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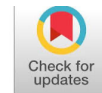
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Analysis of Elementary School Students' Creative Thinking in Solving Mathematical Problems Based on Level of Mathematical Understanding

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ABSTRACT

Creative thinking is an essential mathematics competency, supporting idea generation, strategy selection, and non-routine problem solving. At the elementary level, it must be developed systematically so students move beyond routine procedures toward flexible, logical, reflective thinking. This study describes sixth-grade students' creative thinking in solving data-handling problems by level of mathematical understanding. Using a qualitative descriptive approach, three sixth-grade students at UPT SD Negeri 099 Masamba were purposively selected for high, moderate, and low understanding levels. Data were collected through a creative-thinking test and semi-structured interviews, analyzed using fluency, flexibility, originality, and elaboration indicators. Credibility was strengthened through triangulation of written responses and interviews; data were processed through reduction, display, verification, and conclusion drawing. The high-ability student displayed all four indicators strongly and consistently, proposing alternative strategies, adjusting solution steps, developing logical plans, and re-checking solutions. The moderate-ability student showed all indicators but was inconsistent in exploring ideas, developing solutions, and evaluating answers. The low-ability student showed limitations in independently generating strategies, developing solutions, and explaining reasoning in detail. These findings show that understanding level relates to differences in students' creative-thinking characteristics in problem solving. Instruction should therefore give students room to explore strategies, explain reasoning, and reflect on solutions.



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Introduction

Social change, technological development, and the growing complexity of problems in 21st-century life require education not only to develop mastery of knowledge but also to develop learners' ability to use that knowledge adaptively (Waluya et al., 2025). One

competence that is important in this context is creative thinking. Creative thinking enables learners to generate diverse ideas, judge the feasibility of those ideas, develop alternative solutions, and refine solutions according to the demands of a problem (Dwi Ferdiani et al., 2022; Ferdiani & Harianto, 2024; Hobri et al., 2021). In the PISA 2022 framework, creative thinking is defined as the competence to engage productively in the generation, evaluation, and improvement of ideas that can result in original and effective solutions, advances in knowledge, and impactful expressions of imagination (Habibi & Suparman, 2020; Setiawan et al., 2024). This definition emphasizes that creative thinking is not merely about producing new ideas; it also involves evaluating and refining ideas so that they are relevant and useful for solving problems.

The importance of creative thinking is also related to learners' need to deal with situations that cannot always be resolved through routine procedures (Hobri et al., 2021; Rachman & Rosnawati, 2021). In PISA 2022, creative thinking is understood through three main processes: generating diverse ideas, generating creative ideas, and evaluating and improving ideas. The PISA 2022 results showed that the mean creative thinking score of Indonesian students was 19 out of 60 points, lower than the OECD average of 33 points (OECD, 2018). This finding indicates the need to attend to instruction that gives students greater opportunities to put forward alternative ideas, evaluate strategies, and improve solutions.

In the Indonesian context, the development of creativity is also in line with the orientation of the Merdeka Curriculum (Kurikulum Merdeka), which positions learners as active agents in learning. This curriculum promotes learning that gives students opportunities to construct understanding, communicate ideas, reason, and solve problems in various contexts. In mathematics, creativity is relevant because solving mathematical problems is not always restricted to a single procedure or a single form of representation (Voigt et al., 2020). Students may use pictures, tables, diagrams, symbols, verbal reasoning, or different computational strategies to understand and solve a problem (Finesilver, 2022; Kosko, 2020; Yao, 2022). Accordingly, mathematics instruction should not be oriented solely toward correct final answers but also toward the processes by which students generate, select, explain, and evaluate solution strategies.

Mathematics plays a strategic role in developing higher-order thinking because it requires students to understand relationships, identify patterns, construct arguments, select strategies, and verify the correctness of solutions (Rahmayani et al., 2025). In problem solving, mathematical creative thinking becomes evident when students are able to view a problem from more than one perspective, generate various ideas or strategies, use appropriate representations, and provide logical explanations for the solutions they obtain. Therefore, mathematical creativity cannot be understood merely as the novelty of an answer (Xu et al., 2020). A solution can be regarded as creative if it contains an element of relative novelty, is consistent with mathematical concepts, is relevant to the problem, and can be justified through sound reasoning.

Mathematical creative thinking is commonly analyzed through four indicators: fluency, flexibility, originality, and elaboration (Dwi Ferdiani et al., 2022; Lithner, 2017; Norqvist et al., 2019). Fluency refers to the ability to generate a number of relevant ideas or answers. Flexibility concerns the ability to use more than one approach, strategy, or representation in solving a problem. Originality refers to the ability to produce ideas or solutions that are relatively uncommon yet mathematically correct. Elaboration refers to the ability to develop ideas through explanations, detailed steps, justifications, or refinement of solutions. These four indicators are important because they provide a more complete picture of students' thinking processes than merely judging whether a final answer is right or wrong.

One mathematical topic that is relevant for examining students' creative thinking is data handling. Data handling requires students not only to read or construct tables and diagrams but

also to understand information, compare data, choose appropriate forms of presentation, interpret results, and draw conclusions from data (Hu et al., 2025; R. S. Jones & Rosenberg, 2022; Yigiter, 2025). In the Phase C Mathematics Learning Outcomes (Capaian Pembelajaran), which cover Grades 5 and 6 of elementary school, students are expected to be able to order, compare, present, and analyze count data and measurement data in the form of pictures, pictograms, bar charts, and frequency tables to obtain information.guru.

The nature of data handling allows students to use a variety of representations and solution strategies. For example, when students are asked to determine the most appropriate type of chart for presenting certain data, they need not only to know the procedure for constructing the chart but also to consider the purpose of the presentation, the characteristics of the data, and the information they wish to highlight (Yigiter, 2025). In such situations, students may use frequency tables, bar charts, pictures, or verbal explanations as a basis for constructing a solution. Therefore, open-ended data handling problems have the potential to reveal students' fluency in generating ideas, flexibility in choosing representations, originality in developing solutions, and elaboration in explaining their mathematical reasoning.

The urgency of developing these abilities is also evident from Indonesian students' mathematics achievement in international assessments. PISA 2022 showed that only 18% of Indonesian students reached at least Level 2 in mathematics, compared with an OECD average of 69%. At this minimum level, students are expected to be able to recognize and interpret mathematical representations of simple situations without direct instruction. In addition, almost no Indonesian students reached Level 5 or 6, the levels that require the ability to model complex situations and to select, compare, and evaluate problem-solving strategies. These data cannot be used directly to describe the abilities of elementary school students because PISA assesses 15-year-olds; nevertheless, they provide national context regarding the importance of strengthening reasoning, problem solving, and the meaningful use of mathematical strategies from the early grades.

