# Problem-solving in elementary school mathematics learning: Cognitive flexibility

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**Journal of Research and Advances in Mathematics Education**
Volume x, Issue x, xxxxx 2020, pp. xx – xx
DOI:
p-ISSN: 2503-3697, e-ISSN: 2541-2590

# Problem-solving in elementary school mathematics learning: Cognitive flexibility

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ARTICLE INFO

*Article history:*
Received:
Revised:
Accepted:
Published online:
Published regularly:

*Keywords:*
Creative thinking, Cognitive flexibility, online-based research

ABSTRACT

The ability of cognitive flexibility is essential for students to support learning in the Covid-19 pandemic. Cognitive flexibility is the ability to use solutions that are new, diverse and unique. This can encourage student creativity in solving mathematical problems. Therefore necessary to explore students' cognitive flexibility processes in solving mathematical problems. Two students were selected as research participants from all grade 4 elementary school students in Makassar, namely one male and one 10-year-old female. The selected participants are students who excel and have good communication skills. Task sheets, interview sheets and think aloud as tools to get data through the zoom application. The findings of this study are cognitive flexibility ability of students occurs when solving fraction problems by experimenting with various perspectives on problem-solving so that recalling the concept of fractions that have been encountered before. The cognitive flexibility abilities of students involving cognitive processes in the form of the ability to assess the number of numbers, mental computing, estimation, and determine the rationality or reasonableness of the calculation results obtained. However, this research only uses participants at the elementary school level, therefore the researchers recommend further research relating to the abilities of students at all levels as well as design learning models that can develop student cognitive flexibility.



## Introduction

Problem-solving is one of the main aspects of the mathematics curriculum, which is not only applied in Indonesia but also throughout the world. Unfortunately, the results of the study show that students have difficulty in solving mathematical problems (Tambychik & Meerah, 2010). Teaching and learning of mathematics in schools has focused on problem-solving activities during the last few years (Daher & Anabousy, 2020). But surprisingly, students are still weak in problem-solving and view mathematics as one of the subjects that is difficult and boring to learn and deal with a variety of topics (Bishara, 2016). The goal of growing students' problem-solving skills can be achieved if the teacher considers more

*To cite this article:*

aspects of the teaching and learning process (Singer & Voica, 2013). Mathematics education should help and guide students in understanding mathematical concepts, processes and techniques, developing the ability to solve various mathematical problems (Santos-trigo & Gooya, 2015; Mosimege & Engagment, 2016).

Conventional teaching strategies with demonstrations, exercises and practice using closed problems with expected solutions are not enough in preparing students for future mathematics (Mann, 2006). Students do not have enough ability to apply their problem-solving skills successfully. Also, concerns have increased over the past few years when students enter the university environment with inadequate mathematical knowledge. Mathematical skills taught in schools seem to be an insufficient basis for further study. Therefore a slap for every policymaker, educator and other stakeholders at all levels of education to seek an explanation of the situation. Mathematics is known as the heart of science, and mathematical creativity can help students to understand what is happening around them.

One indicator of creativity that must be possessed by every student is cognitive flexibility. Cognitive flexibility is one's ability to adjust work strategies to modify task demands. Also, cognitive flexibility has been conceptualized, which consists of three primary constructs, namely cognitive variation, cognitive novelty, and changes in cognitive framing (Rahayuningsih, 2017; Singer & Voica, 2015). In the context of problem-solving, Singer considers that a student has cognitive flexibility when he can propose solutions to new problems that are different from a variety of solving strategies, produce products in the form of solutions that have never been encountered before, and can change the frame of mind before (Singer et al., 2017; Singer & Voica, 2015). Cognitive flexibility occurs when students can change ideas and approach problems in various ways (Daher & Anabousy, 2020).

