


Complex Thinking: How are Students' Mathematical Problem-Solving Skills in Elementary School?

Irfan Fauzi^{1*}, Cece Rakhmat¹, Nandang Budiman¹

¹Universitas Pendidikan Indonesia, Indonesia

 If96@upi.edu

Abstract

This study aims to see an overview of students' mathematical problem-solving skills in elementary school. This study uses a quantitative approach with a descriptive method. The subjects in this study amounted to 25 grade 5 students in one of the elementary schools in Bandung with details of 10 male and 15 female students. The data collection technique used is a mathematical problem-solving test instrument based on Polya theory on fractional concept material. The data analysis carried out was to calculate descriptive statistics using Microsoft excel and SPSS version 24 to see an overview of mathematical problem-solving skills, categorization of problem-solving scores based on high, medium, and low, and the achievement of students' mathematical problem-solving indicators. From these data, it is then analyzed in depth and linked with relevant theories. The results of this study showed that based on the categorization of student scores, 4 students were in the high category, 15 students were in the medium category, and 6 students were in the low category. The indicator that has a high percentage of students mastered is understanding the problem at 73%, and the lowest indicator at re-checking is 44%. This research can contribute to efforts to create meaningful learning in mathematics by involving complex thinking skills including mathematical problem-solving skills.

Keywords: Complex Thinking, Mathematical Problem-Solving Skills, Elementary School

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INTRODUCTION

The development of the times is so fast, a new chapter in the 21st century has begun by bringing various important components, the emergence of a multicultural structure of society and the complexity of life in the 21st century forces individuals to acquire new skills that are urgently needed (Suto, 2013). 21st century skills are competencies that can help individuals prepare for developments in today's and tomorrow's world (Özeren, 2023). The education sector must understand the importance of 21st century skills (Ekizer & Yıldırım, 2023). So, the various skills in the 21st century should be taught in the context of education and learning in the classroom. According to Güven & Alpaslan (2022) Individuals who have excellent 21st century skills will be able to come up with quick and effective solutions to solve problems they face in everyday life.

Thinking skills are a very important part in the means of cognitive development of students. Thinking skills can be developed by enriching meaningful experiences through

problem-solving in everyday life. According to Clement (2008), thinking will be able to form intuitive schemes, this will be useful in interpreting physical phenomena and emphasize that physical intuition can assist students in thinking about heuristic ideas in terms of conceptual understanding. Intuitive words are part of the thought process that needs to be developed in learning. In other languages, intuition is defined as the process of discovery, characterizing thinking in the context of problem-solving carried out by the child (Park & Song, 2017).