Preliminary observations at UPT SD Negeri 099 Masamba indicated that, in mathematics lessons, some sixth-grade students tended to follow the solution steps modeled by the teacher. When given problems that differed from routine examples, some students had difficulty determining a strategy independently and rarely attempted other approaches. Students were also not accustomed to explaining the reasons behind their answers or checking whether their solutions were consistent with the available information. These conditions suggest that students' thinking processes in generating and developing solution strategies have not been fully revealed through regular instruction or assessment. A preliminary interview with the sixth-grade teacher also indicated that students still had difficulty understanding information in tables and charts, relating data to the problem context, and drawing conclusions from the available data. In everyday lessons, the problems used were mostly routine and had solution procedures that had been modeled beforehand. Consequently, students had limited opportunities to choose representations, compare strategies, explain their considerations, and find alternative solutions. These conditions warrant deeper investigation because creative thinking concerns not only the answers students produce but also the ways in which they understand problems, construct ideas, use strategies, and reflect on solutions.

Several previous studies have examined mathematical creative thinking through the implementation of various instructional models, such as Problem-Based Learning, Project-Based Learning, Realistic Mathematics Education, open-ended problem-based learning, and the use of digital media (Hakamata et al., 2023; Kotto et al., 2022; Morrison et al., 2020). These studies have generally focused on score gains or differences in creative thinking ability following an intervention. Although this focus is important, it does not fully explain the

characteristics of students' creative thinking processes as they work directly on mathematical problems. Moreover, some of these studies were conducted at different educational levels, on different topics, and in different school contexts, so their findings may not reflect the situation of sixth-grade elementary students solving data handling problems.

A research gap is also evident in the need for studies that link creative thinking to students' level of mathematical understanding. Mathematical understanding serves as a foundation that enables students to recognize relevant information, select appropriate concepts, use representations, and develop solution strategies. Students with different levels of mathematical understanding may therefore exhibit different creative thinking characteristics. However, such differences cannot be adequately understood through test scores alone. A qualitative approach is needed to reveal how students with high, medium, and low levels of understanding generate ideas, change strategies, provide justifications, and develop solutions when dealing with data handling problems.

This study employed a qualitative descriptive approach to describe the creative thinking characteristics of sixth-grade students in solving data handling problems based on their level of mathematical understanding. The analysis focused on four indicators: fluency, flexibility, originality, and elaboration. Through analysis of written responses and interviews, this study is expected to provide deeper insight into how students with high, medium, and low mathematical understanding comprehend problems, generate strategies, develop solutions, and re-check their answers. Theoretically, the findings are expected to contribute to the understanding of the characteristics of mathematical creative thinking among elementary school students, particularly in the context of data handling. Practically, the findings may serve as a basis for teachers to design instruction and assessment that not only evaluate the correctness of answers but also give students opportunities to use multiple representations, propose alternative strategies, explain their mathematical reasoning, and reflect on the solutions they produce.

Creative Thinking Processes in Problem Solving

Assessing creative thinking in mathematical problem solving cannot be done solely by looking at the correctness of students' final answers. A correct answer does not necessarily indicate that a student has generated diverse ideas, used flexible strategies, developed a solution independently, or checked the answer (Norqvist et al., 2019). Conversely, an answer that is not entirely correct may still reveal creative thinking potential if the student is able to propose alternative ideas, use appropriate representations, explain the reasons for choosing a strategy, or attempt to improve the solution procedure (Dwi Ferdiani et al., 2022). Therefore, the analysis of creative thinking should be directed at the processes by which students understand the problem, generate ideas, select strategies, develop solution steps, and evaluate solutions.

In mathematical problem solving, students' thinking processes can be observed through the ways they identify what is given and what is asked, relate this information to relevant concepts, and determine the representations or strategies to be used. Students with creative thinking ability do not merely seek a single answer; they also consider other possible ways of solving the problem (Ferdiani & Harianto, 2024). This process may become apparent when students try to construct tables, charts, pictures, calculations, or verbal explanations to make sense of the problem situation (Rachman & Rosnawati, 2021). Thus, mathematical creativity is related to the quality of students' reasoning and decision-making processes, not merely to the number of answers produced.

In-depth analysis is also necessary because students' written responses often do not fully capture the thinking processes that take place. A student may write brief solution steps but may in fact have considered several alternatives before choosing one strategy. Conversely, a student may produce an answer that appears complete but be unable to explain the meaning of the steps

taken or the reasons for choosing a particular strategy. Therefore, interviews conducted after the test are needed to confirm students' thinking, probe the reasons behind each step, and identify strategies that may have been considered but were not expressed in the written answer.

An in-depth and contextual approach is particularly important for elementary school students because their ability to express ideas in writing is still developing. Limitations in writing do not necessarily reflect limitations in understanding or in creative thinking potential. By combining written tests with semi-structured interviews, researchers can obtain a more authentic picture of how students understand problems, generate ideas, change strategies, explain solutions, and re-check their answers. In this way, students' creative thinking characteristics can be analyzed more comprehensively based on the indicators of fluency, flexibility, originality, and elaboration. In this study, creative thinking was analyzed in depth and in context by considering students' written responses, oral explanations, strategies used, forms of representation chosen, and the reasons underlying their decisions when solving data handling problems. The analysis was not intended merely to classify students according to whether their answers were right or wrong but to describe the characteristics of the creative thinking processes of students with high, medium, and low levels of mathematical understanding. This approach is expected to reveal students' potential, difficulties, and learning needs in a more meaningful way, providing a basis for designing mathematics instruction that creates room for exploring diverse ideas and solution strategies.

Method

Research Type and Design

This study employed a qualitative descriptive approach. This approach was chosen because the study focused on understanding and describing in depth the characteristics of students' creative thinking when solving mathematical problems on data handling. The study was not intended to test the effect of an instructional model, measure statistical relationships between abilities, or generalize to the entire population of elementary school students. Instead, it sought to uncover students' thinking processes through their written responses, solution strategies, oral explanations, and the reasons underlying their decisions while solving problems. In qualitative research, the primary data consist of words, descriptions, actions, and artifacts of participants' work, which are interpreted in light of the research context. Accordingly, the researcher acted as the key instrument, designing the study, collecting data, conducting interviews, organizing data, analyzing participants' responses, and developing interpretations and conclusions. Non-human instruments, namely a mathematical understanding test, a data handling problem-solving test, and a semi-structured interview guide, were used to help the researcher obtain systematic and in-depth data. The study was carried out in several stages: (1) identifying prospective participants; (2) measuring mathematical understanding of data handling; (3) grouping prospective participants into high, medium, and low mathematical understanding categories; (4) purposively selecting three participants; (5) administering the data handling problem-solving test; (6) conducting semi-structured interviews based on participants' written responses; (7) method triangulation; and (8) analysis and conclusion drawing. The analysis focused on four indicators of creative thinking: fluency, flexibility, originality, and elaboration.

