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Primary school students' mathematical literacy in solving multiple-solution

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Abstract: This study aims to analyze primary school students' mathematical literacy (ML) in solving multiple-solution (MS) problems. We call students ML to solve MS with MS-ML. The research subjects are students from grade four in a Sidoarjo, East Java primary school. The research method used is descriptive qualitative with a case study approach. The instruments used were an MS-ML test and an interview. Interviews were conducted with several students who were selected through the MS-ML category. There are three indicators of MS-ML: the formulating stage, the employing stage, and the interpreting stage. The results of the analysis showed that there were appropriate and inappropriate MS-ML categories. Most students are in the inappropriate MS-ML category. Many students struggle to formulate, employ, and interpret the correct divergent solution. We suggest that one familiarize oneself with divergent ML-MS-based problem-solving in learning and teaching, namely building ML problem-solving with multiple solutions or MS strategies.

Keywords: Mathematical literacy, multiple-solution, problem-solving

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INTRODUCTION

Mathematical literacy (ML) is the ability of an individual to formulate, employ, and interpret mathematics in various contexts (OECD, 2015). In Indonesia, ML is known as numeracy in the 2021 guidelines for strengthening literacy and numeracy in schools (Kemdikbud, 2021). Including primary school students, ML is needed as a foundation for preparing and projecting mathematics in various contexts in 21st-century competencies (Nagasaki, 2015). In this case, it is expected that through ML, students can train their reasoning in applying and verifying mathematical concepts presented in a real problem (Yang, Kuo, & Jiang, 2019). In other words, ML is needed so that students not only focus on products or formulas but also use formulas to solve problems (Lanya, Zayyadi, & Sulfiah, 2021; She, Stacey, & Schmidt, 2018).

Students with good ML can be seen from the sensitivity of using appropriate mathematical concepts to find the correct problem-solving solution (Hera & Sari, 2015). Meanwhile, the benchmark for student success in solving ML problems can be seen in students' success in formulating and interpreting the problem's surrounding situation (Purnomo & Sari, 2021). In addition, Khikmiyah and Midjan (2017) said that ML can be seen from students' ability to analyze, convey reasons and ideas effectively, and interpret mathematical problems in various forms and circumstances. Therefore, it is essential to pay attention to ML, especially for primary school students, not only the product but also the process of using ML in solving problems.

Unfortunately, the level of ML involving primary school students is still inadequate. Compared to other countries, the ML competitiveness of students in Indonesia tends to be less competitive (Nirmala, 2022). Based on the PISA (Program for International Student Assessment) study, Indonesia's score is still lagging compared to other countries. Students' ML in Indonesia is still low. This was shown in 2018, which obtained a score of 379 from the highest score of 691 and the lowest score of 325 (Schleicher, 2018). Suharta and Suarjana (2018) and Masfufah and Afriansyah (2021) stated that students' ML is low because Indonesia's learning and teaching process differs from its evaluation; the problems presented are not ML-based.

Most problems in mathematics can be solved using several methods (Große & Renkl, 2006). We can measure this by using multiple-solution (MS) based problems. MS can provide leeway for students to give multiple answers to other solutions that fit their mindset. MS can also be viewed as a task that indirectly asks students to find various ways of solving (Leikin & Levav-Waynberg, 2009; Levav-Waynberg & Leikin, 2012). MS are also referred to as exemplary tasks with mathematical challenges, as they encourage the performance of solutions that differ from typical solutions (Guberman & Leikin, 2013).

Through MS problems, students will explore creating and using more than one solution or strategy so that students can be trained in their mindset and choose the easier or more relevant way to do it (Stupel & Ben-Chaim, 2017). In addition, MS problems can measure students' level of thinking in solving a problem with various solutions (Verschaffel, Schukajlow, Star, & Van Dooren, 2020). Using MS-based problems will increase students' enthusiasm and curiosity in solving them (Stupel & Ben-chaim, 2017). Therefore, we hope that MS-based ML problems (MS-ML) can be a solution to evaluate students' skills more flexibly and give students leeway in providing more varied solutions.

