced by students in solving social arithmetic problems. This research used a qualitative approach with a case study design. The participants of this study were 22 students of class VII of State Junior High School 3 Satu Atap Tawangharjo. Data validity uses triangulation of methods, namely through interviews and observations, and source triangulation. Data analysis technique with the flow method of the Miles and Huberman model. The study found that students experienced errors at each stage of Polya's steps. The percentage of student errors at each step is as follows: 20% in the understanding the problem step, 30% in the devising a plan step, 35% in the carrying out the plan step, and 15% in the looking back step. Three students were selected as samples, S-1, S-2, and S-3, each showing errors at different stages. S-1 made errors in understanding the problem and devising a plan, S-2 in devising a plan and carrying out the plan, while S-3 made errors in carrying out the plan and looking back. This research will describe the problem-solving errors experienced by students based on each Polya step they perform.

Keywords : Arithmetic, Error Analysis, Polya Steps, Problem Solving

How to Cite: Wardani. D, M., Mahmudah. M, H., Hidayati. M, & Hidayati. Y, M. (2025). Analysis of Procedural Errors in Arithmetic Problem Solving Through Polya Steps. *Mathline: Jurnal Matematika dan Pendidikan Matematika*, *10*(1), 271-285. http://doi.org/10.31943/mathline.v10i1.846

PRELIMINARY

The rapidly evolving and complex digital era is creating urgent global challenges that demand individuals to think critically, creatively, and collaboratively to find innovative solutions. In response to these demands, 21st-century learning is designed to equip students with the essential skills necessary to tackle future challenges. As Widodo. & Wardani (2020) explain, addressing the challenges of 21st-century learning requires students to develop proficiency in various key skills, such as effective communication,

teamwork, critical thinking, and problem-solving. Among these, problem-solving is particularly crucial, as it enables students to approach complex issues systematically, evaluate potential solutions, and adapt their strategies in dynamic environments skills that are indispensable in navigating the ever-changing global landscape. Thus, fostering problem-solving abilities is central to preparing students for the future.

In line with this, Pratama et al. (2022) argue that one of the learning objectives in the modern curriculum is how teachers, acting as facilitators, can direct, hone, facilitate, and elaborate students' thinking skills. Critical thinking skills are essential in helping students view problems from crucial perspectives, overcome challenges, and make informed decisions to achieve their goals (Amin et al., 2020; Antika, 2017). This learning objective is the cornerstone of 21st-century education. One effective way to develop students' critical thinking skills is by providing problem-solving-based tasks (T. Wulandari et al., 2017). Students should be trained and accustomed to tackling problem-solving assignments that require advanced cognitive skills, as this also helps assess their understanding of the material taught by the teacher (Rohmah et al., 2023). George. (1973) defines problem-solving as the process of seeking a solution to a goal that cannot be easily or immediately attained, requiring significant effort to accomplish. In the context of mathematics learning, problem-solving plays a central role in helping students not only develop their critical thinking and reasoning skills but also deepen their understanding of mathematical concepts. Given the importance of problem-solving, the approach and orientation of learning objectives in mathematics should focus on providing students with problem-solving tasks that challenge them to apply mathematical principles and strategies in complex, real-world scenarios (Yuliarni & Hidayati, 2023). This approach encourages students to think critically, analyze problems, and explore multiple methods of solving them, ultimately fostering the skills necessary for success in both academic and everyday contexts. Mathematical problem solving is a problem in which solving it requires mastery of good mathematical concepts with the problems given referring to non-routine problems (Can. & Özdemir., 2020; N. P. R. Wulandari et al., 2020).

Problem-solving in students is still very low, this is explained in research (Azzahra & Pujiastuti, 2020; Pramesti & Sari, 2024) that students' skills in problem-solving are still reasonably low. Based on the 2018 PISA study results, Indonesia's Mathematics PISA ranking is 72 out of 78 participating countries (Schleicher, 2019). These results are still far from what is expected, especially if you look at the score of Indonesian students, which only obtained 380 points. According to the 2022 International Report from the Program for

International Student Assessment (PISA), the average score is 472 points (OECD, 2023). This suggests that students in Indonesia still have relatively low mathematical problem-solving skills, with social arithmetic being one of the topics frequently perceived as difficult. This material is one of several mathematical materials where solving it requires a critical thinking process to get the right results. Social arithmetic materials such as profit and loss percentages, which require critical thinking, are often an obstacle for students. With basic knowledge, students should be able to easily understand problems related to social arithmetic material. However, in practice, some students still struggle to comprehend problems related to social arithmetic material. This is indicated by the fact that some students still make mistakes when solving social arithmetic problems (Sapitri et al., 2020). Social Arithmetic is closely connected to daily life, offering a variety of problems that can be utilized to enhance students' problem-solving abilities (Zaeny et al., 2021). Social Arithmetic, while highly relevant to real-life situations, is often challenging for students due to the need to apply abstract mathematical concepts to practical problems. Many students struggle with tasks involving percentages, interest calculations, and financial decisions, as they find it difficult to connect theoretical knowledge with real-world applications. This disconnect affects their problem-solving abilities and performance, highlighting the challenge of not just performing calculations but also interpreting and applying them in everyday contexts. Therefore, in problem-solving, it is necessary to improve the problem-solving (Wandanu et al., 2020).