Research on teaching and learning that involves cognitive flexibility has a long history. First, "flexibility" is defined as offering several choices in the educational environment, as well as adjusting learning provided to meet student needs. A flexible learning environment, some obstacles might prevent students from attending specific educational contexts, such as not having a classroom (Huang et al., 2020). Therefore, it is crucial to provide some learning options for students, including the allocation of time in class, learning content, teaching approaches, learning resources and locations, use of technology, and communication media (Goode et al., 2007; Huang et al., 2020). The development of information and communication technology has led to the emergence of new learning models that can open more opportunities to develop cognitive flexibility, one of which is open learning. Open learning aims to make students more independent, while teachers only act as facilitators in learning (Wiki, 2019). With the development of technology, cognitive flexibility is considered an essential component in learning, which usually empowers students and teachers to exchange information in a two-way way. Then, the scope of flexible learning has been expanded even further from the dimension of information delivery to include flexible pedagogy (Gordon & Gordon, 2014; Ryan & Tilbury, 2013)

In the teaching and learning process during the Covid-19 pandemic, cognitive flexibility is needed about when and where learning takes place. As a result of the spread of COVID-19, Normal University in China called for stopping the learning process in the classroom. An alternative way the teacher uses is to post a list of learning tasks and upload related resources to the learning management system. Students can then access the learning material and learning resources at any time. Students can be offered choices based on their needs (for example, study at night or weekends). The location of students to conduct learning activities and access learning materials can also be flexible anywhere at any time via mobile devices, such as on-campus, home, public transportation, airports or even on planes (Collis et al., 1997; Gordon & Gordon, 2014)

The ability of cognitive flexibility must be possessed by students during the Covid-19 pandemic. Like what and how students will learn when faced with a situation like today. With cognitive flexibility possessed by students, it allows students to determine the part and sequence of content according to their wishes, the learning path, the form of orientation in learning, the size and scope of learning through content modulation (Collis et al., 1997).

Therefore the importance of exploring students' cognitive flexibility processes in learning mathematics, especially in solving mathematical problems, because it can show how to encourage creative problem solving for students. Individuals who successfully adapt are those who can be called elastic (Pelczer et al., 2013). Elastic referred to in the realm of education is known as openness/flexibility in thinking, even openness/cognitive flexibility or better known as cognitive flexibility.

Cognitive flexibility is the ability to think about things in different ways. Open/flexible/elastic thinking is one of the three primary executive skills. The other two are operational memories and self-control. Together, these skills enable children to manage their thoughts, actions and emotions to get things done. Cognitive flexibility allows one to think and choose various ways to get things done. Sirajuddin et al (2020) revealed that high thinking skills are needed to be able to find various problem-solving. These skills play an essential role in learning and everyday life. The ability to think openly/flexibly helps students to get along with others, helps groups to be more productive and helps students solve problems and or try new ways of doing things (Rahayuningsih et al., 2019).

## Research Methods

This research is a type of case study. Because only certain subjects can do cognitive, this is a particular case, so a qualitative approach is needed to produce a good description (Yin, 2014). The case in this study is the phenomenon of participants in solving mathematical problems. Meanwhile, the qualitative approach was chosen because researchers wanted to get genetic data. The intended natural data is data that describes the subject's condition as it is and is obtained without any treatment (Creswell, 2012; Fraenkel, 2011)

Participants in this study were grade 4 elementary school students in Makassar City, South Sulawesi, Indonesia. The selection process of participants with the consideration of these students is high-achieving students and often participates in the Olympic competition besides the selection of research participants is also based on the following considerations (1) excellent communication skills that can communicate ideas clearly so that researchers can express the creativity of participants well; (2) willing to be used as a research subject. Two students were selected as participants in this study using pseudonyms to keep participants' identities confidential. The selected participants were one male and one female aged ten years.

Research participants were asked to solve elementary school mathematics problems in grade 4. The following are the forms of assignments students must complete.

1. A rope is cut $\frac{1}{3}$ part. The remaining piece of rope is 18 m. what is the length of the rope first? Make a variety of ways to find answers.
2. Determine fractions that lie between $\frac{4}{9}$ and $\frac{5}{9}$. Make a variety of possible solutions.

3. Is $\frac{5}{8}$ or $\frac{7}{12}$ closer to 0.5? Make a variety of possible solutions.

To analyze the creative problem-solving process of students, researchers refer to Singer's theory (Singer & Voica, 2015; 2016), when students can propose solutions to different new problems ranging from diverse solving strategies, produce products in the form of solutions that have never been encountered before, and can change the previous frame of mind. We also assume that the cognitive flexibility process occurs when students can solve mathematical problems in a variety of different ways or ways that are used unusual / have never been encountered before.

The method used to collect data is Think Out Louds (TOL). Olson et al (Subanji, 2016), explains that: (1) Think Out Loud method aim s to study how a person solves a problem, that is when someone solves a problem. What is thought can be recorded and analyzed to determine the cognitive processes associated with a given problem because COVID-19 pandemic conditions require the process of taking interview data and TOL to participants through Zoom (https://zoom.us/). The questions used at the interview are slightly different from the interview guidelines that have been made previously, to find the problem more openly and the parties invited to the interview are asked for their opinions.

