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Combinatorial Thinking Analysis for Solving Partition Type Combinatorial Problems

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Abstract

Purpose: This study aims to analyze the combinatorial thinking process of elementary school students in solving partition-type mathematical problems.
Methodology: The research approach used is descriptive qualitative with five sixth-grade elementary school students selected through purposive sampling. Data were collected through written tests, observations, and semi-structured interviews, then analyzed using the Miles, Huberman, and Saldana model, which includes data reduction, data presentation, and conclusion drawing.
Results: The results showed that students went through four stages of combinatorial thinking, namely identifying, selecting, closing, and reflecting. In the identifying stage, students are able to understand the important elements of the problem; in the selecting stage, students develop strategies and find all possible divisions; in the closing stage, students draw logical conclusions; while in the reflecting stage, students recheck the results to ensure the accuracy of the procedure. These findings indicate that combinatorial thinking can improve students' systematic, reflective, and logical thinking skills in solving mathematical problems.
Applications/Originality/Value: The originality of this study lies in its focus on analyzing the combinatorial thinking process of elementary school students in solving partition-type problems, which has rarely been explored in depth at the primary education level. This research not only highlights the final outcomes of problem-solving but also traces students' thinking stages systematically through identification, strategy selection, conclusion drawing, and reflection. Thus, this study provides a new contribution to the development of combinatorial thinking research and serves as a foundation for innovative mathematics learning that emphasizes logical and reflective thinking from an early age.

Keyword: combinatorial thinking, problem solving, partition type

Introduction

The development of 21st-century education requires higher-order thinking skills (HOTS) as part of the core competencies that students must possess. In the context of mathematics learning, HOTS are reflected in the five process standards established by the National Council of Teachers of Mathematics (NCTM), namely problem solving, reasoning and proof, communication, connection, and representation. These five standards not only support conceptual understanding but also train students' critical and reflective thinking skills (Midgett & Eddins, 2001). Mathematical literacy is an important foundation in applying these standards because it is related to the ability to use mathematics functionally in real life. This literacy includes the ability to formulate, apply, and interpret mathematics in various contexts (Pugalee & Chamblee, 2000) in the era of the Industrial Revolution 4.0, global challenges demand complex problem solving that requires systematic and logical thinking. Therefore, strengthening logical thinking through numeracy literacy is essential for helping students deeply understand mathematical concepts and apply them effectively in problem-solving (Pratiwi et al., 2024). This entire process is also in line with the demands of technology-based learning and innovation that place logic at the center of decision-making. Therefore, it is necessary to further explore forms of logical thinking that are relevant in the context of mathematics, including combinatorial thinking.

Uripno & Rosyidi (2019) reveal that the development of combinatorial thinking in solving mathematical problems, especially in questions using multiplication and combination rules, not only involves technical strategies such as direct calculation or diagrams but also supports students' affective aspects and metacognitive aspects during the problem-solving process. This process also fosters curiosity because students are interested in exploring many valid possible answers (Hidayati et al., 2019) . Students' confidence increases when they are able to find solutions independently and verify the results in different ways. In addition, combinatorial thinking fosters critical thinking habits through comparing strategies and selecting the most appropriate approach (Khunaifi, 2023). In practice, students also learn to reflect on their thinking

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processes, thereby increasing their metacognitive awareness. This makes combinatorial thinking not only a cognitive tool, but also a means to shape the character of resilient and reflective learners (Salavatinejad et al., 2021). Therefore, combinatorial thinking can be a bridge between mathematical abilities and strengthening the character of 21st century learners. For this reason, its application in learning needs to be reviewed from a deep curriculum and practice perspective.

The application of combinatorial concepts in mathematics learning in elementary schools is still far from optimal and is often neglected in the main curriculum of basic education. Simamora & Zunaiedy (2021) found that combinatorial topics are rarely researched or developed systematically in early education, even though the potential for developing systematic thinking is enormous. Furthermore, Ergasheva & Egamberdiyeva, (2024) states that the integration of combinatorics into the basic curriculum is still in the exploratory stage and has not yet formed a strong understanding of this topic among teachers and students. Without visual representations or concrete contexts, students find it difficult to understand the distribution of objects in partition-type problems. A study by Rakic et al., (2021) shows that well-structured combinatorial tasks can significantly improve elementary school students' logical- combinatorial thinking skills. Due to the lack of attention and reinforcement at the elementary level, students' readiness to tackle combination problems, especially partition-type problems, is still very low and requires a more contextual, adaptive, and meaningful learning approach.