Polya's steps can be one of many methods to improve problem-solving skills. According to Polya (2014), there are four stages of problem-solving skills, namely: 1) understanding the problem, 2) devising a plan, 3) carrying out the plan, and 4) looking back. Problem-solving activities with Polya's steps are an effort to increase students' level of understanding and be able to determine the steps of solving (Setiana et al., 2021). Polya's steps can be used to solve mathematical problems and find errors in social arithmetic (Yusuf & Fitriani, 2020).

Difficulty is the cause of errors (Furtado. et al., 2019; Ilhan & Akin, 2022). According to Ratnayanti et al. (2021), the causes of student errors in solving story problems are transformation errors caused by students not mastering the prerequisite material; process skill errors, namely errors caused by students not being careful and not mastering the material; answer writing errors, namely errors caused by students not checking the answers written to shorten their processing time. Rushton (2018) explains that student errors may stem from various factors, including internal and external influences.

Internal factors are those originating from within the students themselves. The internal factors in question are students' intelligence, talent, interest, motivation, and physical health. External factors refer to influences that originate outside the student. These factors include teaching methods, teacher-student relationships, student interactions, and the availability of school facilities and infrastructure. Mathematical errors occur when actions or outcomes deviate from the correct steps or procedures required to solve mathematical problems (Syahrir et al., 2023). A teacher must know the causes of these errors to improve student problem-solving (Gholami et al., 2021).

Brown & Skow (2016), student errors in mathematics are classified into three categories, namely: 1) Factual errors are errors made by students due to lack of factual information, 2) Procedural errors are errors caused by inaccuracy in applying mathematical procedures, 3) Conceptual errors occur when students have a misunderstanding or misunderstanding of the concepts related to the problem. It is important to understand the types of math errors that occur to students, because with this understanding, educators can identify the source of the problem and design more effective teaching strategies (Segura & Ferrando, 2021). In this study, researchers chose the type of procedural error due to several factors, namely, procedural errors are often the main barrier for students in mastering mathematical concepts well and lack of skills in planning and solving problems in the right way. Winarso and Toheri (2021) emphasized the importance of identifying and addressing students' errors when solving math problems. Insights into errors made while solving mathematical problems can be utilized to enhance mathematics teaching and learning processes, ultimately aiming to improve students' academic performance (Chiphambo & Mtsi, 2021). Thus, a teacher needs to conduct an error analysis to find out where students make mistakes when solving math problems, so that errors do not occur in solving problems.

Previous research on the analysis of arithmetic problem-solving errors has been conducted. Research by Das (2020) in India focuses on the lack of knowledge in arithmetic expressions and difficulties operating expressions for mathematical applications at the school level. Furthermore, research by Nugraha (2022), the results of this study indicates that students have high, medium, and low mathematical problem-solving abilities in solving mathematical problems. Then, research by Soto-Ardila et al. (2022) in Spain, the findings of this study suggested a relationship between teacher expectations and student performance in basic arithmetic. In addition, research by Simsek & Soylu (2020) in Turkey, the results of this study indicates that most participants, both prospective teachers,

and teachers, prefer to use an algebraic approach when solving problems and tend to have difficulty using an arithmetic approach.

Furthermore, research by Hellstrand et al. (2024) in Finland the findings revealed that cognitive and language skills made distinct contributions to various areas of math ability, even after accounting for factors such as children's gender, age, parental education, and family income. Then, research by Puspitasari et al. (2019) indicates that subjects who fall into the high-ability category in mathematics do not show problems in the aspects of fluency, flexibility, and originality, except in the aspect of elaboration. However, no specific research examines the analysis of procedural errors in solving social arithmetic through Polya's steps.

This study will analyze procedural errors in student problem-solving through Polya's steps based on this description. This research aims to analyze and describe procedural errors in solving social arithmetic problems using Polya's steps.

METHODS

This study employs a qualitative approach, which systematically and accurately describes data based on facts, phenomena, and social processes (Creswell, 2014) according to facts in the field without any manipulation (Kholid, Rofi'ah, et al., 2022). This research uses a case study approach, which focuses on understanding phenomena in a particular context or a particular unit of analysis in depth for individuals, groups, institutions, social movements, or certain events (Merriam. & Tisdell., 2015; Sutama et al., 2022b). This study explicitly describes and analyzes procedural errors in solving social arithmetic through Polya's steps.