Hwang and Ham (2021) examined the advantages of learning mathematics by working on varied problems that can improve students' ML. Almarashdi, Mohamed, and Jarrah (2023) stated that MS-ML given to students can be used to measure students' ability to use other alternative solutions. While looking for alternatives, students will do flashbacks to remember previous experiences in solving their problems (Schindler & Lilienthal, 2020).

The results of Shore and Kobiela's (2020) research state that participants working on MS-ML can provide multiple answers, but for non-standard solutions or solutions that students do not commonly write. Anggraeny and Siswono (2013) also confirmed in their research that in writing MS, students write non-standard solutions with a different scope from the supposed solution, resulting in inaccurate results.

Some previous research results show that primary school students are still not skilled in ML, so students still have difficulty in solving it (Hapsari, Saputro, & Sadewo, 2022; Hillman, 2014; Nirmala, 2022; Ojose, 2011). This MS-based problem will encourage students to build many solutions by writing down different mathematical procedures (Schukajlow & Krug, 2014b). Another study by Hwang and Ham (2021) showed that ML can be improved by working on problems presented in various solution strategies. These existing studies have not discussed the ML of primary school students when given ML. This study analyzes primary school students' ML in solving MS to determine how primary school students' MS-ML. Hence, this study analyzes ML-MS or ML primary school students in solving MS problems.

METHODS

Research Design

The method used in this research is a qualitative research method with a case study approach. Qualitative methods are analytically descriptive. The written description is based on data obtained from interviews, observations, and document analysis (Sohilait, 2018). The data presented is in the form of students' ML in solving MS. Research through case studies is a method used to analyze data from a case to explore human behavior. The observed behavior is the MS-ML of primary school students.

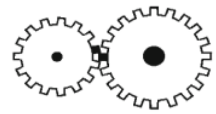
Participant

The research was conducted at Sekolah Dasar Muhammadiyah 2 Sidoarjo and involved 19 students at the fourth-grade level. We chose to conduct research at the fourth-grade level because this level is a stage where students have begun to think divergently in finding varied solutions, which is a requirement for solving MS. So, students can provide ML-solving processes with various solutions or strategies in solving MS.

Material

In this study, we used MS-ML test instruments and interview guidelines. The MS-ML instrument contained one essay problem, as shown in Table 1. After students did the MS-ML test, the researcher interviewed several students using a purposive sampling technique. Students were grouped based on the MS-ML category, namely appropriate and inappropriate MS-ML. One student each was selected to be interviewed to represent the MS-ML answer category. The interview was conducted to provide several questions regarding the solution that students provided on the answer sheet. Some aspects that researchers asked students during the interview included 1) the material of the problem given, 2) the standard solution that students provide, 3) student difficulties in the process of working, 4) other solutions that can be given besides the standard solution, 5) the reason why choosing the solution chosen, 6) student interpretation of the results that have been obtained.

TABLE 1. *MS-ML Instrument*

The two types of two gears differ in size, so their number of teeth is also different. The small gear has 15 teeth, while the large gear has 20 teeth. The two gears are juxtaposed together, as shown in the side image. Each gear has one tooth marked; then, both gears are rotated. When will the marked teeth come together for the first time?	

Sources : (Guberman & Leikin, 2013)

Data analysis was carried out by reducing, presenting, and concluding. Meanwhile, data credibility uses source triangulation. The sources needed to justify data credibility are documents of MS-ML test results, interview results, and observations. All data sources were analyzed for student ML based on student mathematical activities in solving MS. Mathematical activities are focused on MS-ML activities, including the formulating stage, employing stage, and interpreting stage, as shown in Table 2.

TABLE 2. *MS-ML Indicators*

MS-ML Activities: Descriptors	**MS-ML Indicators**
Formulating stage: Formulating situations mathematically	- Identifying variables in real-world problems to mathematical structures. - Using understanding in solving math problems.
Employing stage: Using mathematical concepts, facts, procedures, and reasoning	- Applying effective and sustainable multi-procedures to provide mathematical solutions, conclusions, or generalizations. - Writing the procedure used to determine the result of the mathematical solution. - Assembling the information in the problem to determine the mathematical solution used, processing the information, or multi-step argumentation.
Interpreting stage: Interpreting, applying, and evaluating mathematical results	- Interpreting the results obtained in various situations or appropriate uses and evaluating two or more representations of a situation. - Providing an explanation based on the context of the problem being solved.