Various approaches have been used in mathematics education research to examine students' combinatorial thinking. Previous studies include the use of semiotic models to understand students' combinatorial thinking, geometric problem-solving experiments to reveal systematic thinking, and curriculum studies that highlight the need to develop various modes of thinking in combinatorics teaching (Rezaie & Gooya, 2011) . In the research Hastuti et al (2019) , combinatorial identities in total rainbow connection coloring were used to trace students' thinking processes through patterns of strategy, generalization, and mathematical proof based on the Research-Based Learning approach. In the context of elementary education, Hidayati et al., (2019) presents an alternative approach by linking combinatorial thinking processes in selection-type questions with the use of table representations to help students identify systematic and accurate enumeration patterns. Based on these results, it can be concluded that understanding mathematical strategies and expressions is an important foundation in designing combinatorial learning interventions.

In the context of combinatorial partition problems, Lockwood & Caughman, (2016) explored students' understanding of the concept of set partitioning and the multiplication principle, and found that most students had difficulty identifying the crucial features of this principle when solving partition problems. This difficulty indicates the need for a more structured formulation of thinking stages to guide students in solving problems systematically. In line with the framework developed by Pólya, the stages of combinatorial thinking can be arranged to include understanding the problem, solving the problem, implementing the plan, and reflecting, which are considered capable of helping students in the process of solving combinatorial problems comprehensively (Polya, G. 1957) . Hidayati et al., (2019) state that combinatorial thinking has four stages, namely identification, selection, conclusion, and reflection, which have been proven to help students develop strategies for solving selection and partition problems more logically and efficiently. With this stage structure, teachers can provide more targeted feedback and develop in-depth assessments of students' thinking processes in the context of partitioning.

This article is expected to contribute to the development of combinatorial thinking studies through three main focuses, namely: (1) formulating stages of combinatorial thinking relevant to partition problems, (2) identifying thinking patterns that emerge when individuals encounter partition-type combinatorial problems, and (3) examining various problem-solving strategies applied in this context. The novelty of this research lies in its emphasis on the study of combinatorial thinking of the partition type in elementary school children, which has rarely been explored in depth until now, so it is expected to provide a new perspective in the development of mathematics learning at the elementary education level.

Method

Research Subjects

The research subjects were five sixth-grade elementary school students. The subjects were selected using purposive sampling, which is a sampling technique based on certain considerations relevant to the research objectives (Ahmad & Wilkins, 2025) . The criteria used included: (1) Student activity during classroom learning (2) Students with high mathematical thinking abilities (3) Student willingness to participate in interviews and complete problems.

Data Collection Techniques

Data collection techniques in this study were conducted through written tests, observation sheets, and semi-structured interview guidelines. Written tests were used to measure students' combinatorial thinking abilities through essay questions containing indicators of partition-type combinatorial thinking abilities. The observation sheets were used to record all student activities during the problem-solving process, while semi-structured interviews were conducted to explore in greater depth the students' ideas, strategies, and ways of thinking in finding solutions. Data validity was ensured through triangulation techniques, both technical and source triangulation, by comparing the results of the three data collection methods.

Data Analysis

The data obtained from the three methods was then analyzed using the Miles et al. (2014) model, which consists of three stages: data reduction, data presentation, and conclusion drawing and verification. Data reduction was carried out by selecting and simplifying the data from observations, tests, and interviews. Data presentation was carried out by compiling the findings in the form of narratives and tables of students' combinatorial thinking stages, while the final stage was drawing conclusions to interpret students' thinking patterns and ensure the validity of the analysis results.

Result and Discussions

Result

The results of the study show that elementary school students go through four stages of combinatorial thinking in solving partition-type combinatorial problems, namely identifying, selecting, closing, and reflecting (Lockwood, 2013).

Table 1. *Stages of combinatorial thinking in students when solving combinatorial problems of the selection type.*

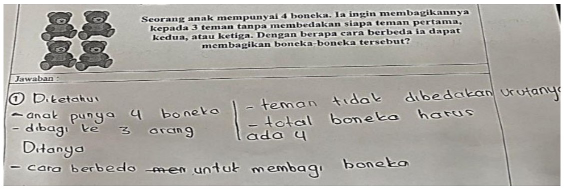
Stage	Characteristics	Indicators
Identifying	Students are able to understand the context of the problem and determine the important elements (objects, groups, and division rules).	1. Understanding sets 2. Identify an object as a set 3. Understand that all set notations must be selected based on problem criteria
Selecting	Students can organize thinking strategies to find all possible logical and systematic divisions.	1. Determine the number of objects, the number of parts in the partition, and the conditions for division. 2. Determine all possible partitions of the object according to the rules 3. Determine the number of possible partitions and recheck all possibilities
Concluding	Students can logically conclude the final result.	1. Draw conclusions based on the problem
Reflecting	Students demonstrate reflective skills by assessing the accuracy of the results and the correctness of the procedures used.	1. Systematically checking all possible structures 2. Checking all possible structures 3. using combinatorial concepts and procedures

The following presents the results of the subject's (KM) work in solving mathematical problems related to combinatorial thinking of the partition type.