This study's participants consisted of 22 seventh-grade students from State Junior High School 3 Satu Atap Tawangharjo. They were randomly selected and experienced procedural errors in solving social arithmetic problems. The subjects were chosen because they had taken social arithmetic material and voluntarily participated in this study without coercion and expressed their willingness to provide the information needed.

Data was collected through observation, tests, document analysis, and in-depth interviews. Observations were conducted directly in the classroom to observe students' behavior in solving problems. Tests were conducted to find out how procedural errors affect student problem-solving. The researchers analyzed student work documents from the tests that had been conducted to describe and analyze the errors experienced by the students. Researchers then conducted structured interviews with the students to obtain

more in-depth data about the errors they experienced. Data validity uses triangulation of methods and sources. Triangulation of methods by checking data from the same source using different methods. Meanwhile, source triangulation is done by checking data obtained from various sources (Sutama et al., 2022a).

Data analysis techniques using the flow method. The process of analyzing data through activities to collect or compile information systematically. Based on the results of observations, documentation, and interviews, the data is organized into categories, broken down into units, synthesized, arranged into patterns, and then filtered to identify the most important aspects of the study. Finally, conclusions are drawn to ensure both the researcher and others easily understand the findings. The data analysis procedure consists of three stages: data reduction, data presentation, and conclusion drawing (Miles & Huberman, 1922).

At the data reduction stage in this study, students' answers were identified according to Polya's steps. Then, it is analyzed and converted into notes as interview material. The results of interviews with research subjects will be arranged in appropriate language so that the data is ready to use. The data for this study presents the results of the student answers studied and the results of the interviews, and then it is analyzed to find and complete the errors made by these students. The conclusion of this research is drawn by comparing the results of the analysis of answers and interviews with research subjects to identify the mistakes in problem-solving Polya steps.

Students' errors in solving social arithmetic problems were analyzed using Polya's problem-solving steps, with the corresponding indicators outlined in Table 1

Table 1. Error Indicators Based on Polya's Problem-Solving Steps

Solving Steps	Error Indicators
Understanding the problem	1. Students do not write down what is known in the problem. 2. Students do not write what is asked of them in the problem.
Devising a plan	1. Students do not write arithmetic formulas or concepts to Devising a plan strategy. 2. Students are wrong in linking what is known and what is unknown.
Carrying out the plan	1. Students are wrong in implementing the planned solution strategy. 2. Students are wrong in writing numbers in the solution strategy. 3. Students are wrong in doing calculations.
Looking back	Students are wrong in rechecking the correctness of answering the question.

Source: (Saifurrisal, 2022)

RESULT AND DISCUSSION

Understanding the types of errors students make during problem-solving is crucial for improving educational strategies and enhancing students' learning outcomes. In this regard, the findings of this research are significant, as they provide insight into the challenges students face when applying Polya's steps to solve problems. Based on the research, it was found that students experienced different errors in problem-solving using Polya's steps. Figure 1 displays the percentage of students who made errors at each stage of Polya's problem-solving method. 20% of errors occurred in understanding the problem, 30% of errors occurred in devising a plan, 35% of errors occurred in carrying out the plan, and 15% of errors occurred in looking back. Then, three student answers were taken. Namely, S-1 had problem-solving errors at the step of understanding the problem and devising a plan, S-2 had problem-solving errors at devising a plan and carrying out the plan, and S-3 had problem-solving errors at carrying out the plan and looking back. Furthermore, we will examine students' problem-solving errors in Polya's steps based on the errors they have experienced.

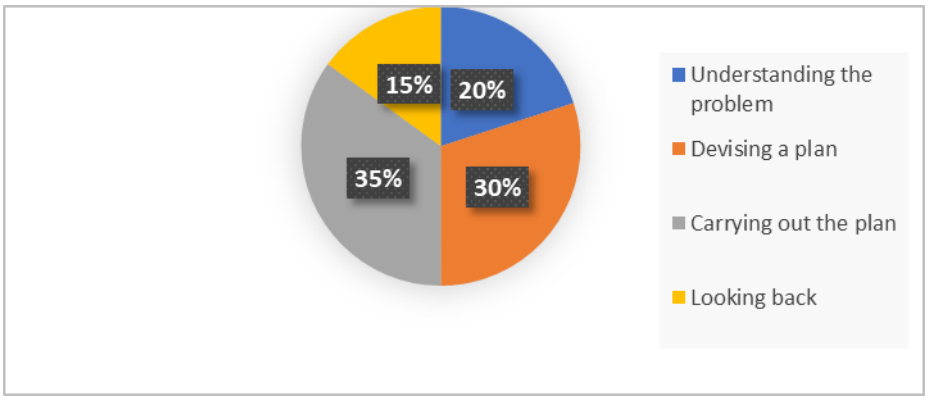

Figure 1. Percentage of Student Errors at Each Step

The first problem, which is about profit material with the problem of the selling price of an item which is then resolved using the indicators of Polya's steps to understanding the problem, devising a plan, carrying out the plan, and looking back. The following is an image of problem number 1 in Figure 2.