The results of the transcript and physical behaviour exhibited by participants were analyzed with the following steps: (1) Analyzing and examining all available data from various sources, namely from interviews, Think Out Louds videos and field notes; (2) Carry out data reduction by making abstractions. Abstraction is an attempt to make a summary of the core, process, and statements that need to be maintained to remain in it; (3) Arrange in units which are further categorized by making coding; (4) Conduct data validity checks, utilizing time triangulation; Analysis of exciting things, i.e. behavioural analysis shown by research participants who are unplanned and unrelated to the research objectives; (5) Interpretation of data/conclusions (Creswell, 2012).

## Results and Discussion

The results showed the cognitive ability of the two students was different. But in general, students can solve mathematical problems by using their cognitive flexibility. Students solve the problems given by doing four process components, namely assessing the number of numbers, mental computing, estimation, and assessing the rationality or reasonableness of the calculation results obtained. The following is the complete process by participant 1 (Sub1).

> Initially, the length of the rope is one part, then cut $\frac{1}{3}$ part, therefore the left is $1 - \frac{1}{3}$
> $= \frac{3}{3} - \frac{1}{3} = \frac{2}{3}$
> Because $\frac{1}{3}$ the part is smaller than the length of the rope initially, to get the length of the rope after being cut $\frac{1}{3}$ the part is by subtracting the first length of the rope with $\frac{1}{3}$ part and finally get $\frac{2}{3}$ parts.
> $\frac{2}{3}$ parts = 18 m
> (both sides are multiplied with $\frac{3}{2}$ to make one part)
> $(\frac{2}{3} \times \frac{3}{2})$ section = $(18 \times \frac{3}{2})$ m
> 1 part = 27 m

so the length of the initial rope = 27 m
or
$\frac{1}{3}+\frac{1}{3}+\frac{1}{3}=\frac{3}{3}, \frac{3}{3}=1$, because $\frac{2}{3}=18$ m then $\frac{2}{3}:2=\frac{1}{3}$ means $18:2=9$ so that it is obtained
$\frac{1}{3}+\frac{1}{3}+\frac{1}{3}=?$
$(\frac{1}{3}+\frac{1}{3})$ is $\frac{2}{3}=18$ m, then $\frac{1}{3}=9$
So the initial length is $\frac{1}{3}+\frac{1}{3}+\frac{1}{3}=1$, $9+9+9=27$ m
So the length of the rope was originally 27 meters
**(TOL Sub1)**

The results of the answers to the completion of the first subject (Sub1) shows that Sub1 can express more than the problem-solving process, meaning that the subject's ability to interpret the problem-solving process is given in various ways. It is proven that the subject has the ability of cognitive flexibility in solving mathematical problems. Then the results of investigators investigating the completion of the process done proved that Sub1 was able to assess the number of numbers, do mental computing, estimate, and assess the rationality or reasonableness of the calculation results obtained, following Sub1 narrative:

| | | |
|---|---|---|
| Researcher | : | Explain what do you think after reading the question? |
| Sub1 | : | First, I saw that question was fraction word problem, and then I suppose that the initial length of the rope is one part that was cut to be some parts. It's given that $\frac{1}{3}$ part and the left was 18 m. It means the left of the length of the rope 18 m is $\frac{2}{3}$ part. |
| Researcher | : | How come you get $\frac{2}{3}$ ? |
| Sub1 | : | (Drawing a rope then divide to be three parts and explain that was the fraction form). This is $\frac{2}{3}$ parts. I got it from subtracting a whole part (one) with $\frac{1}{3}$. |
| Researcher | : | Okay, next look at the next answer, why multiply $\frac{3}{2}$on the left and right-hand sides? |
| Sub1 | : | To make both sides equal, because I multiplied by $\frac{3}{2}$ on the right-hand side and so does left-hand side. |
| Researcher | : | Why? |
| Sub1 | : | It won't change the initial given. ..." Because it is given that the length of the rope is 18 m after it was cut by $\frac{1}{3}$ parts, then the left $\frac{2}{3}$, because one whole piece is equal to $\frac{3}{3}$. $\frac{1}{3}$ plus $\frac{1}{3}$ is the same as $\frac{2}{3}$, so we get a length of rope 9 meters from 18 meters because half of 18 meters is 9 meters. Means $\frac{3}{3}$ the part is 27 meters ... hmmm, ... multiple of 9... " |
| | | **(Transcript of interview Sub1)** |