From **Figure 1**, at the identification stage, subject KM began by understanding the context of the problem given. The subject wrote down important information, namely that there were four dolls and three friends. Next, the subject confirmed that the friends who would receive the dolls were not distinguished, so that the order of distribution did not affect the results. This shows that KM understood that the situation was a partition problem without regard to order. In addition, the subject also wrote that the total number of dolls must remain four, which means that all notation sets must be selected based on the criteria of the problem.

The interview excerpt shows that the subject KM believes that the meaning of distributing objects does not take into account the order of recipients, and demonstrates the ability to understand the core of the problem in the question based on the subject's initial understanding.

Original Version



Seorang anak mempunyai 4 boneka. Ia ingin membagikannya kepada 3 teman tanpa membedakan siapa teman pertama, kedua, atau ketiga. Dengan berapa cara berbeda ia dapat membagikan boneka-boneka tersebut?

Jawaban :

1. Diketahui
- anak punya 4 boneka
- dibagi ke 3 orang

- teman tidak dibedakan urutanya
- total boneka harus ada 4

Ditanya
- cara berbedo ~~men~~ untuk membagi boneka

Translated Version

A child has 4 dolls. He wants to share them with 3 friends without distinguishing between the first, second, or third friend. How many different ways can he share the dolls?

Answer :

1.is known :

- the child has 4 dolls
- the are to be divided among 3 people

-The order of the friends does not matter
-There must be a total of 4 dolls

Question : Different ways to divide the dolls.

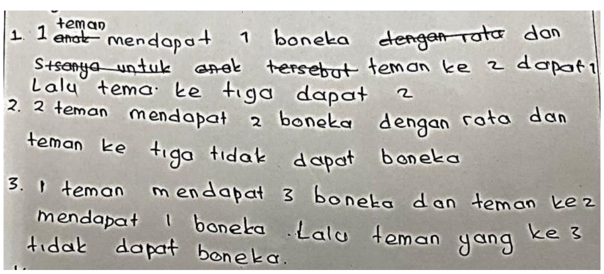
Figure 1. *Students' answers in identifying combinatorial selection problems*

P	*: What do you understand from the question?*
KM	*: I know there are four dolls that must be distributed to three friends. Since the friends are not distinguished, the order in which they receive the dolls is not important; what is important is that the total number of dolls remains four.*
P	*:So you already know what you need to find?*
KM	*: Yes, I have to find all the possible ways of distributing the dolls based on those rules.*

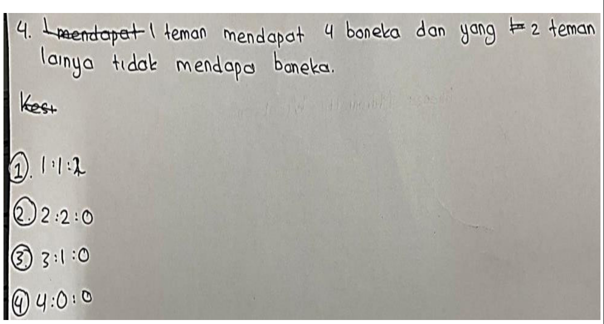
Based on these steps, it appears that subject KM was able to identify the important elements in the problem, namely the number of objects (dolls), the number of groups (friends), the distribution rule (no distinction between order), and the total requirement that must be met. This stage reflects KM's initial understanding in developing combinatorial thinking to construct the next possible partition.

Furthermore, as seen in **Figure 2** at the selection stage, the subject KM began to try various possibilities for distributing the dolls to three friends with the condition that the total number of dolls remained four and the order of recipients was not taken into account. The subject wrote down the possible results, namely (1,1,2), (2,2,0), (3,1,0), and (4,0,0).

Original Version



1. 1 ~~anak~~ teman mendapat 1 boneka ~~dengan rata~~ dan S~~isanya untuk~~ ~~anak~~ ~~tersebut~~ teman ke 2 dapat 1 Lalu tema ke tiga dapat 2
2. 2 teman mendapat 2 boneka dengan rata dan teman ke tiga tidak dapat boneka
3. 1 teman mendapat 3 boneka dan teman ke 2 mendapat 1 boneka. Lalu teman yang ke 3 tidak dapat boneka.