1. Suatu barang dibeli dengan harga Rp. 27.500,00. kemudian dijual lagi. Tentukan kerugian yang diderita pedagang itu jika barang tersebut dijual lagi dengan harga Rp. 20.500,- !
1. An item is purchased for Rp. 27,500 and then sold again. Determine the loss suffered by the trader if the goods are sold again at a price of Rp. 20,500!

Figure 2. Problem 1 Social Arithmetic Problem-Solving

Error Understanding the problem and Devising a plan

Errors in solving problem one according to Polya's steps, particularly in understanding the problem and devising a plan, are evident in the students' work, which does not correctly follow Polya's method. Figure 3 shows one of the student answer sheets for working on social arithmetic problems.

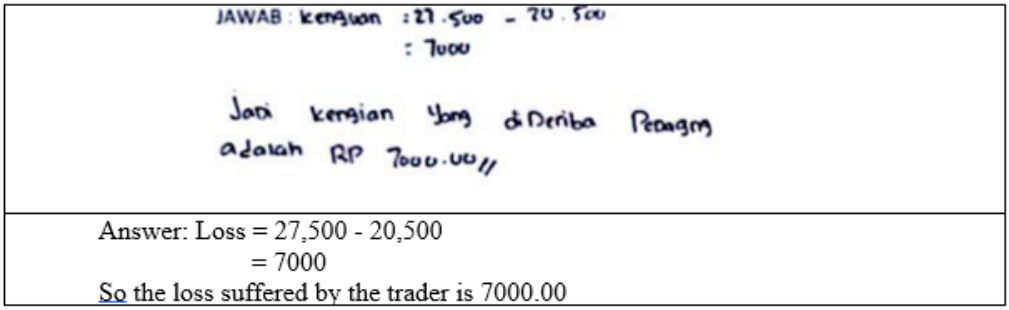

Figure 3. Problem-Solving Number 1 S-1 Error understanding the problem and devising a plan

It can be seen that S-1 students have difficulty in understanding the problem appropriately, as well as planning an effective solution strategy. Overall, S-1 immediately solved the problem without first recording the known and asked information about the problem. He immediately performed the subtraction operation to find the answer. Based on the interview, S-1 showed difficulty understanding the problem, despite having read it repeatedly, and did not know the right way to solve it. S-1 performed the subtraction operation to find the answer, although the result was incorrect. This student then tried to recheck his answer by writing the conclusion at the end, but the check was also inaccurate. This is in line with the research of Son et al. (2019), which states that students who make mistakes since the early stages of solving tend to be hampered in applying Polya's steps appropriately.

In the second problem, which is about profit material with the problem of the selling price of an item is then resolved using Polya's step indicators to understanding the problem, Devising a plan, perform the solution, and re-examine the results of the solution. The following is an image of problem number 2 in Figure 4.