The results of the answers to the completion of the first subject (Sub1) shows that Sub1 can express more than the problem-solving process, meaning that the subject's ability to interpret the problem-solving process is given in various ways. It is proven that the subject has the ability of cognitive flexibility in solving mathematical problems. Then the results of investigators investigating the completion of the process done proved that Sub1 was able to assess the number of numbers, do mental computing, estimate, and assess the rationality or reasonableness of the calculation results obtained. The interview transcript Sub1 is presented as follows:

| | | |
|---|---|---|
| Researcher | : | Can you tell us what you think after reading the questions above? |
| Sub2 | : | At first, I saw that the problem above was a question of a fraction story, then I suppose that the length of the original rope was one part that was cut into several parts, the problem known was 1/3 part, the remaining part was 18 m long. Means that the remaining 18 meters are 2/3 |
| Researcher | : | Why 2/3? |
| Sub2 | : | (Draw a piece of string then divide it into three parts and explain that this is the shape of the fraction) This is a part which is 2/3 part. The process is easy enough to reduce one to one-third of the known part of the problem. |
| Researcher | | Alright try to consider your next answer, why multiply 3/2 on each section? |
| Sub2 | | To make the right-hand section an integral part. Because my right side is 3/2, the left is the same. |
| Researcher | | Why does it have to be like that? |
| Sub2 | | So as not to change the first grade. |
| | | **(Transcript of interview Sub1)** |

In addition to the ability of Sub1 to assess the magnitude of numbers, perform mental computation, estimate, and assess the rationality or reasonableness of the calculation results, Sub1 also outlines the logical and reasonable reasons for each process that is passed.

The second student (Sub 2) does the process by looking for patterns of numbers, try and solve them with pictures. The following image is the result of Sub2:

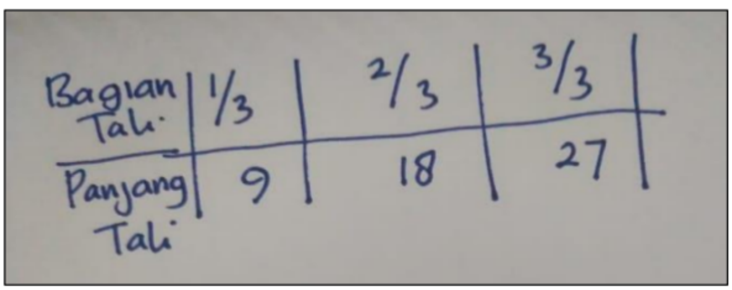


**Figure 1.** Completion results Sub1, No.1

The picture above is the answer of Sub2, showing that the ability to provide different and unusual solutions is the ability of cognitive flexibility possessed. Sub2 only gives a sketch of a table image while explaining each process carried out. The following is a description of the subject of the results of the completion carried out:

…" because what is known is the length of the rope 18 meters after being cut $\frac{1}{3}$ part, then the remaining part should be $\frac{2}{3}$, because a whole part is equal to $\frac{3}{3} \cdot \frac{1}{3} + \frac{1}{3} = \frac{2}{3}$

So it is obtained 9 meters of 18 meters because half of 18 meters is 9 meters. Means that $\frac{3}{3}$ *the* part is 27 meters. A multiple of 9
**(TOL Sub2)**

Sub2 represents the concept of a mathematical problem by explaining the image made, then looking for patterns of multiples of 9, 9, 18 and 27. Furthermore, making a fractional pattern of $\frac{2}{3}$, $\frac{2}{3}$ and $\frac{3}{3}$, by adding multiples of $\frac{1}{3}$.. So Sub2 pairs each fraction with the length of the string. Finally, the initial length is 27 meters.

| | | |
|---|---|---|
| Researcher | : | Do you have other programs to get the same results? |
| Sub2 | : | Because $\frac{2}{3}$ is equal to 18 meters, then $\frac{1}{3}$ are 9 meters, Therefore, $\frac{1}{3}$ x 3 = 9 x 3 so $\frac{3}{3}$ = 27 or the initial is 27 meters. |
| Researcher | : | Why has it to be multiplied by 3? |
| Sub2 | : | to make $\frac{3}{3}$ = 1, it must be multiplied by 3, as well as a rope length of 9 meters multiplied by three so that the initial length obtained before cutting is 27 meters |