Sources: (OECD, 2022)

Data Analysis

Data analysis will be carried out using the research data that has been collected by reducing and categorizing the data. Based on the research results on MS-ML in research participants, there are two grouping categories, appropriate and inappropriate MS-ML, as shown in Table 3.

TABLE 3. *Achievement of student work*

MS-ML Category	Total number of students	Coding	Percentage
MS-ML inappropriate	18	S1	95%
MS-ML appropriate	1	S2	5%

From Table 3, 18 (95%) of students are in MS-ML inappropriate because they can only write one answer or solution as they have learned during learning. In contrast, students categorized as correct MS-ML are only 1 (5%) of the total research participants. S1 and S2 represented the inappropriate and appropriate MS-ML categories, respectively.

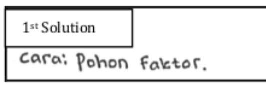
RESULTS

Based on the research results by students, it can be stated that primary school students who are presented with MS-ML problems are categorized into two categories. The first category is students who give MS-ML inappropriately, and the second category is students who can give MS-ML appropriately.

Category MS-ML inappropriate (S1)

Formulating stage

In the 1st solution, according to OECD, S1 identified the problem variables. It used his concept understanding in solving MS by writing the formulating stage using a solution as a factor tree. S1 chose to use a factor tree based on his understanding of the context for the ML-solving process. In the formulating stage, S1 only wrote the type of solution used in the process of working, which can be seen in Figure 1. As for the 2nd and 3rd solutions, S1 skipped the formulating stage and directly performed the completion process at the employing stage.



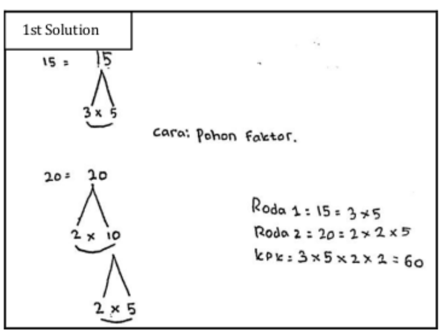
Translation :
solution : factor tree

FIGURE 1. *Formulating stage by S1*

Employing stage

At the employing stage of the formula, S1 began to connect the pieces of information in the MS problem to get the results of the mathematical solution he chose. In the 1st solution, S1 solves the factor tree by finding the least common multiple (LCM) of number 15 and number 20. After calculating with the factor tree, S1 calculates the LCM of numbers 15 and 20 using the factor tree. After using the factor tree, S1 found the final result, number 60.

For the 2nd solution, S1 wrote the solution with multiplication. The multiplication in the answer column is stacking multiplication and sequential multiplication of 2x5, 5x3, and 5x4. Then, 3rd solution, S1 wrote the addition of the number 15, which was arranged twice, and the result was added with the number 15 multiplied by the number 2. This can be seen in Figure 2.



Translation :
solution : factor tree

Gear 1 --> 15=3x5
Gear 2 --> 20=2x2x5
LCM = 3x5x2x2 = 60

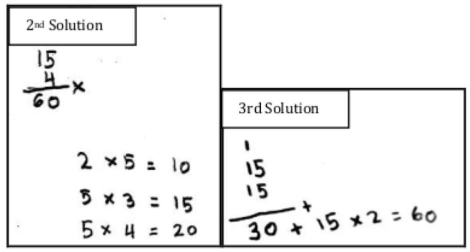


FIGURE 2. *Employing stage by S1*

Interview transcript 1

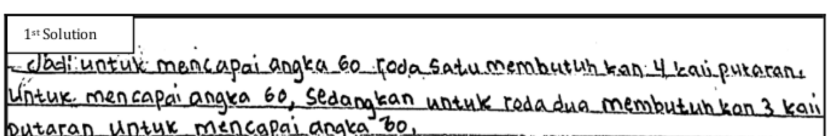
Researcher	:	Do you know what material the question is taken from?
S1	:	Yes, about LCM
Researcher	:	What is the solution to solve the LCM problem?
S1	:	Using factor tree
Researcher	:	Can you use other than the factor tree?
S1	:	I don't think so
Researcher	:	Then what is the 2nd solution? What solution did you write?
S1	:	In the 2nd solution, I wrote the solution by multiplication
Researcher	:	Yes, then, for the 3rd solution?
S1	:	I wrote the solution in the form of stacking addition, and then there is multiplication too
Researcher	:	Why did you write the solution?
S1	:	I multiply it so that the column is not empty

Transcript 1 shows that S1 has understood the problem given well. However, S1 still cannot give MS correctly because S1 feels that there is only one solution in the material. It causes S1 to be unable to write other solutions correctly. Even the procedures written down also do not produce the correct answer.