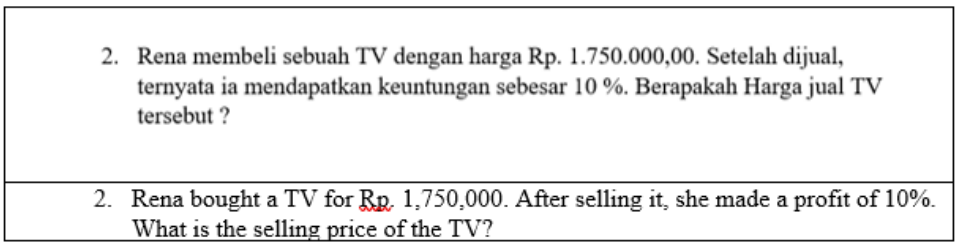

Figure 4. Problem 2 Social Arithmetic Problem Solving

Errors in Devising a Plan and Carrying Out the Plan

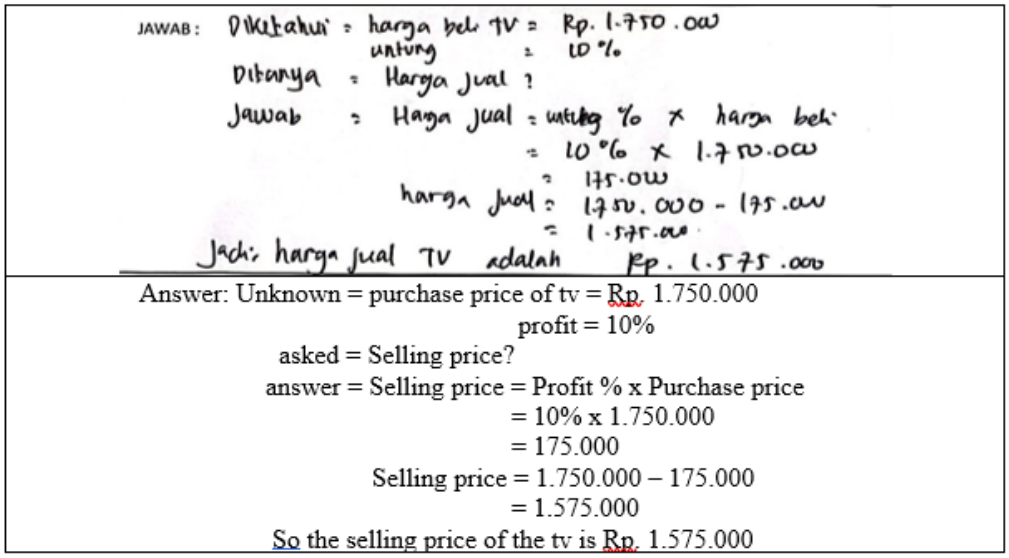

Figure 5. Problem-Solving Number 2 S-2 Error devising a plan and carrying out the plan

In problem number 2, which involves social arithmetic on discounts, students demonstrate an understanding of the problem by accurately writing down the given information and what is being asked, in alignment with the topic. At the planning stage, student S-2 also wrote down the formula used to solve the problem, but the formula used was incorrect, so there was an error when calculating the discount price. Thus student S-2 also made an incorrect solution. Although, student S-2 re-checked the answers obtained, the final results were still not correct. Based on the interview, S-2 was able to explain what was in the problem but forgot to write what the question asked. This is because S-2 was not careful in reading the problem while working. Students also explained that there was an error in planning the solution because they forgot the formula used, so students were wrong in the solution process. Consistent with the study by Ismiranda et al. (2024), students who struggle to understand the problem often do so because they are not accustomed to writing down what is known and what is being asked.

Third problem is about discount material and the money that must be paid by someone to buy an item. It is then resolved using the indicators of Polya's steps to understand the problem, Devising a plan, execute it, and re-examine its results. The following is a picture of problem number 3 in Figure 6.

3. Aditya membeli baju seharga Rp 150.000,00 jika baju yang dibeli aditya mendapat diskon 20%, maka besar uang yang harus dibayarkan oleh aditya?
3. Aditya bought a shirt for Rp 150,000.00 if the shirt purchased by Aditya received a 20% discount, then how much money must be paid by Aditya?

Figure 6. Problem 3 Social Arithmetic Problem Solving

Errors in Carrying Out the Plan and Looking Back

Jawab : ① besar diskon : harga beli x diskon = 150.000 x 20 % = 30.000 ② Uang yang dibayar : harga beli – diskon = 150.000 – 20.000 = 130.000
Answer: 1. amount of discount = purchase price x discount = 150.000 x 20% = 30.000 2. money paid = purchase price – discount = 150.000 – 20.000 = 130.000

Figure 7. Problem-Solving Number 3 S-3 Error in Carrying out the plan

Jadi, Rp. 130.000 //
So, Rp. 130.000

Figure 8. Problem-Solving Number 3 S-3 Error in Looking Back

From the picture, student S-3 could write a solution plan and perform the solution in stage 1 correctly to find the discount amount. Then, in the second stage, S-3 students also wrote a solution plan and carried out the solution, but it was less precise. S-3 made a mistake in entering the amount of discount received, so the final result was incorrect. This student also tried to re-examine the answers found, but the writing was still incomplete, and the results obtained were less precise. Based on the interview, S-3 did not find it difficult to solve the problem, so S-3 students were able to write and explain the problem by writing the known questioned completely and accurately, able to write and explain the solution plan still, but in doing the solution there was still an error in entering the discount price into the formula. Student S-3 explained that he was in a hurry to work on the problem, so he was not careful in entering the amount of discount that had been found. S-3 also explained that when rechecking the results found to be fixed, there were still errors. In line with research conducted by Himawati et al. (2021), not carrying out the completion

planning stage is the main factor for students to make mistakes in the Polya step indicators, and checking back is rarely done by some students.