**(Transcript of interview Sub2)**

The same resolution process is seen in answer number 2. The consistency of the subject resolves the problem with the same process seen from Sub2. Answer Sub2 to problem No. 2, presented as follows:

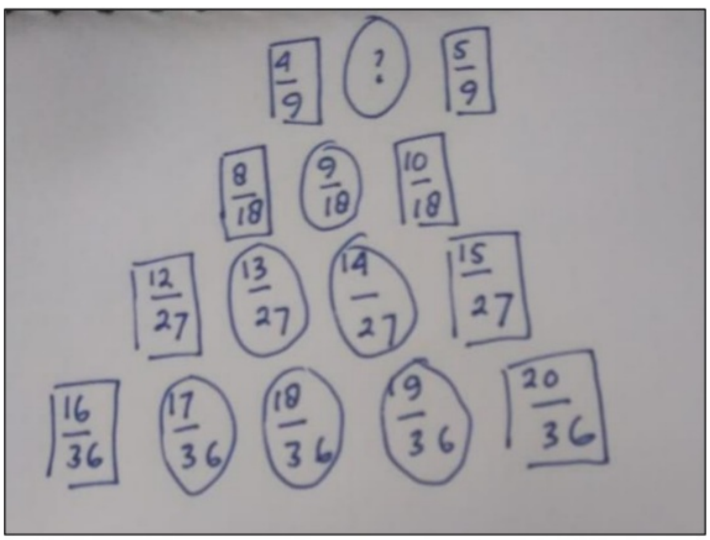


**Figure 2.** Completion results Sub2, No.2

Shows that Sub2 completes by making a number pattern then marks each answer with a circle, and a square sign indicates the same fraction value. Make conclusions from perspectives and representations according to the illustration of the problem where Sub2 can conclude that the higher the denominator value of the two known fractions, the more fraction values are found between the two fractions.

> ..."$\frac{4}{9}$ and $\frac{5}{9}$, looking for fractions that exist in between, I have to find similar fractions, through the Least common multiple of 9, that was 18, so it was obtained $\frac{8}{18}$ and $\frac{10}{18}$, and finally got $\frac{9}{18}$, the fraction between both fractions, look for the denominator with a multiple of 9, that was 27, then get $\frac{13}{27}$, $\frac{14}{27}$, , I tried with denominator 36, obtained $\frac{17}{36}$, $\frac{18}{36}$ *and* $\frac{19}{36}$"...
> **(TOL Sub2)**

The completion of Sub2 in problem number 3 is also seen using cognitive flexibility. Based on the results of the completion of Sub 2, No.3 presented as follows:

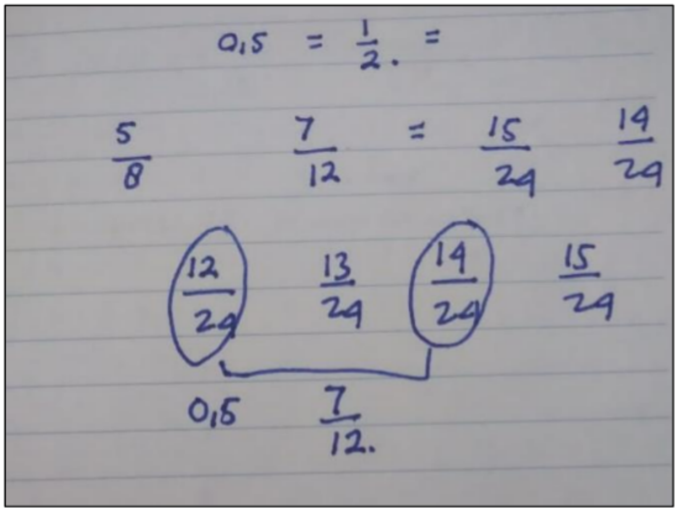


**Figure 3.** Completion results Sub2, No.3

Seen on the results of completion Sub2 completes by the process of finding the value of a fraction worth, which is $0.5 = \frac{1}{2} = \frac{12}{24}$. The next step looking for a fraction worth by equating the denominator of two fractions, $\frac{5}{8} = \frac{15}{24}$ then $\frac{7}{12} = \frac{14}{24}$. Then next order the fractions $\frac{12}{24}$ $\frac{13}{24}$ $\frac{14}{24}$ $\frac{15}{24}$ so that $\frac{7}{12}$ is obtained closer to 0.5. The solution used by Sub2 is a solution that is rarely used by students in general. The cognitive process that occurs when solving these problems, Sub2 dabbled in various perspectives on solving, recalling the concept of fractions that had been encountered before and re-examining the answers obtained.