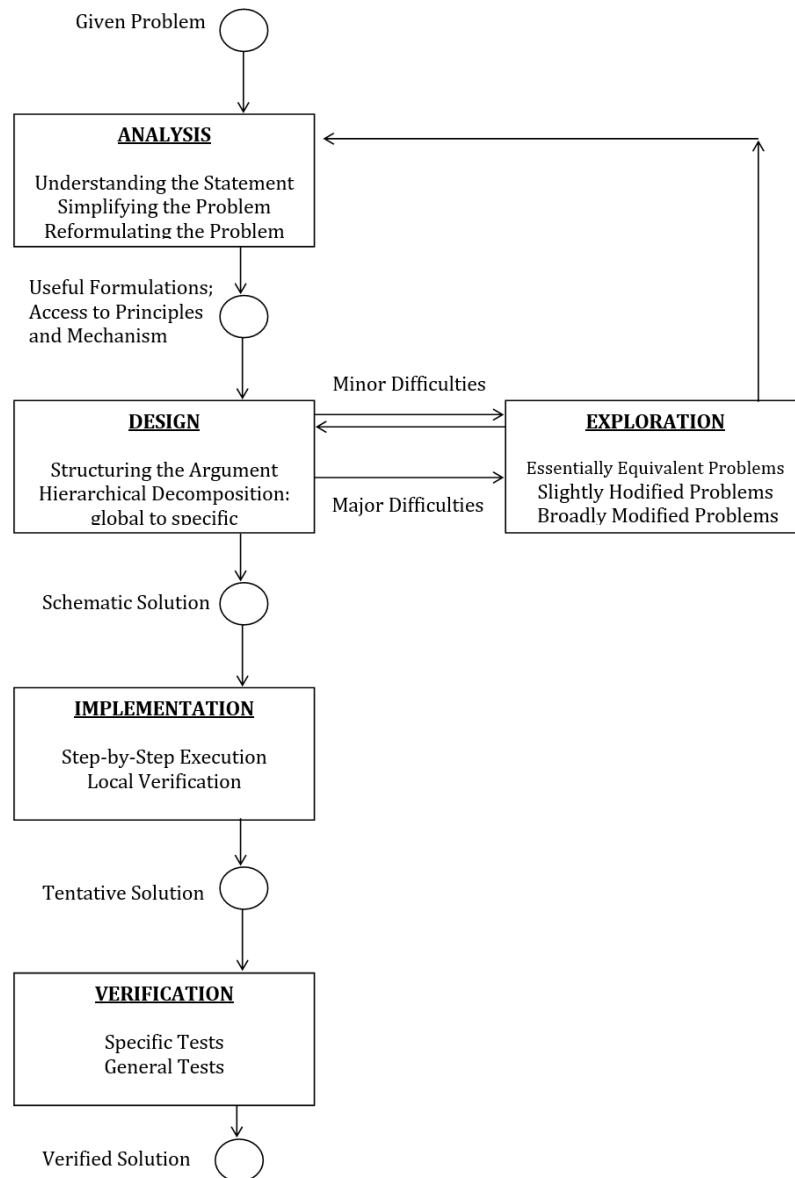
All learning aims at developing means of thinking from basic to complex. Complex thinking is a cognitive process that involves many stages in solving a particular problem. Complex thinking is an activity that requires thinking fundamentally and in it demands various possible answers, assessment of answers, and giving meaning to certain situations. Furthermore, Baena-Rojas (2022) explains that complex thinking concerns not only part of the process of thinking and understanding reality, but also the way people manage uncertainty in learning and education. Complex thinking consists of several elements, involving different domains and relevant to the teaching and learning process in the classroom (Suárez-Brito et al, 2022). Complex thinking processes are part of higher-order thinking skills, consisting of problem-solving, decision-making, critical thinking, and creative thinking (Costa, 1985).

This ability to think complex is also very relevant to the needs of the 21st century. Some of the skills needed in the 21st century are critical thinking and problem-solving, creative, communication, and collaboration (Erol, 2021., Kaufman, 2013., & Voogt & Roblin, 2012). These skills are considered the key to success in learning to live in the future (Triling & Fadel, 2009), and problem-solving skills are a very important part of the 21st century.

Problem-solving skills are part of individual skills to overcome various existing problems through cognitive structures owned (Wang & Chiew, 2010) and with scientific methods and procedures. These skills are closely related to the talents and cognitive structures possessed by individuals, and this can be found from an early age because they will find problems when they play (Stacey, 2005). Habituation of the process in problem-solving encourages learners to use their knowledge innovatively and creatively so that it can increase their understanding (Crebert et al, 2011), students also need experience in transdisciplinary problem-solving as an ability need in the 21st century (Drake & Reid 2020), and this allows students to be able to apply them in a variety of fields (Epepe et al, 2022).

Students who have good problem-solving skills will be able to produce creative, innovative and practical solutions, and demonstrate independence and initiative in identifying problems and solving problems, both individually and in teams (Business Council of Australia and Australian Chamber of Commerce and Industry, 2002). The schematic outline of the problem-solving strategy is described in the figure below.

Figure 1. Outline of the Scheme of the Problem-solving Strategy (Schoenfeld, 1980)



One of the most important subjects is mathematics. According to Golji & Dangpe (Çelik, 2018), mathematics has an important role in contributing to the development of science and technology, and this is useful for everyday life. Mathematics is considered to encourage students' abilities (Unlu et al, 2017) including problem-solving. According to Baykul (2009), mathematics is an important tool used to solve problems both in the context of science and real life. In addition, mathematics helps us think creatively and critically, and helps to understand real life. The importance of problem-solving is also included in the mathematics learning objectives that have been explained by the Kemendikbud (2014), namely shaping students' ability to solve a problem systematically. This is done by making patterns as hypotheses and making generalizations from existing phenomena or data.

Problem-solving skills in mathematics are a very important part for students to master. This means that these skills have an urgency to be taught early. According to (Suhartono, 2018), at the higher education level, students' problem-solving skills depend on students' learning experience at the elementary level. The process of solving

mathematical problems will help the development of students' critical thinking skills (Dinc et al, 2022). This study aims to see how the profile of students' mathematical problem-solving abilities in elementary schools. The stages in problem-solving in this study refer to Polya (1973), namely understanding the problem, devising a plan, carrying out the plan, and looking back.