This research can help educators understand the common errors that occur when students apply Polya's steps in mathematical problem solving. By knowing the types of errors that often appear, educators can focus more on strengthening areas that require deeper understanding, so that students can be more effective in mastering problem solving using Polya's steps. These findings can be used in the design of learning by incorporating targeted interventions and instructional strategies that specifically address the procedural errors identified in the research. For instance, teachers could provide additional exercises focusing on each of Polya's steps, offer more guided practice, and facilitate discussions that help students understand the reasoning behind each step.

One recommendation for teachers in overcoming procedural errors is to provide continuous formative assessments to monitor students' understanding at each stage of the problem-solving process. Offering immediate feedback when errors are made allows students to recognize and correct mistakes promptly. Furthermore, teachers can encourage collaborative learning, where students work in pairs or small groups to discuss and solve problems together, thus enhancing their ability to follow each of Polya's steps accurately.

This research is also relevant to problem-solving-based learning in general, as it emphasizes the importance of systematic approaches in tackling mathematical problems. Problem-solving-based learning encourages students to develop critical thinking and reasoning skills, both of which are essential for success in mathematics and beyond. By addressing procedural errors identified in this study, educators can foster more effective problem-solving skills, not only in social arithmetic but in other areas of mathematics as well. This aligns with broader educational goals of cultivating problem-solving abilities that students will need to navigate complex real-world challenges.

CONCLUSION

This study identifies various procedural errors made by students when solving social arithmetic problems using Polya's problem-solving steps. Errors in the 'understanding the problem' stage (20%), errors in the 'devising a plan' stage (30%), and errors in the 'carrying out the plan' stage (35%) were the most frequent, while the least errors occurred in the 'looking back' stage (15%). These errors were caused by misinterpreting the problem, incomplete mastery of social arithmetic, calculation errors, and rushing through the solution process. To assist students' understanding, it is important

to practice various problem formats and provide detailed explanations using Polya's steps. This research offers opportunities to explore factors influencing procedural errors in social arithmetic problem-solving, such as the impact of student characteristics on learning outcomes. Furthermore, a comparative study between Polya's steps and other problem-solving methods is needed to assess their strengths and weaknesses.

REFERENCES

Amin, A. M., Corebima, A. D., Zubaidah, S., & Mahanal, S. (2020). The correlation between metacognitive skills and critical thinking skills at the implementation of four different learning strategies in animal physiology lectures. *European Journal of Educational Research*, *9*(1), 143–163. https://doi.org/10.12973/eu-jer.9.1.143

Antika, L. T. (2017). Hubungan Antara Minat Baca dan Hasil Belajar Biologi Siswa Yang Diajar Dengan Model Reading-Concept Map-Think Pair Share (REMAP TPS). *Wacana Didaktika*, *5*(1), 28–35. https://doi.org/10.31102/wacanadidaktika.5.01.28-35

Brown, J., & Skow, K. (2016). *Identifying and Addressing Mathematics :* https://iris.peabody.vanderbilt.edu/wp-content/uploads/pdf_case_studies/ics_matherr.pdf

Can., D., & Özdemir., İ. E. Y. (2020). An Examination of Fourth-Grade Elementary School Students' Number Sense in Context-Based and Non-Context-Based Problems. *International Journal of Science and Mathematics Education*, *18*(7), 1333–1354.

Chiphambo, S. M., & Mtsi, N. (2021). Exploring Grade 8 Students' Errors When Learning About the Surface Area of Prisms. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(8), 1–10. https://doi.org/10.29333/EJMSTE/10994

Creswell, J. W., & Creswell, J. D. (2014). Mixed Methods Procedures. In *Research Defign: Qualitative, Quantitative, and Mixed M ethods Approaches*.

Das, K. (2020). A Study on Misconception of Using Brackets in Arithmetic Expression. *Shanlax International Journal of Education*, *8*(4), 76–80. https://doi.org/10.34293/education.v8i4.3252

Furtado., P. G. F., Hirashima., T., Hayashi., Y., & Maeda., K. (2019). Application focused on structural comprehension of mathematics contextual problems for kindergarten students. *Research and Practice in Technology Enhanced Learning*, *14*(2). https://doi.org/10.1186/s41039-019-0096-1

George., P. (1973). How To Solve It (2nd ed.). In *New York: Princenton Science Library*.

Gholami, H., Ayub, A. F. M., & Yunus, A. S. M. (2021). Analysis of the Mathematics Function Chapter in a Malaysian Foundation Level Textbook Adopted by a Public University. *Mathematics Teaching-Research Journal*, *13*(3), 81–98.