In this 2nd solution and 3rd solution, S1 did not fulfill all indicators of ML and solution, and also, the results he wrote were not correct. S1 could not provide another solution correctly, so S1 wrote another solution randomly. By writing another solution randomly and the results obtained are incorrect, then what is written by S1 is included in the MS-ML inappropriate category.

Interpreting stage

In the previous stage, S1 got the result of solving the factor tree, namely number 60. The interpreting stage in OECD is writing the interpretation of the results obtained under the MS that has been completed. In the interpreting stage, S1 wrote the word that should be written for each problem presented in ML, which is equipped with the word 'so' at the end of the solution. This can be seen in Figure 3. With the explanation of 'so', it can be seen that the student has understood the result of the solution he wrote down.



Translation :
So to reach number 60, wheel 1 needs 4 turns to reach number 60, while wheel 2 needs 3 turns to reach number 60.

FIGURE 3. *Interpreting stage by S1*

From these results, it can be stated that S1 can formulate and find the results of the employing stage correctly, and S1 has also written an explanation of the results obtained under the formula of the solution he wrote. The explanation written in the interpreting stage contains a detailed explanation of the final result of the problem-solving process questioned in the given problem. There were, 18 (95%) students who gave answers from MS-ML with complete ML indicators. These students have fulfilled the indicators of ML in the 1st solution but still have not given MS-ML appropriately in the 2nd solution and 3rd solution.

Category MS-ML appropriate (S2)

Formulating stage

In the 1st solution, S2 wrote the formulating stage, as usual, using a solution as a factor tree. The factor tree is a problem-solving procedure usually used to solve LCM problems in general. S2 chose to use a factor tree based on the experience he gained in class for the solution process in MS-ML. In the formulating stage, S1 only wrote down the type of solution used in the process of working, which can be seen in Figure 4. During the formulating stage for the 2nd solution and 3rd solution, S2 did not write the formula because S2 still doubted whether the solution he used was correct or not.

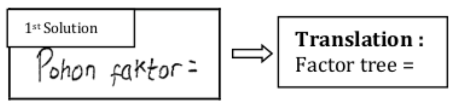


FIGURE 4. *Formulating stage by S2*

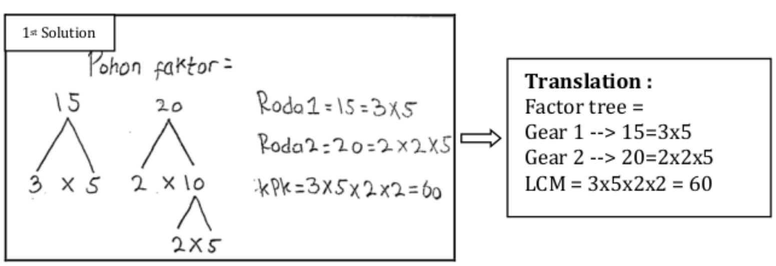
Employing stage

After the formulating stage, then proceed with the employing stage. Based on OECD, the employing stage contains the procedural mechanism of the solution provided by the student. At this stage, S2 looks for the LCM of number 15 and number 20 using a factor tree. Through calculations with the factor tree, the final result by S2 is number 60. This can be seen in Figure 5.

In writing another solution, S2 wrote the 2nd solution by multiplying the number of wheel teeth in the MS-ML problem, namely number 15 and number 20. The two numbers are multiplied by others that can produce the number 60. S2 multiplies number 15 by number 4 and number 20 by number 3, resulting in number 60.

For the 3rd solution, S2 wrote the ordered addition of numbers 15 and 20, which were summed repeatedly. For number 15, S2 repeated addition 4 times to get the number 60 result. As for number 20, S2 repeated addition 3 times to get the number 60 result.