Several studies on the mathematical problem-solving skills of elementary school students have been conducted, among which many studies examine the effectiveness of a learning approach/model in problem-solving abilities such as Indrawati et al (2014)., Muslihah & Suryaningrat (2021)., & Widyastuti & Airlanda (2021). In addition, research conducted by Hidayah et al (2020) explained that elementary school students still find difficulties in solving problems, especially at the stage of rechecking problem-solving. In addition, students also tend to find it difficult to solve problems in math story problems (Aminah & Kurniawati, 2018). What is different from previous research is how this study can describe the overall mathematical problem-solving skills of students in elementary school by examining the theory that has been explained by Polya (1973).

METHOD

This study used a quantitative approach with a descriptive method. This research was conducted in an elementary school in Bandung with a total of 25 subjects in grade 5. Data collection techniques in this study use problem-solving skills tests based on Polya theory, namely understanding the problem, devising a plan, carrying out the plan, and looking back. The test made in this study refers to fractional material in grade 5 elementary school. The data analysis used in this study refers to the Polya theory using scores with a range of 0-4. The analysis is as follows.

Tabel 1. The Analysis Data of Mathematical Problem-solving Skills

Variable	Score	Information
Understanding the problem	4	Complete and correct
	3	Mostly correct
	2	Mostly incorrect
	1	Ignore the problem
	0	Misidentified problem
Devising a plan	4	Make a strategy plan with correct and complete procedures
	3	Creating a strategy plan with correct and incomplete procedures
	2	Creating a strategy plan with incorrect and incomplete procedures
	1	Creating irrelevant strategy plans
	0	Do not have a strategy plan
Carrying out the plan	4	Implement the strategy plan with correct and complete procedures
	3	Implement the strategy plan with correct and incomplete procedures
	2	Implementing a strategy plan with incorrect and incomplete procedures
	1	Implementing irrelevant strategic plans
	0	Not implementing the troubleshooting plan
Looking back	4	Double-check troubleshooting with correct and complete procedures
	3	Double-check incorrect troubleshooting, and try to

		fix it
2	Double-check incorrect troubleshooting, and don't	fix it
1	Check troubleshooting with irrelevant procedures	
0	Not checking troubleshooting	

Data obtained from student test results were processed using Microsoft excel and SPSS version 24 to find descriptive statistics from the results of obtaining student scores related to problem-solving skills. Such results are presented both in tabular form and figure. Data analysis was also conducted by categorizing students' grades based on high, medium, and low. The categories are as follows

Table 2. Student Grade Categories of Mathematical Problem-solving Skills

Category	Interval
High	Z score < -1
Medium	-1 ≤ Z score ≤ 1
Low	Z score > 1

The results are then analyzed in depth by interpreting the existing findings and relating them to relevant theories

RESULT AND DISCUSSION

Students' mathematical problem-solving skills were measured by referring to fractional material in grade 5 elementary school using Polya theory. The number of students is 25 students with details of 10 male students and 15 female students. In detail, the results of students' mathematical problem-solving skills can be seen in the table below.

Table 3. Descriptive Statistics of Students' Mathematical Problem-solving Skills

Problem-solving		
N	Valid	25
	Missing	0
Mean		59.12
Median		63
Mode		71
Std. Deviation		18.306
Skewness		-.649
Std. Error of Skewness		.464
Minimum		21
Maximum		88

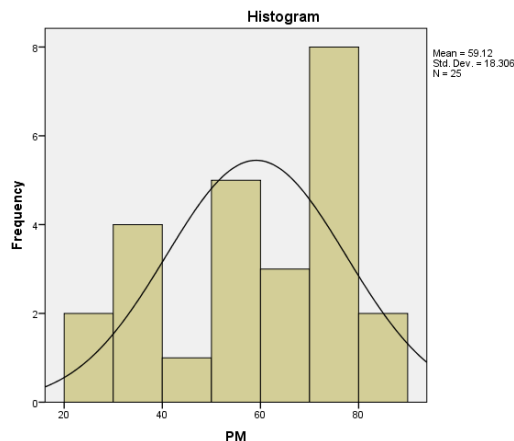
From the Table 3 above, it can be seen that the average score of students on mathematical problem-solving skills is 59.12, with the middle score is 63 and the mode is 71. The minimum score obtained by students is 21 and the maximum score is 88. If you look at the categorization of grades, namely high, medium, and low, the distribution of students' mathematical problem-solving abilities can be seen in the table below.