Hellstrand, H., Holopainen, S., Korhonen, J., Räsänen, P., Hakkarainen, A., Laakso, M. J., Laine, A., & Aunio, P. (2024). Arithmetic fluency and number processing skills in identifying students with mathematical learning disabilities. *Research in Developmental Disabilities*, *151*(June). https://doi.org/10.1016/j.ridd.2024.104795

Himawati, S. A., Aini, I. N., & Warmi, A. (2021). Description Of Mathematic Problem Solving Ability for Class X Senior High School Students Based On Polya Steps. *Mathline : Jurnal Matematika Dan Pendidikan Matematika*, *6*(2), 191–206. https://doi.org/10.31943/mathline.v6i2.226

Ilhan, A., & Akin, M. F. (2022). Analysis of Contextual Problem Solutions, Mathematical Sentences, and Misconceptions of Pre-Service Mathematics Teachers. *International Electronic Journal of Mathematics Education*, *17*(1). https://doi.org/10.29333/iejme/11470

Ismiranda, K., Nurcahyo, A., & Utami, N. S. (2024). Analysis Of Contextual Problem-Solving Ability Of Three-Variable Linear Equation Syestem Material Given Mathematical Disposition. *M A T H L I N E Jurnal Matematika Dan Pendidikan Matematika*, *9*(4), 1237–1252. https://doi.org/http://doi.org/10.31943/mathline.v9i4.720

Kholid, M. N., Rofi'ah, F., Ishartono, N., Waluyo, M., Maharani, S., Swastika, A., Faiziyah, N., & Sari, C. K. (2022). What Are Students' Difficulties in Implementing Mathematical Literacy Skills for Solving PISA-Like Problem? *Journal of Higher Education Theory and Practice*, *22*(2), 180–199. https://doi.org/10.33423/jhetp.v22i2.5057

Kholid, M. N., Sa'Dijah, C., Hidayanto, E., & Permadi, H. (2022). Students' reflective thinking pattern changes and characteristics of problem solving. *Reflective Practice*, *23*(3), 319–341. https://doi.org/10.1080/14623943.2021.2025353

Merriam., S. B., & Tisdell., E. J. (2015). Qualitative Research: A Guide to Design and Implementation. In *San Francisco, CA: Wiley.*

Miles, M., & Huberman, M. (1922). Qualitative Data Analysis. In Analisis Data Kualitatif: Buku Sumber Tentang Metode-metode Baru [Qualitative Data Analysis. In Qualitative Data Analysis: A Sourcebook of New Methods]. In *Analisis Data Kualitatif: Buku Sumber Tentang Metode-metode Baru*. Universitas Indonesia (UI-PRESS).

Nugraha, I. D. (2022). Students' Mathematical Problem-Solving Ability on Social Arithmetic Material. *Journal of Innovation and Research in Primary Education*, *1*(2), 33–39. https://doi.org/10.56916/jirpe.v1i2.171

OECD. (2023). *PISA 2022 Results (Volume I): The State of Learning and Equity in Education*.

Polya, G. (2014). How to Solve it: a New Aspect of Mathematical Method. *In Princeton University Press*.

Pratama, R., Alamsyah, M., & Noer, S. (2022). Analisis Kebutuhan Guru Terhadap Pengembangan Modul dalam Meningkatkan Kemampuan Berpikir Kritis Peserta Didik. *EduBiologia: Biological Science and Education Journal*, *2*(1), 7–13. https://doi.org/10.30998/edubiologia.v2i1.9769

Ratnayanti, N., Sumadji, & Suwanti, V. (2021). Analisis Kesalahan Konsep Matematika Siswa dalam Menyelesaikan Soal Berdasarkan Taksonomi SOLO. *Buana Matematika : Jurnal Ilmiah Matematika Dan Pendidikan Matematika*, *11*(1), 95–110. https://doi.org/10.36456/buanamatematika.v11i1.3714

Rohmah, A., Rosita, M. D., Fatimah, E. R., & Wahyuni, I. (2023). Analisis kemampuan berpikir kritis siswa kelas vii smp dalam menyelesaikan soal cerita materi segitiga. *Jurnal Inovasi Pembelajaran Matematika: PowerMathEdu*, *2*(2), 175–184. https://doi.org/10.31980/powermathedu.v2i2.3098

Rushton, S. J. (2018). Teaching and learning mathematics through error analysis. *Fields Mathematics Education Journal*, *3*(4), 1–12. https://doi.org/10.1186/s40928-018-0009-y

Sagala, R., Nuangchalerm, P., Saregar, A., & El Islami, R. A. Z. (2019). Environment-friendly education as a solution to against global warming: A case study at Sekolah Alam Lampung, Indonesia. *Journal for the Education of Gifted Young Scientists*, *7*(2), 85–97. https://doi.org/10.17478/jegys.565454

Saifurrisal, A. H. (2022). Students' Errors in Solving Sequences and Series Word Problems Based on Problem-Solving Steps of Polya. *International Conference on Studies in Education and Social Sciences*, *10*(13), 89–100. www.istes.org

Sapitri, Y., Fitriani, N., & Kadarisma, G. (2020). Analisis kesulitan siswa smp dalam menyelesaikan soal pada materi aritmetika sosial. *Jurnal Pembelajaran Matematika Inovatif*, *3*(5), 567–574. https://doi.org/10.22460/jpmi.v3i5.567-574

Schleicher, A. (2019). PISA 2018 Insights and Interpretations. *OECD Publishing*.