Participants

The participants were three sixth-grade students at UPT SD Negeri 099 Masamba, each representing a high, medium, or low level of mathematical understanding of data handling. To

maintain confidentiality, they were coded ST (high), SS (medium), and SR (low). Participants were selected purposively, that is, deliberately on the basis of criteria relevant to the research objectives rather than through random sampling. Consistent with qualitative descriptive research, the three participants were not intended to represent student proportions statistically. Rather, they were chosen to allow in-depth analysis of how creative thinking characteristics vary across levels of mathematical understanding. The selection proceeded as follows. All sixth-grade students at the school were first listed as prospective participants. Each of them individually completed a mathematical understanding test on data handling. Their answers were scored using a scoring rubric, and the students were grouped into high, medium, and low categories based on their scores. From each category, the researcher selected one student who met the research criteria and whose responses could be explored in depth through interviews. The three selected participants then completed the data handling problem-solving test and took part in semi-structured interviews.

Research Instruments

The research instruments consisted of a primary instrument and supporting instruments. The researcher was the primary instrument, while the supporting instruments comprised (1) a mathematical understanding test on data handling; (2) a data handling problem-solving test; (3) a semi-structured interview guide; and (4) documentation sheets and field notes.

Mathematical Understanding Test

The mathematical understanding test was used to obtain preliminary information on students' mastery of data handling and as the basis for grouping prospective participants into high, medium, and low categories. The test was administered individually to all sixth-grade students before participant selection. The test items were developed based on the scope of the Grade 6 data handling content, including the ability to read tables and charts, interpret data, compare data, identify relevant information, and draw simple conclusions from data.

Data Handling Problem-Solving Test

The data handling problem-solving test served as the primary data source for analyzing students' creative thinking characteristics. The instrument consisted of [two contextual, non-routine essay problems on data handling; Problem 1 comprised five sub-items (1a–1e)]. The problems were designed to allow students to use more than one strategy, choose appropriate forms of representation, develop solution steps, and justify their chosen solutions. Each participant completed the test individually within 40 minutes. Students' written answers were analyzed using four indicators of creative thinking. Fluency refers to the ability to generate several relevant ideas, possible answers, or alternative solutions. Flexibility refers to the ability to use, switch between, or compare different strategies and representations. Originality refers to the ability to produce ideas or strategies that are relatively uncommon yet mathematically correct and relevant. Elaboration refers to the ability to develop ideas or solutions through detailed steps, justifications, explanations, checking, or refinement. In this study, originality was understood as relative novelty. A response was judged original if its solution or strategy departed from commonly used routine procedures, or from the dominant approach in participants' answers, while remaining consistent with mathematical concepts and the demands of the problem. Originality was therefore assessed not merely on whether an answer differed from others but also on its accuracy, relevance, and supporting mathematical reasoning.

Semi-Structured Interview Guide

The interview guide was used to explore creative thinking processes that are not always visible in written answers. Interviews were conducted after participants had completed the problem-solving test. The interviews were semi-structured; that is, the researcher prepared core questions but could ask follow-up questions in response to each participant's answers. The interview questions were designed to explore (1) how participants understood the given information and what the problem asked; (2) participants' reasons for choosing a particular strategy or form of representation; (3) alternative ideas or strategies they had considered; (4) their reasons for not using or for changing a strategy; (5) detailed explanations of the solution steps they wrote; and (6) how participants re-checked the accuracy of their answers.

Instrument Validation

Before use, the mathematical understanding test, the data handling problem-solving test, and the interview guide were validated by experts. Validators could include mathematics education lecturers, educational evaluation lecturers, or sixth-grade teachers familiar with data handling content and the developmental characteristics of elementary school students. Instrument validation covered content validity, construct validity, and language. Content validity was assessed to determine the alignment of the problems with Grade 6 data handling competencies and content, their alignment with the research objectives, and their adequacy in eliciting students' mathematical understanding or creative thinking. Construct validity was assessed to determine whether the problems were genuinely mathematical problems requiring reasoning, contained no ambiguous information, provided sufficient information, and allowed more than one solution strategy. Language validation was conducted to ensure that the sentences, terms, contexts, numbers, symbols, and instructions in the problems could be understood by sixth-grade students.

Data Collection

Data were collected in stages to obtain in-depth (Figure 1), systematic, and complementary evidence. The researcher first obtained research permission from the relevant authority and from UPT SD Negeri 099 Masamba. The purpose, procedures, benefits, and confidentiality of the study were then explained to the principal, the sixth-grade teacher, prospective participants, and their parents or guardians. After that, all sixth-grade students completed the mathematical understanding test, and three participants were selected as described in the previous subsection. Each of the three participants completed the data handling problem-solving test individually in a quiet, undisturbed setting. While they worked, the researcher recorded noteworthy events in field notes and gave no assistance or solution hints. After the test, each participant took part in an individual semi-structured interview. The participant's answer sheet served as a stimulus for exploring ways of thinking, reasons for strategies, alternative solutions, and the process of checking solutions. With the consent of participants and their parents or guardians, all interviews were audio-recorded and transcribed verbatim, and each participant and response was coded to protect identity. Finally, the researcher compared the written test data, interview transcripts, and field notes to triangulate methods and to carry out an initial verification of the emerging interpretations. During the interviews, the researcher acted as an information gatherer rather than an instructor and did not provide example strategies, confirm answers, or offer corrections. Each interview began with neutral probing questions, such as asking participants to explain what they had done or why. When a participant could not proceed or gave an unclear answer, the researcher posed guiding

questions that directed attention to relevant information in the problem without supplying the solution procedure. Responses produced spontaneously were distinguished from those produced after such prompts, and this distinction was taken into account in the analysis.