Table 4. Categorization of the Value of Students' Mathematical Problem-solving Skills

Categorization of the value		
High	Medium	Low
4 students	15 students	6 students

From the Table 4 above, student scores (Z score) which are in the interval < -1 on the histogram are as many as 6 students or can be said to be in the low category, student scores (Z score) which are in the interval $-1 \leq Z \text{ score} \leq 1$ are as many as 15 students or can be said to be in the medium category, and student scores (Z score) which are in the interval > 1 are as many as 4 students or can be said to be in the high category. From these data, the distribution of values can be seen from the histogram below.

Figure 2. Histogram of Students' Mathematical Problem-solving Skills Scores



Mathematical problem-solving skills based on Polya theory have 4 indicators, namely understanding the problem, devising a plan, carrying out the plan, and looking back. The percentage of the answer is as follows.

Table 5. Percentage of Achievement of Students' Mathematical Problem-solving Skills

Understanding the problem	Devising a plan	Carrying out the plan	Looking back
73 %	56 %	65 %	44 %

From the Table 5 above, the largest indicator aspect mastered by students in mathematical problem-solving ability is 73%, and the lowest aspect is the re-examination indicator at 44%. Another aspect is that planning completion gets 56% and implementing the plan gets 65%.

Students' Mathematical Problem-Solving Skills

Problem-solving skills are a very important part of solving problems in the mathematics, but in practice this requires special skills, namely basic problem-solving skills such as establishing relationships and differences between concepts, to think algorithmically, and to analyze and approach problems from different perspectives (Ersoy & Dağyar, 2022). Students who have low mathematical problem-solving skills tend to have low basic skills, they have not been able to connect various concepts from the problems presented. To improve this, students must have a complete understanding of mathematical content and practice problem-solving skills (Yapatang & Polyiem, 2022). Students who have medium problem-solving skills tend to already understand the problems presented, some students can solve problems through concepts and theorems that they already know through the process of memorization, but when they find different situations, they will have difficulties. According to Septiani et al (2019), it is because students are often presented with math problems in the usual form (routine), so when students are presented with problems in non-routine form, they will have difficulties. Even though non-routine questions are important given to students to train their thinking

skills (Agustyaningrum, 2015), including in problem-solving. In addition, students who have a high category in problem-solving skills tend to have a good understanding of concepts in math content. According to Komariyah et al (2018) that understanding this concept is very important in solving a mathematical problem. Students in this category are also able to apply their understanding to new situations. According to (Suryadi, 2018) =, the use of new knowledge in different situations can strengthen the internalization process in students which illustrates the increase in capacity in students, including this affects problem-solving skills.

The first indicator of problem-solving skills is understanding the problem with a percentage achievement of 73%. On this aspect, students identify problems through what is known, what exists, amounts, relationships and associated values. Students are presented with a picture to identify the size of the fraction. The types of questions are as follows.

Figure 3. Question 1: Understanding the Problem Indicator

SOAL 1

Perhatikan gambar di bawah ini!



Berapakah besaran pecahan yang di arsir tersebut! Kemukakan alasanmu menjawab tersebut!

Usually, the shape of the picture obtained by students has the same size shape, but in the picture above presented a picture in which one of the shapes has a different size. Some of the problems faced by students in understanding the above problems are students' inability to understand the concept of fractions as part to whole, some of students' incorrect answers are $\frac{1}{4}$. Students only see 1 shaded area i.e, 1 part and 4 parts that are not shaded. According to (Rohmah, 2018), this is because students do not understand the concept of fractions intact, and this is related to students' understanding of numerators and denominators (Moyo & Machaba, 2021). There were some students who also answered $\frac{1}{5}$, they already understand the concept that the numerator is the observed part and the denominator is the concept of the whole, but they do not realize that the parts of the fraction should be the same size. According to (Malika & Amir, 2018), this is related to the meaning of fractions that are interpreted differently, students do not pay attention to the parts of the whole of the same magnitude or not. From these incorrect answers, actually students who have a low understanding of problem-solving tend to have low concept understanding skills as well. Students are also given different questions to see indicators of understanding the problem. The form of the question is as follows.

Figure 4. Question 2: Understanding the Problem Indicator

SOAL 2

Perhatikan gambar di bawah ini!



Tara membuat kue, dan disimpan di lemari es (kulkas). Tiba-tiba, adik Tara membuka lemari es dan memakan bagian kue, sehingga sisa bagian kue tersebut tampak pada gambar di samping. Berapa bagian sisa kue yang dimiliki Tara sekarang?