By writing down the other solution, S2 can find the correct result from the other solution he wrote down. S2 stated that the simple solution that came to his mind was confirmed through the interview with S2 (see interview transcript 2). From the solutions written by S2, it can be stated that S2 has provided other solutions correctly, so S2 is included in the category of students with the MS-ML appropriate.



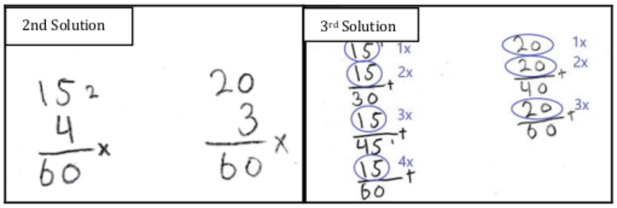


FIGURE 5. *Employing stage by S2*

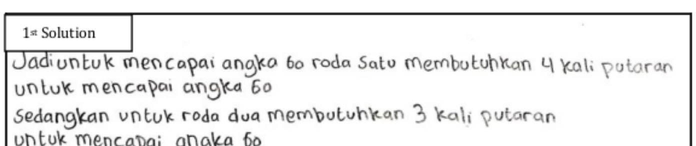
Interview transcript 2

Researcher	:	How can you develop the solutions you gave in the 2nd and 3rd solution?
S1	:	I based on the result of the 1st solution, which is number 60
Researcher	:	Why did you base it on the number 60?
S1	:	Because the answer produced in the 1st solution is 60
Researcher	:	So you wrote it without formulating it and looked for the number 60?
S1	:	Yes, I tried to write another solution to find the number 60 with a simpler solution
Researcher	:	Can you explain the solution you wrote in the 2nd solution?
S1	:	For the 2nd solution, I multiplied the number in the given problem with another number that can produce the number 60
Researcher	:	Then, the 3rd solution?
S1	:	I repeat the addition to each number until, I find the result 60
Researcher	:	Why don't you write your explanation in the answer column?
S1	:	I didn't have time because the time was up

From the transcript of interview 2, S2 stated that he wrote other solutions based on the results of the 1st solution. That way, S2 used various solutions to produce the number 60 again with different solutions. From the solutions written in the 2nd solution and 3rd solution, only S2 himself can explain the meaning of the work steps he wrote. This is due to the absence of information included in the answer column. If the researcher does not conduct an interview, the researcher also does not understand the solution written by the student in the answer column.

Interpreting stage

After getting the result from finding the result through the factor tree, S2 wrote the word 'so' in the interpreting stage as the last stage of the solution he wrote. The interpreting stage is written to explain the meaning of the number 60 in the problem being solved. S2 wrote this interpreting stage to make it easier to interpret the results that have been obtained. The writing of the interpreting stage of the 1st solution can be seen in Figure 6. While in the 2nd solution and 3rd solution, students did not have time to write because of the limited time in working on it.



Translation :
So to reach number 60, wheel 1 needs 4 turns to reach number 60, while wheel 2 needs 3 turns to reach number 60.

FIGURE 6. *Interpreting stage by S2*

In this study, there was only 1 (5%) student who could provide answers with the correct MS. Of the three explanations given, one answer fulfilled the three ML indicators. In addition, two other solutions only write about other solutions that can be used to get the final result that has been found in the previous solution. From the answers written by S2, who can write the correct MS in doing it. Although S2 was able to provide the correct MS, the MS given by S2 was not written in detail according to the ML indicator. In the 2nd solution and 3rd solution, there is only the process of using the formula without any formulation or interpretation written in the answer column.

DISCUSSION

The results of the data analysis found the MS-ML categories to be appropriate and inappropriate. The inappropriate and appropriate MS-ML categories use a factor tree in the formulating stage. They are only written on the 1st solution, while the 2nd solution and 3rd solution cannot reach the formulating stage. This is because students still have difficulty in determining other solutions to be used. Then, for the employing stage, the MS-ML category did not correctly write three solutions; for the 1st solution, S1 registered the primary solution as a factor tree, while the 2nd solution and 3rd solution were still incorrect because S1 wrote the solution randomly. It can be interpreted that the standard solution does not precisely guide the MS-ML category, so it cannot produce other solutions. In comparison, the MS-ML appropriate category can provide an employing stage by using a factor tree in the 1st solution, stacking multiplication in the 2nd solution, and stacking addition in the 3rd solution. The three solutions written down can lead to the correct result, so it is included in the MS-ML appropriate category. The interpreting stage given by the inappropriate MS-ML category and the appropriate MS-ML category is only written on the 1st solution. In contrast, for the 2nd solution and 3rd solution, the interpretation is not written because of the short time, so it is not sufficient to write interpretations on all the solutions given.