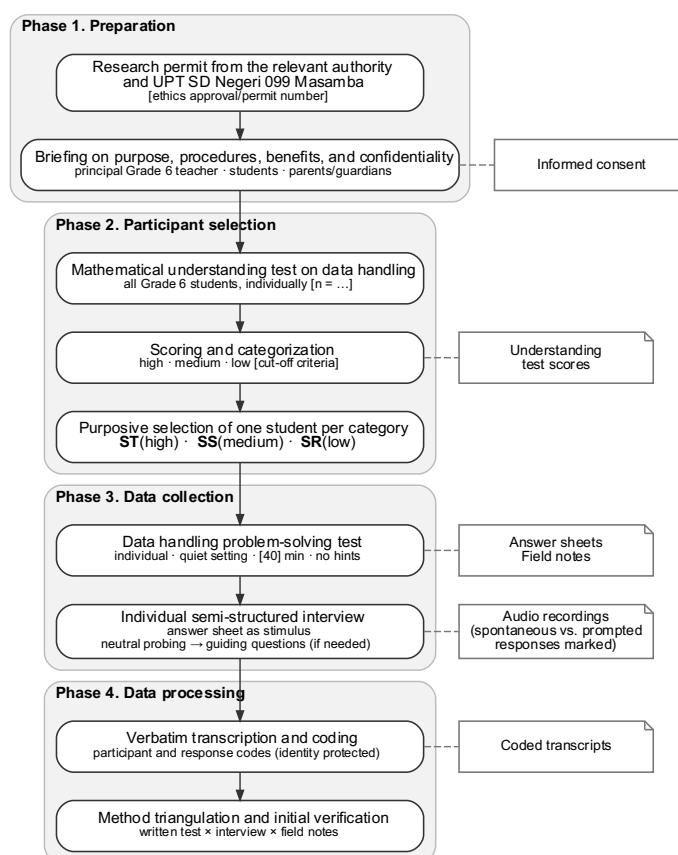


Figure 1. Data Collection Flow

Data Analysis

Data were analyzed interactively from the data collection stage through to conclusion drawing. The analysis followed the Miles, Huberman, and Saldaña model, which comprises three interrelated streams of activity: data condensation, data display, and conclusion drawing and verification.

Preparing and Organizing the Data

The researcher compiled all data, consisting of mathematical understanding test results, problem-solving test answer sheets, interview recordings, interview transcripts, and field notes. Each data item was assigned an identification code. The participant codes were ST for the student with high mathematical understanding, SS for the student with medium mathematical understanding, and SR for the student with low mathematical understanding. Examples of data coding: ST-T1-L3 denotes the written response of the high-category student, first problem, step 3; ST-W1-B12 denotes the interview with the high-category student, first interview, line 12; SS-T2-L4 denotes the written response of the medium-category student, second problem, step 4; and SR-W1-B8 denotes the interview with the low-category student, first interview, line 8.

Data Condensation

Data condensation was carried out by selecting portions of the written answers, interview transcripts, and field notes that were relevant to the research objectives. The relevant data were classified according to students' understanding of the problem, the information used, the forms of representation chosen, the solution strategies used, the alternative strategies or solutions generated, the reasons for choosing and changing strategies, the detail of explanations or solution development, the process of checking and evaluating answers, and the indicators of fluency, flexibility, originality, and elaboration. Data that were not relevant to the research objectives were not used in the main analysis but were retained as part of the study's audit trail.

Coding Based on Indicators

The condensed data were assigned initial codes based on the creative thinking indicators: FL for fluency, FX for flexibility, OR for originality, EL for elaboration, PM for problem understanding, and EV for solution evaluation. Fluency was marked by the emergence of more than one relevant idea, answer, or alternative. Flexibility was marked by the use, comparison, or change of strategies and representations. Originality was marked by the emergence of relatively uncommon yet correct and relevant ideas or strategies. Elaboration was marked by detailed steps, justifications, explanations, checking, or refinement of solutions. Problem understanding was marked by the ability to identify the given information, the question, and the relevant information. Solution evaluation was marked by efforts to re-check procedures, results, or the consistency of answers with the problem context. Coding was performed by comparing written responses and oral explanations. If a student wrote only one strategy on the answer sheet but was able to explain in the interview that he or she had considered another strategy and gave reasons for not using it, this information was still recorded as evidence of flexibility, provided that the explanation was consistent and relevant.

Data Display

Data were displayed in the form of narrative descriptions, matrix tables, excerpts of written responses, and interview excerpts. The data display aimed to portray each participant's creative thinking characteristics in depth and then to compare tendencies across ST, SS, and SR. The data display matrix could include columns for participant, fluency, flexibility, originality, elaboration, and test and interview evidence. This display was not intended to assign final quantitative scores to the three participants but to present evidence of creative thinking processes narratively and in context. Test and interview results were presented in an integrated manner so that readers could see the basis of the researcher's interpretations.

Conclusion Drawing and Verification

Conclusions were drawn by interpreting each participant's creative thinking patterns based on the coded and displayed evidence. The conclusions were then verified iteratively by returning to the answer sheets, recordings, interview transcripts, field notes, and the results of method triangulation. The final outcome of the analysis was a description of the creative thinking characteristics of students with high, medium, and low mathematical understanding in solving data handling problems. The conclusions of this study are not intended as statistical generalizations; rather, they explain the tendencies in characteristics that emerged among the three participants within the research context.

Trustworthiness

The trustworthiness of the data was maintained through four criteria: credibility, transferability, dependability, and confirmability. These strategies were used to ensure that the research process and findings were traceable, supported by data, and credible. Credibility was maintained through method triangulation, in-depth interviews, limited member checking, and peer debriefing. Method triangulation was conducted by comparing the data from the data handling problem-solving test, participants' explanations in the interviews, and field notes. The researcher's interpretations were based not only on written answers but also on students' explanations of their reasons for using particular strategies and representations. Member checking was conducted in a limited manner by asking participants to reconfirm a summary of their explanations or the intended meaning of their answers at the end of the interview. Because the participants were elementary school students, member checking was conducted using simple language and did not require students to evaluate the researcher's overall theoretical interpretation. Peer debriefing was conducted by asking the supervisor, mathematics education experts, or fellow researchers to review the consistency among the raw data, codes, categories, and preliminary conclusions. This debriefing was used to reduce overly subjective interpretations and to clarify the boundary between empirical data and the researcher's inferences.

Transferability

Transferability was addressed by providing a detailed description of the research context. The description includes the characteristics of the research site, grade level, data handling content, participant selection process, types of problems used, test and interview procedures, and evidence from participants' responses. Such thick description enables readers or other researchers to judge for themselves the applicability of the findings to different contexts. Transferability is not interpreted as a claim that the findings from three students apply to all sixth-grade students. Rather, transferability lies in the completeness of the contextual description and the clarity of the analytical process, which allow readers to consider the relevance of the findings to similar learning situations.