These types of questions are given so that students can solve problems, especially on indicators of understanding problems related to the reduction of equal-denominator fractions. The answer to the picture should be $\frac{7}{8}$ with the argument that the answer is 1 whole part of the cake minus $\frac{1}{8}$ ($\frac{8}{8} - \frac{1}{8} = \frac{7}{8}$). Some of the problems faced by students in understanding the above problems are inaccuracy in reading the question instructions,

this is evidenced by some students who answered $\frac{1}{8}$, they assume that what is eaten is the rest of the cake. There are also students who answer $\frac{6}{7}$, this is based on seeing the size of the cake which has 7 parts, and then 1 part is eaten by his sister, so $(\frac{7}{7} - \frac{1}{7} = \frac{6}{7})$. Obviously, this is incorrect because students do not see the various relationships that exist in the picture.

The second indicator measured is devising a plan with a percentage achievement of 56%. On this aspect, students identify and formulate the operations involved for the resolution of the problems presented. Students are presented with a problem about fraction comparison, but before students solve the problem, students are directed to create a solution strategy. The form of the question is as follows.

Figure 5. Question about Devising a Plan Indicator

SOAL 4

Jeni sedang berulang tahun, dia membagikan kue ke teman-temannya. Andi mendapatkan $\frac{1}{8}$ bagian, Budi mendapatkan $\frac{5}{12}$ bagian, dan Cery mendapatkan $\frac{3}{24}$. Siapa yang mendapatkan bagian kue terbanyak!
a. Bagaimana cara kamu menyelesaikan soal di atas!

In the question above, students are directed to plan the completion of answers related to fraction comparison. The strategy answer should be 1) to equate the denominator of the fraction to find the smallest common multiple of 24, 2) to change the denominator of the fraction to the smallest known common multiple of the equation, and the numerator also changes ($\frac{1}{8} = \frac{3}{24}$, $\frac{5}{12} = \frac{10}{24}$, and $\frac{3}{24} = \frac{3}{24}$), and 3) if the denominator numbers are the same and the numerator has also been changed, then the final step is to compare the numbers to the fractional numerator ($\frac{10}{24}$, $\frac{3}{24}$, and $\frac{3}{24}$). In the answer, most students answered that the above problem can be solved by finding the Smallest Common Multiple/equating the denominator of fractions, but after that the problem was not resumed, there were also some students who wrote that $\frac{3}{24}$ is the largest part, students conclude that a large number on a fraction has a large value, like $\frac{1}{8}$ is greater than $\frac{1}{4}$ because the numbers $8 > 4$, and this is a mistaken concept. According to (Obersteiner, 2013), a common mistake in fractions is to think of fractions as two separate natural numbers, not as a sum. This is the problem faced by students when presented with fraction comparison problems, which in the end they will solve the problem by comparing components separately instead of looking holistically at the fraction value itself.

The third indicator measured is to carry out completion planning with the achievement of a percentage of 65%. In this aspect, the solution planning that has been made by students becomes the basis for translating into mathematical concepts, so that effective problem-solving is obtained. The problem given to this student is closely related to the previous problem on the indicator of devising a plan. The form of the question is as follows.

Figure 6. Question about Carrying out the Plan Indicator

SOAL 4

Jeni sedang berulang tahun, dia membagikan kue ke teman-temannya. Andi mendapatkan $\frac{1}{8}$ bagian, Budi mendapatkan $\frac{5}{12}$ bagian, dan Cery mendapatkan $\frac{3}{24}$. Siapa yang mendapatkan bagian kue terbanyak!

- a. Bagaimana cara kamu menyelesaikan soal di atas!

- b. Kerjakanlah soal di atas sesuai dengan cara yang kamu tulis!

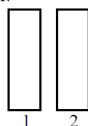
Because the form of the question above is closely related to the devising a plan indicator, the correct answer of the student should be *"The most part of the cake is Bob with the fractional part is $\frac{5}{12} = \frac{10}{24}$ ".* In the answer, there are some students who are correct in answering, but there are also some students who are still incorrect, this is because students' concept abilities related to understanding fractions as part of a whole are not yet fully owned by students, which finally they determine the largest fraction is $\frac{3}{24}$. Another error from the student's answer is that, when the smallest common multiple is known, the student does not compare fractions, but adds up the number of fractions that exist ($\frac{3}{24} + \frac{10}{24} + \frac{3}{24} = \frac{16}{24}$). This error is due to students' inability to understand the questions presented, and this is also found in (Fauzi, 2020) research that often students do not understand the questions as a whole which results in learning obstacles.