We found that most students were in the inappropriate MS-ML category. This is because many students still cannot formulate divergent MS-ML solutions correctly. Correct means that in providing multiple solutions or solutions other than the standard solution written down, students employ and interpret solutions with correct results and interpretations. This is also the case in research conducted by Shore and Kobiela (2020) which states that students in their study also provide MS answers with incomplete solution writing. This is also supported by several studies by Muzaki and Masjudin (2019), which state that the research results show that ML is still low. Another study by Faiziyah, Hanan, and Azizah (2022) stated that students' ML in creative thinking to solve MS-based problems is still not optimal. It can be seen from the results of student answers that they still cannot write entirely from the formulating, employing, and interpreting stages.

MS-ML will require students to provide multiple solutions in the solution process. This MS-based problem trains students to find other solutions besides the ones they usually use to solve the problems provided. Other solutions are solutions that can facilitate students in solving the problems provided with each student's mindset, so each student has a different solution. In MS answers, there are standard solutions and non-standard solutions. In the standard solution, students can explain the solution they wrote. In contrast, for the non-standard solution, students go directly to the solution strategy without writing the type of solution they give.

It was found that even though students understood the purpose of the problem given, students gave MS-ML answers that were inappropriate and not detailed for each stage. Students still cannot write MS-ML appropriately in the multiple solutions they give. This happens because students are not used to solving MS-ML, so they are still confused about formulating other appropriate solutions. In addition to educators who have not accustomed students to solving MS-ML problems, Bingolbali (2019) stated that in primary school mathematics textbooks, there are still few that present questions or problems that have multiple solutions in solving them. Therefore, students still cannot provide solutions to problems in other ways in a structured manner, making it easier for them to solve a problem. Hence, students must be familiarized with this MS-ML problem.

Another category is MS-ML appropriate, students who are in this category show that they have used mathematical reasoning that is related to real life and their experiences (De Lange, 2006). Students' problem-solving levels will be better if the problems presented describe real-life experiences (Kolar & Hodnik, 2021). Through MS-ML assignments, students can unleash their potential to generate various new solutions to mathematical problems (Mahlaba, 2020). That way, students should be able to think of solving problems with multiple topics and feel that 'Aha! I have experienced this' (Schindler & Lilienthal, 2020).

This MS-based problem can be passed on to students through experience, knowledge, and initial competence so that students can solve a problem with various solutions (Achmetli, Schukajlow, & Rakoczy, 2018). Prior knowledge is also important in solving problems because each student will have different answers to the questions presented. This is caused when students make different assumptions, so they have different ways of solving problems and will not necessarily get the same results (Schukajlow & Krug, 2014a). Therefore, the importance of students' prior knowledge is useful to bring up students' understanding in digesting the problem so that it can produce various solutions (Almarashdi, 2020).

CONCLUSION

The research findings show that there are appropriate and inappropriate MS-ML. Most of the students were in the inappropriate MS-ML. This was caused by errors in the formulating stage, leading to the failure of the employing and interpreting solution stages. The solutions given by students mostly still use convergent or standard solutions. In addition, students are still unfamiliar with MS-ML problems, and teachers are not accustomed to letting students practice by providing multiple solutions in their assignments. This has an impact on inhibiting ML to provide divergent MS solutions.

Meanwhile, students' appropriate MS-ML can be seen from formulating and planning multiple solutions appropriately, which leads to the success of employing and interpreting. MS-ML provides opportunities for students to find and use other solutions that they think can facilitate their process in solving the problem with their respective mindsets. Therefore, teachers and learning practitioners need to teach and teach divergent ML-MS-based problem solving, so students are expected to have many alternatives in the formulating stage of the solution, which leads to the diversity of the employing and interpreting stages.

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