Research results show that cognitive flexibility that occurs involves cognitive processes in the form of the ability to assess the number of numbers, mental computing, estimation, and assess the rationality or reasonableness of the calculation results obtained. In line with Hadi (2015) explains that cognitive flexibility can be observed when the subject performs four-component sense numbers, namely assessing the number of numbers, mental computation, estimation, and assessing the rationality or reasonableness of the calculation results which is obtained.

Understanding number magnitudes occur when students can compare numbers, sort numbers, recognize two numbers that are closer to the third number, and identify numbers between two given numbers. In line with the opinion of (Thompson, 1993) suggested that 'someone understands a quantity by understanding the quality of an object if someone understands how to measure it.

Cognitive processes that occur when a subject solves a given problem are the ability to do the process by looking for patterns of numbers, trial-and-error (also known as guess-and-check) and solve with diagram drawings. Clements & Sarama (2007)suggest that algebra begins with pattern searching. Identifying patterns, helping students bring order, cohesion, and certainty to situations that seem unorganized and allow one to recognize relationships and make generalizations. Pattern as a support to be able to distinguish predictability from randomness. Students can develop algebraic insight when students learn the rules of substitution and apply them without regard to specific items involved in patterns, (patterns that emerge can show relationships with each other even though they differ in real nature). Therefore, "pattern recognition and analysis are important components of children's intellectual development because they can provide a basis for the development of algebraic thinking" (Clements & Sarama, 2007)

It seems that increased recognition of patterns involves increased recognition of differences and similarities in pattern elements (Papic, 2007). Also, increased recognition of alternating patterns can increase the abstraction of a reciprocal relationship and generalize the relationship to a new form (for example, from colour to shape or size; Ljung-Djärf et al., 2013). When a child gives the same name for a change to a new form that is very different (e.g. colour and shape) the child has named a variable, which is characteristic of algebraic thinking (Pasnak et al., 2016).

The process of trial-and-error (also known as guess-and-check) and drawing a diagram appear to be seen in the problem-solving process. In line with Yew et al (2016) prove that the problem-solving process involves the ability to try simple cases; trial-and-error (also known as guess-and-check); draw a diagram; identify patterns; make a table, chart, or systematic list; simulation; use an analogy; working backwards; logical reasoning; and using algebra. Resolving a mathematical case or mathematical problem also requires sensitivity and reasoning (Saleh et al., 2019). Also, creative thinking is needed to solve mathematical problems (Nugroho et al., 2020). In solving problem tendencies students use the four basic operations in Mathematics and manipulate all data contained in the problem, then stop when they feel they have arrived at a reasonable answer based on their estimated answers (Tan, 2018). The oldest strategy used in problem-solving is trial-error. Trial-error is not a systematic approach used when faced with a problem but is applied to the situation of someone unable to find a solution to the problem at hand. Systematic exploration can be considered as the opposite of trial-error strategy. A systematic exploration is an approach that involves steps such as hypothesis testing, planning, and evaluating the results of an action (Van Der Linden et al., 2001). So it was concluded that students who have cognitive flexibility through a trial-error process when solving problems before finding a solution.

## Conclusion

The conclusion of this study are cognitive flexibility of students occurs when solving fraction problems by experimenting with various perspectives on solving which then recall the fraction concept that was previously encountered and re-examine the answers obtained. The cognitive flexibility that occurs involves cognitive processes in the form of the ability to assess the number of numbers, mental computing, estimation, and assess the rationality or reasonableness of the calculation results obtained. Cognitive processes involved when students solve problems, namely the ability to do the process by looking for patterns of numbers, trial-and-error (also known as guess-and-check) and solve with diagram drawings. Students who have cognitive flexibility through a trial and error process when solving a problem before finding a solution. However, this study only uses students at the elementary school level, therefore the researchers recommend further research related to the abilities of students at all levels and design learning models that can develop student cognitive flexibility.

**Acknowledgement**

Thanks to STKIP YPUP Makassar and Makassar Muhammadiyah University. The author also thanks all participants involved in this study, especially to all fourth-grade students of elementary schools in Makassar

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