Dependability

Dependability was maintained by constructing an audit trail. The researcher systematically documented the entire research process, from proposal preparation, instrument development and validation, test administration, participant selection, interview recording and transcription, and coding, to category revisions and conclusion drawing. The researcher also retained supporting documents, such as instruments before and after revision, expert validation sheets, test results, interview transcripts, coding tables, and analytic notes. This documentation enables supervisors or other reviewers to trace the consistency among the research procedures, the data collected, the analysis, and the findings.

Confirmability

Confirmability was maintained by ensuring that the interpretations and conclusions were based on empirical evidence traceable to the answer sheets, interview excerpts, and field notes. Every claim regarding the creative thinking indicators needed to be supported by clear evidence, such as quotations of students' statements, written work, or comparisons of the strategies used. The researcher also practiced reflexivity by recording assumptions, expectations, and potential biases throughout the study. The researcher recognized that students who speak more fluently do not necessarily have higher creative thinking ability than students who are less verbally

expressive. Therefore, interpretations were based not merely on verbal fluency but on the consistency among written responses, oral explanations, and the evidence of solution strategies demonstrated by the students.

Results

This section reports the findings from the Creative Thinking Ability Test (CTAT) and the follow-up interviews with the three participants: ST (high mathematical understanding), SS (medium), and SR (low). The test problem presented a school canteen's sales of three foods over five days, Monday to Friday: *nasi kuning* (yellow rice; 20, 18, 25, 22, and 30 portions), *bakso* (meatball soup; 15, 17, 20, 18, and 25 portions), and bread (10, 12, 15, 14, and 20 portions). It comprised five sub-items (Table 1). For each participant, written work and interview data are reported together and organized by the four indicators of creative thinking. Responses that emerged only after guiding questions are distinguished from spontaneous ones. Method triangulation for all fifteen participant–item combinations is summarized in Table 5, and the section closes with a cross-case comparison (Table 6).

Table 1. Sub-items of the data handling problem and the indicators they primarily elicited

Item	Task	Indicator(s) primarily elicited
1a	Process and present the sales data	Fluency (alternative representations)
1b	Decide which food should be supplied in larger quantities	Fluency, elaboration
1c	Show more than one way to determine the most popular food	Flexibility
1d	Plan the quantity of each food for the following week	Originality
1e	Identify factors other than sales figures that should be considered	Originality, elaboration

High-Understanding Participant (ST)

ST answered every sub-item correctly and showed all four indicators. Most of them emerged without prompting (Figure 2; Table 2).

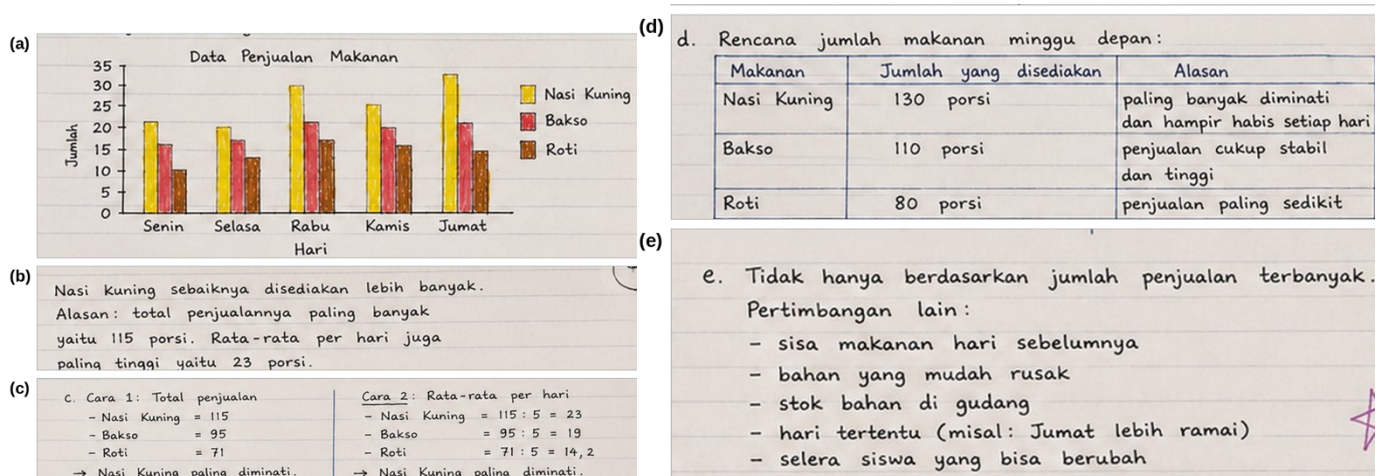


Figure 2. Written work of ST on sub-items 1a–1e (panels a–e)

Fluency. In 1a, ST converted the sales table into a bar chart (Figure 2a). In the interview, ST named two further representations, a line chart “to see how sales changed from Monday to Friday” and a table of totals. ST also explained what each representation offers: “With a table, the numbers are more complete and easy to use for calculating. With a bar chart, the differences show up faster.” In 1b, ST supported the choice of *nasi kuning* with two quantitative bases, total sales (115 portions) and mean daily sales (23 portions) (Figure 2b), and interpreted the mean correctly: “It doesn’t mean that exactly 23 portions were sold every day, but the average value is 23.”

Flexibility. In 1c, ST compared the foods by both totals and means (Figure 2c) and explained why the two methods give the same ranking: “All the totals are divided by five, so the order doesn’t change.” The researcher then posed a hypothetical case in which *bakso* was recorded for only three days. ST switched to the mean and gave the reason: with unequal periods, “the food recorded for more days could look higher even though it’s not necessarily more popular.” ST also proposed a third approach, identifying which food had the highest sales on each day. ST’s flexibility therefore went beyond using several procedures. It extended to judging which procedure suited the structure of the data.

Originality. In 1d, ST planned 130 portions of *nasi kuning*, 110 of *bakso*, and 80 of bread, each above the previous week’s totals (Figure 2d). ST distributed the *nasi kuning* unevenly across the week, for example 25 portions from Monday to Thursday and 30 on Friday, “because the data show that Friday had the highest sales.” In 1e, ST listed five considerations that were absent from the data: leftover food, perishable ingredients, ingredient stock, busier days, and changing student preferences (Figure 2e). In the interview, ST linked each one to a concrete supply decision.