4. ~~1 mendapat~~ 1 teman mendapat 4 boneka dan yang 2 teman lainya tidak mendapa boneka.

Kes.

1. 1:1:2
2. 2:2:0
3. 3:1:0
4. 4:0:0

Translated Version

1. One friend gets one doll, the second friend gets one, and the third friend gets two.

2. Two friends get two dolls each, and the third friend gets no doll.

3. One friend gets three dolls, the second friend gets one doll, and the third friend gets no doll.

4. One friend gets four dolls, and the other two friends get no dolls.

1. 1 : 1 : 2

2. 2 : 2 : 0

3. 3 : 1 : 0

4. 4 : 0 : 0

Figure 2*. Students' answers in selecting combinatorial selection-type problems*

This sequence shows that KM has demonstrated the ability to find all possible distributions that meet the conditions, in accordance with the characteristics of the selection stage in combinatorial thinking. Although KM has not used a systematic pattern in determinin the partition, but rather mentions combinations randomly based on intuition and logical estimates. This is clarified by the following interview excerpt.

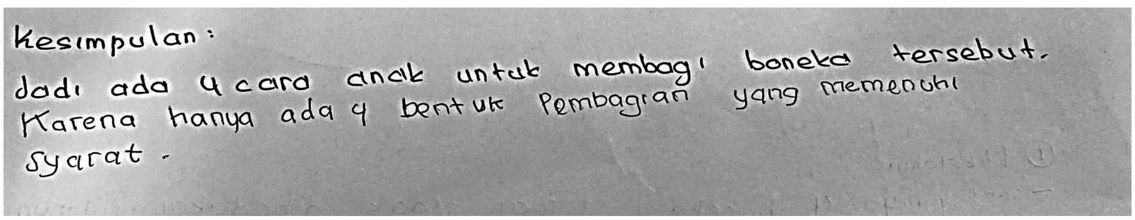
P : *How did you answer those questions?*

KM :*The numbers indicate the number of dolls each friend received. I didn't pay attention to the order, as long as the total remained four. I just wrote down all the possibilities that came to mind, starting with (1,1,2), then (2,2,0), then (3,1,0), and finally (4,0,0). After checking, they all met the total of four dolls, so I thought those were all the possibilities.*

In **Figure 3**, KM was able to draw conclusions based on the problem given in a logical and systematic manner. KM was able to summarize the results of the problem accurately according to the data, so that the conclusions drawn were clear. After trying various possibilities for dividing the dolls that met the total requirement of four and without paying attention to the order, KM concluded that there were four different possible ways. This conclusion was made based on the pattern found earlier from exploring the distribution forms, namely (1,1,2), (2,2,0), (3,1,0), and (4,0,0). This shows that KM can reason and draw conclusions rationally using concrete evidence from the problem-solving process that has been carried out.

From the interview excerpt, it can be seen that the KM subject is able to draw logical conclusions based on the results obtained. The subject explains that there are four different ways to divide four dolls among three friends while fulfilling the condition of a total of four and without regard to the order of recipients, which demonstrates a conceptual understanding of the problem being solved.

Original Version


Kesimpulan:
Jadi ada 4 cara anak untuk membagi boneka tersebut.
Karena hanya ada 4 bentuk Pembagian yang memenuhi syarat.

Translated Version

Conclusion:

So there are four ways for the children to divide the dolls. This is because there are only four ways of dividing that meet the conditions.

Figure 3. *Students' answers in closing the combinatorial selection type question*

P : *How did you conclude that there are four different ways?*

KM : *Because of all the divisions I made, there are only four forms that remained four in number and no order was taken into account. So I concluded that there were only four ways.*

In the final stage, which is reflection, KM can systematically check all possible structures so that no possibilities are overlooked. In addition, KM is also able to use combinatorial concepts and procedures well in checking structures. This shows that KM has fulfilled the *reflection* indicator well in both aspects observed. This can also be seen from the following interview excerpt.