The fourth indicator measured is looking back with a percentage achievement of 44%. In this aspect, students are directed to check important information, available calculations, the cohesiveness and logic of answers, alternative answers, and in the end students conclude whether the answers are correct or still incorrect. Students are presented with a story question form about fraction comparison. The form of the question is as follows.

Figure 7. Question 1: Looking Back Indicator

SOAL 3

Dua buah lilin menyala secara bersamaan!



Setiap satu jam lilin itu akan berkurang, lilin pertama akan berkurang $\frac{1}{6}$ bagian dan lilin kedua akan berkurang $\frac{1}{3}$ bagian, setelah 2 jam terbakar, lilin yang pertama akan menjadi dua kali lipat panjangnya dari lilin kedua. Buktikan pernyataan tersebut, dan berapa bagian tersisa dari masing-masing lilin tersebut?

From the question above, students are directed to prove an answer by looking at the various relationships available. Actually the answer is *"Correct, the 1st candle will be twice the size compared to the 2nd candle, because at the 2nd hour the 1st candle has a remaining size of $\frac{4}{6}$ and the 2nd candle has the remaining size $\frac{1}{3} = \frac{2}{6}$ ($\frac{4}{6}$ is 2 times that of $\frac{2}{6}$).* Some students answered correctly, but the argument was not based on logical reasons, some students also answered incorrectly and looked confused in solving the above problem. Some of the reasons students are unable to answer the above questions are that the conjecture of mathematical reasoning is not well connected, namely students find it difficult to make generalizations from existing problems, difficult to make answer estimates, and difficult to make proofs based on argumentation and logical thoughts. According to Munawaroh et al (2019), low mathematical reasoning ability is often found in elementary school students. This happens because the learning context is often routine.

Another problem is that students have difficulty in solving story problems. According to Sukri (2018), the difficulty students often find is in solving story problems about fractions. This is based on the fact that often the presentation of questions is only symbolic, or they are presented about stories, but the ability indicators they develop are only in the nature of applying algorithms that have been taught.

Students are given different questions to see the indicators of looking back. The form of the question is as follows.

Figure 7. Question 2: Looking Back Indicator

SOAL 5

Pak Bayu memberikan soal kepada Zaki sebagai berikut!

$$\frac{1}{4} + \frac{5}{8} = \dots$$

Zaki kemudian mengerjakan soal tersebut dengan jawaban di bawah ini!

$$\frac{1}{4} + \frac{5}{8} = \frac{2}{8} + \frac{5}{8} = \frac{7}{16}$$

Menurut pendapatmu, benarkah hasil pengerjaan Zaki? Berikan alasannya!

Students are presented with questions about adding fractions, and students must prove whether the answers are correct or still incorrect. From the question above the answer is "the answer is still wrong, because when the denominator of the fraction already has the same magnitude it does not need to be summed, meaning $\frac{2}{8} + \frac{5}{8} = \frac{7}{8}$ ". Students who understand the concept of fractional addition will then answer correctly that when the denominator is the same, what is operated is the numerator part, and the denominator is the same number. However, students who do not have a good understanding of the concept of fractions tend to answer that the problem is correct, that is, the numerator is added to the numerator, and the denominator is also added to the denominator. This was also found in Fauzi (2020) research that when faced with the problem of adding or subtracting fractions, what students do is directly add or subtract the numerator with the numerator and the denominator with the denominator. According to Hoch et al (2018), students apply the wrong system and show a lack of conceptual understanding.

CONCLUSION

From the research above, it can be concluded that the distribution of students' mathematical problem-solving scores is at most in the medium category, namely 15 students, 4 students are in the high category, and 6 students are in the low category. Based on mathematical problem-solving indicators, the indicator with the greatest achievement is shown in understanding the problem by 73% and the indicator with the lowest achievement is shown in looking back by 44%, and the others are indicators devising a plan by 56% and indicators carrying out the plan by 65%. There are several findings of difficulties faced by students in solving mathematical problem-solving skills, namely students' inability to understand various relationships and concepts presented in the problem, students' inability to understand mathematical concepts, students' inability to do mathematical reasoning, and students' inability to solve story problems. The results of this study can contribute to efforts to create learning that can develop complex thinking skills, especially in the ability to solve problems in the field of mathematics.

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