Elaboration. ST explained calculation steps and the meaning of results throughout. The clearest evidence of evaluation came from 1d. There, ST had justified the plan by writing that *nasi kuning* was “almost sold out every day.” When asked for the basis of this claim, ST acknowledged that the table showed only quantities sold, not initial stock or leftovers. ST then revised the claim to “the food with the highest sales each day.” ST was the only participant who corrected an unsupported claim of their own.

Table 2. Selected interview excerpts: ST

Item	Exchange	Code
1a	R: Besides a bar chart, could you present the data in another form? ST: Yes, sir. The data could be made into a line chart to see how sales changed from Monday to Friday. It could also be made into a table of total sales for each food.	FL1
1c	R: What if <i>nasi kuning</i> was recorded for five days but <i>bakso</i> for only three days? Would the total still be appropriate for comparing them? ST: If the number of days is different, it’s better to use the average, sir. If you use the total, the food recorded for more days could look higher even though it’s not necessarily more popular.	FX2–EL3
1c	R: Besides the total and the average, is there a third way to determine the most popular food? ST: Yes. You can look at which food most often had the highest sales each day. From Monday to Friday, <i>nasi kuning</i> always sold the most.	FL2–FX1
1d	R: Will you divide that amount of food equally across the days? ST: It doesn’t have to be equal, sir. I would supply less on regular days and more on Friday, because the data show that Friday had the highest sales.	FX2–OR3

Item	Exchange	Code
1e	R: You also wrote perishable ingredients. What does that have to do with the sales plan? ST: If the ingredients spoil quickly, the canteen shouldn't make too much. Even if sales are high, the amount has to be adjusted so the ingredients and food don't go stale.	OR2-EL2

Medium-Understanding Participant (SS)

SS also answered every sub-item correctly and showed all four indicators. However, SS tended to settle on the most familiar procedure, and the solutions stayed close to the given data (Figure 3; Table 3).

(a) *Kemampuan Sedang*

a. Tabel total penjualan

Makanan	Senin	Selasa	Rabu	Kamis	Jumat	Total
Nasi Kuning	20	18	25	22	30	115
Bakso	15	17	20	18	25	95
Roti	10	12	15	14	20	71

(b) b. Nasi Kuning. karena totalnya paling banyak (115).

(c) c. Cara 1: lihat total ($115 > 95 > 71$)
 Cara 2: rata-rata per hari
 Nasi Kuning = 23, Bakso = 19, Roti = 14,2
 jadi nasi kuning paling diminati.

(d) d. Rencana minggu depan:
 - Nasi Kuning 120 porsi
 - Bakso 100 porsi
 - Roti 80 porsi
 Alasan: biar cukup dan tidak tersisa banyak.

(e) e. Tidak. Selain jumlah penjualan, saya juga memikirkan bahan, uang, dan banyaknya siswa yang beli. ^ ^

Figure 3. Written work of SS on sub-items 1a–1e (panels a–e)

Fluency. In 1a, SS reproduced the table and added a total column (115, 95, and 71 portions; Figure 3a). This was a modest but functional transformation: “the food that sold the most can be seen right away from the column on the far right.” SS named a bar chart and a line chart as alternatives but kept the table “because it’s easier for me to use.” Alternatives were thus generated but not enacted. In 1b, SS based the choice of *nasi kuning* on a single criterion, its total (Figure 3b), and explained the summation and comparison correctly.

Flexibility. In 1c, SS used both totals and means (23, 19, and 14.2 portions; Figure 3c) and interpreted the mean of 23 as “roughly 23 portions ... every day.” When asked for other approaches, SS mentioned comparing daily sales but added, “I feel more sure using the total and the average.” SS therefore had a repertoire of strategies, but confidence in familiar procedures limited further exploration.

Originality. In 1d, SS planned 120 portions of *nasi kuning*, 100 of *bakso*, and 80 of bread by adding a margin to each previous total (Figure 3d): “*Nasi kuning* was 115 before, and I increased it to 120.” The rationale balanced sufficiency against waste: “not too much in case some don’t get sold.” SS initially intended to distribute the food “almost equally” across the week. During the interview, SS suggested supplying more on Friday, so this adjustment

emerged in dialogue rather than in the written work. In 1e, SS cited ingredients, capital, and the number of buyers (Figure 3e) and linked them to perishability and the risk of loss.

Elaboration. SS's explanations of procedures and of the meaning of results were adequate. At the end of the interview, SS synthesized a conclusion: *nasi kuning* was the most popular food by both total and mean, its supply should rise moderately, and more food could be supplied on Fridays. SS reviewed the answers in this way but did not revise any of them.

Table 3. Selected interview excerpts: SS

Item	Exchange	Code
1a	R: Besides a table of totals, could this data be presented in another form? SS: It could be made into a bar chart, sir. Maybe also a line chart, but it's easier for me to use a table.	FL1
1c	R: Do you know any other way besides the total and the average? SS: You could also look at which food sold the most each day. <i>Nasi kuning</i> was always more than <i>bakso</i> and bread. But I feel more sure using the total and the average.	FL2–FX1
1d	R: Why did you increase <i>nasi kuning</i> only to 120 portions? SS: Because I only wanted to add a little so there's enough, but not too much in case some don't get sold.	OR3–EL2
1d	R: Will the food be divided equally across the days? SS: At first I thought it would be divided almost equally, sir. But because Friday is busier, maybe more should be supplied on Friday.	FX2–OR3
1e	R: Why do capital or money need to be considered? SS: Because you need money to buy the ingredients, sir. If you make too much and it doesn't all sell, the canteen could lose money.	OR2–EL2

Low-Understanding Participant (SR)

SR reached the correct conclusion in 1b. However, every indicator emerged only partially, and several emerged only after guiding questions (Figure 4; Table 4).

(a) *Kemampuan Rendah*

a. Tabel penjualan

Makanan	Senin	Selasa	Rabu	Kamis	Jumat
Nasi Kuning	20	18	25	22	30
Bakso	15	17	20	18	25
Roti	10	12	15	14	20

(b) b. Nasi Kuning, karena paling banyak.

(c) c. Cara 1: Nasi Kuning banyak.
Cara 2: tiap hari juga banyak.

(d) d. Nasi Kuning 120, Bakso 100, Roti 80. ~~Roti 80~~
supaya cukup.

(e) e. Tidak tahu, yang penting banyak yang beli.