P : *After you have written down all the possible ways of dividing the dolls, how do you ensure that your results are correct and nothing has been missed?*

KM : *I check them again one by one to make sure nothing is left out. I try to rearrange the distribution in order, from the least balanced to the most even. That way, I can see if there are any other forms of distribution that I haven't written down yet.*

P : *Then, how do you know if the final result is correct?*

KM : *I recalculated each division and made sure the number of the number of dolls remains four. After double-checking, all the results make sense and there are no repeated divisions. So I'm sure all possibilities are complete and correct.*

Discussion

This study analyzes the combinatorial thinking process of elementary school students in solving partition-type mathematical problems. The findings of this study show that the combinatorial thinking process of elementary school students arises naturally when they are faced with problems that require systematic exploration. This pattern of thinking, which includes the stages of identifying, selecting, closing, and reflecting, is in line with the combinatorial thinking framework proposed by Lockwood, (2013) and the four-step problem- solving model from Pólya., (1957) , namely understanding the problem, planning, implementing, and reviewing the results. Combinatorial thinking is an important cognitive skill that helps students understand patterns, relationships, and structures in mathematical problem solving. According to Aini & Suryowati (2024) , combinatorial reasoning-based learning can foster logical and systematic thinking skills because students are trained to connect rules, patterns, and results in real-world contexts.

At the identification stage, the interview results showed that students were able to understand the problem and recognize the important elements of the question. When given a question about dividing four dolls among three friends, students were able to relate the context to the concept of grouping, not just arithmetic division. The subjects chose to divide the dolls into two, one, and one so that each group got a share. The students' ability to interpret the problem correctly shows that they understand the relationship between the total number of objects and the distribution pattern. These findings are in line with the results of the research by Aini & Suryowati (2024) , which states that elementary school students who are able to recognize the relationship between elements in combinatorial problems will find it easier to develop relevant strategies in finding all possible solutions.

The next stage, namely choosing, illustrates how students organize strategies in arranging all possible divisions. In the interview, students tried several forms of division such as (1,1,2), then (2,2,0), then (3,1,0), and finally (4,0,0), then checked to ensure that the total remained four. This process shows that students used an exploratory approach to explore various possible combinations. These results reinforce the view of Bilkis et al., (2024) which states that combinatorial thinking can be developed through systematic exploration activities, where students are trained to list all possible alternatives and avoid repeating the same patterns. Such exploration activities are important because they help students think more flexibly and understand the structure of the problems they face.

In the closing stage, the student concludes that all possible forms of division have been found and provides a logical reason that all results meet the total of four. He explains that the two-by-two division with one empty group is also correct because the total number remains the same. This stage demonstrates the student's ability to generalize the patterns found through the exploration process. According to Uripno et al., (2023) , the ability to draw logical conclusions from various alternative solutions is a characteristic of mature combinatorial thinking development, because students are not only oriented towards the final result but also towards a logical and consistent thinking process.

Meanwhile, in the reflection stage, students review their work and state that all possibilities have been written down. They check whether there are other forms that may not have been listed, then ensure that they have found all combinations that meet the total of four. This shows reflective awareness in thinking, where students are able to assess the correctness of the steps they have taken. This process demonstrates metacognitive ability, which is the awareness to monitor and evaluate one's own way of thinking. Reflective exercises such as this need to be practiced in mathematics learning because they can improve thinking accuracy, independence, and the ability to correct mistakes independently (Saidakhon & Latofakhon, 2025) .

Overall, the results of this study indicate that students go through four stages of combinatorial thinking well: identifying problems, exploring possibilities, drawing logical conclusions, and reflecting on the results. The thinking patterns demonstrated show that students are not only able to solve problems procedurally, but also demonstrate a strong conceptual understanding. This thinking process is in line with the view of Aini & Suryowati (2024) that combinatorial thinking can be an important basis for the development of higher- order thinking skills, as it trains students to reason, evaluate, and develop more efficient thinking strategies. Therefore, the habit of combinatorial thinking in mathematics learning in elementary school needs to be continuously developed so that students become accustomed to thinking systematically, reflectively, and analytically in solving various mathematical problems.

Conclusion

This study shows that at the elementary school level, students are able to go through the process of combinatorial thinking gradually when solving partition-type mathematical problems. Students can understand the context of the problem, develop strategies to find various possible divisions, draw logical conclusions, and reflect on the results obtained. This study identifies four stages of combinatorial thinking, which include identifying, selecting, closing, and reflecting. In the identifying stage, students are able to understand the context of the problem and determine the important elements; in the selecting stage, students develop strategies to find various possible divisions; in the closing stage, students draw logical conclusions based on the results of their exploration; and in the reflecting stage, students review the steps they have taken to ensure the correctness of the solution. These results confirm that students' combinatorial thinking processes develop through interrelated exploratory and reflective activities, rather than simply applying mathematical procedures. Thus, learning that emphasizes the development of combinatorial thinking is important to be implemented in elementary schools to train students to think logically, systematically, and reflectively in solving mathematical problems

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