Segura, C., & Ferrando, I. (2021). Classification and analysis of pre-service teachers' errors in solving fermi problems. *Education Sciences*, *11*(8), 1–19. https://doi.org/10.3390/educsci11080451

Setiana, N. P., Fitriani, N., & Amelia, R. (2021). Analisis Kemampuan Pemacahan Masalah Matematis Siswa SMA pada Materi Trigonometri Berdasarkan Kemampuan Awal Matematis Siswa. *Jurnal Pembelajaran Matematika Inovatif*, *4*(4), 899–910. https://doi.org/10.22460/jpmi.v4i4.899-910

Simsek, M., & Soylu, Y. (2020). Arithmetic and Algebraic Problem-Solving Approaches of Prospective Teachers and Teachers in Service. *International Journal of Curriculum and Instruction*, *12*(2), 263–278.

Son, A. L., Darhim, & Fatimah, S. (2019). An analysis to student error of algebraic problem solving based on polya and newman theory. *Journal of Physics: Conference Series*, *1315*(1). https://doi.org/10.1088/1742-6596/1315/1/012069

Sutama, Hidayati, Y. M., & Novitasari, M. (2022a). *Metode Penelitian Pendidikan [Educational Research Methods]*. Muhammadiyah University Press.

Sutama, Hidayati, Y. M., & Novitasari, M. (2022b). *Metode Penelitian Pendidikan Matematika (Mathematics Education Research Methods)*. Muhammadiyah University Press.

Syahrir, Fauzi, A., Juliawan, R., & Lapele, D. A. (2023). Analysis of Student Conceptual Errors and Procedural Errors in Solving Mathematical Problems. *Jurnal Ilmiah Mandala Education (JIME)*, *9*(4), 2279–2285. https://doi.org/10.58258/jime.v9i1.5980/http

Wandanu, R. H., Mujib, A., & Firmansyah. (2020). Hypothetical Learning Trajectory berbasis Pendidikan Matematika Realistik untuk Mengembangkan Kemampuan Pemecahan Masalah Matematis Siswa. *Jurnal MathEducation Nusantara*, *3*(2), 8–16.

Widodo., S., & Wardani, R. K. (2020). Mengajarkan Keterampilan Abad 21 4C (Communication , Collaboration , Critical Thinking and Problem Solving , Creativity and Innovation). *Jurnal Program Studi PGMI*, *7*(2), 185–197.

Winarso, W., & Toheri, T. (2021). An Analysis of Students' Error in Learning Mathematical Problem Solving; the Perspective of David Kolb's Theory. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, *12*(1), 762–773. https://doi.org/10.16949/turkbilmat.753899

Wulandari, N. P. R., Dantes, N., & Antara, P. A. (2020). Pendekatan Pendidikan Matematika Realistik Berbasis Open Ended Terhadap Kemampuan Pemecahan Masalah Matematika Siswa. *Jurnal Ilmiah Sekolah Dasar*, *4*(2), 131–142. https://doi.org/10.23887/jisd.v4i2.25103

Wulandari, T., Amin, M., Zubaidah, S., & IAM, M. (2017). Students' Critical Thinking Improvement Through PDEODE and STAD Combination in The Nutrition and Health Lecture. *International Journal of Evaluation and Research in Education (IJERE)*, *6*(2), 110117. https://doi.org/10.11591/ijere.v6i2.7589

Yuliarni, R. W., & Hidayati, Y. M. (2023). *Analysis of Students' Misconseptions in Addition and Subtraction Material*. Atlantis Press SARL. https://doi.org/10.2991/978-2-38476-086-2_148

Yusuf, A., & Fitriani, N. (2020). Analisis Kesalahan Siswa SMP dalam Menyelesaikan Soal Persamaan Linear Dua Variabel Di Smpn 1 Campaka Mulya-Cianjur. *Jurnal Pembelajaran Matematika Inovatif*, *3*(1), 59–68. https://doi.org/10.22460/jpmi.v3i1.p59-68

Zaeny, H. N., Sujiran, & Puspananda, D. R. (2021). Analisis Kesalahan Siswa Dalam Penyelesaian Soal Cerita Ditinjau Dari Tipe Kepribadian Keirsey. *Journal of Mathematics Education and Science*, *4*(2), 51–58. https://doi.org/10.32665/james.v4i2.212