Figure 4. Written work of SR on sub-items 1a–1e (panels a–e)

Fluency. In 1a, SR copied the table without modification (Figure 4a). When asked, SR mentioned a bar chart as an alternative but did not draw one: “I don't really know how to draw it correctly. I was afraid the bars would be wrong.” The alternative was generated verbally, but limited procedural knowledge prevented SR from enacting it. In 1b, SR chose *nasi kuning*

“because it’s the most” (Figure 4b). The interview revealed that this judgment rested on a single salient value, 30 portions on Friday. SR computed the total of 115 portions only after being asked to add up the five days.

Flexibility. This was SR’s weakest indicator. The two “ways” SR wrote for 1c (“*nasi kuning* is a lot” and “a lot every day too”; Figure 4c) restated the same observation, and SR acknowledged, “It’s almost the same, sir.” SR thought the total “might work” but said, “I’m still confused about how to calculate the average.” SR identified the divisor (five) only after the question pointed to the number of days. Indicator FX1 was therefore not met.

Originality. In 1d, SR wrote the plan 120 portions of *nasi kuning*, 100 of *bakso*, and 80 of bread, with the reason “so there’s enough” (Figure 4d). In the interview, SR stated, “I just estimated, sir,” and admitted not checking the plan against the data. Only when reminded of the previous total of 115 did SR justify 120 as a margin for extra buyers. In 1e, SR wrote, “don’t know, what matters is lots of people buy” (Figure 4e). After probing, SR named the cost of ingredients and leftover food as sources of possible loss.

Elaboration. SR’s explanations were brief and seldom connected decisions to the full data set. Nevertheless, at the end of the interview SR recognized that the two ways in 1c were “almost the same” and wanted to add the total sales. This shows emerging reflective awareness, although it was prompted.

Table 4. Selected interview excerpts: SR

Item	Exchange	Code
1a	R: Why didn’t you make a bar chart? SR: I don’t really know how to draw it correctly. I was afraid the bars would be wrong.	FL1 (limited)
1b	R: Which number did you look at to say that <i>nasi kuning</i> is the most? SR: I saw that on Friday <i>nasi kuning</i> was 30. That’s the biggest.	EL1 (limited)
1c	R: You also wrote a second way. How is it different from the first way? SR: It’s almost the same, sir. In the second way I looked from Monday to Friday.	FX1 (not met)
1d	R: Where did you get those amounts from? SR: I just estimated, sir. <i>Nasi kuning</i> is the most, so I gave it 120. <i>Bakso</i> 100 and bread 80.	OR3 (limited)
1e	R: Besides the number of buyers, is there anything else the canteen owner needs to pay attention to? SR: Maybe the money to buy ingredients and the food that’s left over, sir. If a lot is left over, there could be a loss.	OR2 (limited)

Method Triangulation

For all fifteen participant–item combinations, the written responses and the interview data were consistent: no participant contradicted their written answer (Table 5). The interviews nonetheless played different roles across participants. For ST, they mainly confirmed and extended what was already on paper, and in one case (1d) they prompted a self-correction. For SS, they revealed adjustments that the written work did not contain (1d). For SR, they showed what SR could do with support rather than independently: in 1b–1e, the more complete reasoning appeared only after guiding questions.

Table 5. Method triangulation of written responses and interview data

Participant – item	Written response (CTAT)	Interview evidence	Result
ST-1a	Bar chart of daily sales	Justified choice; named line chart and table of totals	Consistent
ST-1b	<i>nasi kuning</i> ; total 115, mean 23	Explained summation; interpreted mean correctly	Consistent
ST-1c	Totals and means	Justified equal rankings; chose mean for unequal periods; third approach	Consistent; extended
ST-1d	130/110/80 with reasons	Uneven daily allocation; revised unsupported claim	Consistent; self-corrected
ST-1e	Five contextual factors	Linked each factor to supply decisions	Consistent
SS-1a	Table with total column	Named bar and line charts; preferred table	Consistent
SS-1b	<i>nasi kuning</i> ; total 115	Explained summation and comparison	Consistent
SS-1c	Totals and means	Interpreted mean; named daily comparison; preferred familiar methods	Consistent
SS-1d	120/100/80 with reason	Margin-based rationale; Friday adjustment emerged	Consistent; extended
SS-1e	Ingredients, money, buyers	Linked to perishability and loss; final synthesis	Consistent
SR-1a	Copied table	Named bar chart; could not draw it	Consistent; limited
SR-1b	<i>nasi kuning</i> “because it’s the most”	Based on Friday value; total 115 after prompting	Consistent; prompted
SR-1c	Two near-identical “ways”	Acknowledged similarity; divisor after prompting	Consistent; FX1 not met
SR-1d	120/100/80 “so there’s enough”	Estimated; justified margin after prompting	Consistent; prompted
SR-1e	“Don’t know, what matters is lots of people buy”	Capital and leftovers after probing; reflection	Consistent; prompted

Cross-Case Comparison

All three participants identified *nasi kuning* as the most popular food. Their creative thinking therefore differed not in the correctness of the final answer but in four respects (Table 6). The first was whether alternatives were enacted or only named: ST enacted them, SS named them but kept the familiar one, and SR named one but could not produce it. The second was whether multiple strategies were genuinely distinct and chosen according to the situation: ST’s were, SS’s were distinct but bounded by preference, and SR’s were not distinct. The third was whether new plans were grounded in data patterns: ST used a pattern-based daily allocation, SS added a uniform margin, and SR estimated and grounded the plan only after prompting. The fourth was whether answers were checked and revised: ST revised an unsupported claim, SS synthesized without revising, and SR recognized a weakness only when prompted.

Table 6. Cross-case comparison of creative thinking indicators

Indicator	ST (high)	SS (medium)	SR (low)
Fluency	Generated and enacted several representations and bases for decisions	Generated alternatives but enacted the most familiar	Named an alternative verbally; could not enact it

Indicator	ST (high)	SS (medium)	SR (low)
Flexibility	Used totals, means, and daily comparison; chose strategy according to data structure	Used totals and means; limited further exploration	Two “ways” not distinct; mean only after prompting
Originality	Pattern-based daily allocation; five contextual factors	Uniform margin on previous totals; three contextual factors	Estimated plan; contextual factors after probing
Elaboration	Detailed justification; revised an unsupported claim	Adequate explanations; final synthesis without revision	Brief explanations; reflection after prompting
Overall	Strong and largely independent	Present but not yet consistent	Emerging and support-dependent

Across the three cases, the completeness and independence of the four indicators followed the participants’ levels of mathematical understanding. Given the descriptive design and the three participants, this pattern is reported as a within-case tendency rather than as evidence of a causal or generalizable relationship.

Discussion

All three participants could name more than one way of presenting the data, so fluency at the level of ideas was present in every case. The difference lay in whether these ideas were put into practice. ST built a bar chart and explained what a line chart or a table of totals would show. SS named the same alternatives but kept a table “because it’s easier.” SR mentioned a bar chart but could not draw one. Generating ideas is therefore only the first stage of creative work. More developed creativity requires the knowledge and willingness to develop and test those ideas (Ferdiani & Harianto, 2024; Granberg & Olsson, 2015; Rachman & Rosnawati, 2021). For SS, the barrier was procedural ease, and for SR it was procedural knowledge. This distinction matters for assessment. A written test would have credited SS and SR with little fluency, whereas the interviews showed that alternatives were available but not used. Students’ written work therefore tends to underestimate their fluency and should be complemented by oral explanation, particularly at the elementary level (Schulz, 2023).

The most discriminating evidence of flexibility came from a follow-up interview probe. When the researcher proposed that one food had been recorded for fewer days, ST abandoned totals in favor of means and explained that totals would favor the food recorded for longer. Flexibility in this sense is not the number of procedures a student can execute. It is the judgment of which procedure fits the structure of the data, the kind of cognitive flexibility that frees students from a single algorithm (Schulz, 2023). SS executed both totals and means correctly and interpreted the mean in context, but preferred familiar methods when invited to look further. SR wrote two “ways” that restated the same observation. This shows that producing more than one answer is not evidence of flexibility when the underlying strategy is unchanged.

SR’s case also suggests why mathematical understanding and flexibility are linked. SR knew that a mean involves summing and dividing but could not identify the divisor until the number of days was pointed out. The knowledge was available but not organized well enough to be activated spontaneously as an alternative strategy. This is consistent with evidence that conceptual understanding is associated with creative thinking because it widens the set of strategies students can draw on (Chorney et al., 2024; Kafetzopoulos & Psycharis, 2022). Conceptual understanding thus appears to act as a precondition for flexibility, not as a separate competence.

In data handling tasks, originality did not take the form of unusual answers. It appeared as new decisions grounded in the data. ST's plan allocated more food to Friday because the data showed a Friday peak. SS added a uniform margin to each previous total. SR first estimated the quantities and grounded them in the data only after prompting. All three plans were reasonable, but they rest on different degrees of data-based reasoning. This supports a view of originality as relative novelty that is valuable only when it remains mathematically justified (Confrey & Shah, 2021; R. S. Jones & Rosenberg, 2022; Utami et al., 2024). Contextual considerations followed the same gradient: ST offered five factors spontaneously, SS offered three, and SR offered two only after probing. Open, contextual problems therefore give students room to connect mathematical results with real-world consequences such as waste, perishability, and capital (S. R. Jones, 2019; Leiss et al., 2019).

All participants could explain their calculations when asked. The clearest difference concerned whether they evaluated their own claims. ST recognized that the claim "almost sold out every day" could not be supported, because the table reported sales rather than stock, and revised it. SS synthesized the answers at the end of the interview but did not revise any of them. SR recognized that the two "ways" were almost the same only when prompted. Evaluating and revising ideas is an integral part of the creative process, not an addition to it, because it determines whether generated ideas are feasible and accurate (Lithner, 2017; Luria et al., 2017). Recognizing the limits of one's own reasoning also reflects metacognitive regulation, which has been linked to stronger problem solving (Abdul-Rahman, 2020). SR's prompted recognition may be an early form of this regulation.

Taken together, the cases show a gradation: the more complete the participant's mathematical understanding, the more complete and independent the four indicators. This pattern does not mean that students with lower understanding lack creative potential. With targeted questions, SR calculated totals, recognized the basis for the mean, considered capital and leftovers, and identified a weakness in an earlier strategy. Creativity therefore appears responsive to support. Scaffolding that withholds procedures but directs attention to relevant information may help it develop (Rachman & Rosnawati, 2021; Singer et al., 2017). At the same time, responses elicited by prompts reflect what a student can do with support, not what the student does independently. The two should be distinguished in research and in classroom assessment.

These findings suggest concrete design principles for data handling instruction. Students could be asked to present the same data in two forms and explain what each reveals. They could compare two solution methods and decide which is fairer when the conditions change. They could also justify a decision with data and check whether each claim is actually supported by the information given. For students like SS, the aim is to widen exploration beyond the most familiar method. For students like SR, the aim is to build the procedural and conceptual base that allows alternatives to be enacted, through graded prompts that are gradually withdrawn. Non-routine, contextual, and open-ended problems are well suited to these purposes (Öçal et al., 2020). They also show that data handling is not merely reading tables and computing means. It is a context in which representation, reasoning, and decision making can be developed together.

Conclusion

This study described the creative thinking of three sixth-grade students with high, medium, and low mathematical understanding as they solved data handling problems. Although the three students reached the same conclusion on the central question, they differed in whether alternatives were enacted or only named, whether strategies were chosen according to the

structure of the data, whether new plans were grounded in data patterns, and whether claims were evaluated and revised. The high-understanding student showed all four indicators strongly and largely independently. The medium-understanding student showed all four indicators but tended to rely on familiar procedures and solutions close to the given data. The low-understanding student showed emerging fluency, originality, and reflection, much of it only after guiding questions, while flexibility was not met. The main contribution of this study is to show that creative thinking in elementary mathematics is better captured by combining written work and interviews. Written responses alone underestimated what two of the three students could generate, and interviews revealed whether ideas were produced independently or with support. Practically, data handling instruction should ask students to use more than one representation, compare strategies under changing conditions, justify decisions with data, and check their own claims. Students with medium and low understanding should be supported by guiding questions that encourage exploration without supplying procedures. These conclusions are limited to three students in one school and one data handling task. They describe tendencies within this context and do not establish causal or generalizable relationships. Future research should involve more participants and schools, other mathematical topics, and designs that examine how conceptual understanding, metacognition, and open-ended instruction jointly support fluency, flexibility, originality, and elaboration.

Conflict of Interest

The authors declare no conflict of interest.

Auhor Contributions

I.N. conceptualized the research idea presented and collected the data. The other three authors (M.I., T. and P.) actively contributed to the development of the theory, methodology, data organization and analysis, discussion of the results, and approval of the final version of the work. All authors confirm that they have read and approved the final version of this manuscript. The percentage contributions for the conceptualization, drafting, and revision of this paper are as follows: I.N.: 40%, M.I.: 20%, T.: 20%, and P.: 20%.

Data Availability Statement

The authors state that the data supporting the findings of this study will be made available by the corresponding author, I.N., upon reasonable request.

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