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Investigating the fragmentation of students' creative thinking structures in realistic mathematics education: A qualitative case study of junior high school students

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Abstract

The fragmentation of creative thinking structures is a phenomenon requiring serious attention in Realistic Mathematics Education (RME). However, studies that systematically explore how students' creative thinking fragmentation manifests across RME learning stages remain limited. This study aims to examine the types and forms of students' creative thinking fragmentation across four RME activities: situation, model of situation, model for knowledge, and formal mathematics. This research employs a qualitative case study design. Participants consisted of 18 seventh-grade students from an Integrated Islamic Junior High School in Sukoharjo Regency. Data were collected through non-routine mathematical problem tests and in-depth interviews, with validity ensured through source triangulation. Data analysis involved thematic coding based on a fragmentation typology aligned with RME stages, followed by data reduction, display, and conclusion drawing. The results identified five types of fragmentation: (1) less-strict fragmentation at the situation stage, (2) translational fragmentation (text to symbol) at the situation stage, (3) pseudo-false fragmentation at the model of situation stage, (4) translational fragmentation (text to image) at the model for knowledge stage, and (5) pseudo-true fragmentation at the formal mathematics stage. These findings extend theoretical perspectives and inform instructional design and scaffolding strategies in RME classrooms.

Keywords: creative thinking; fragmentation; realistic mathematics education; thinking structure

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Introduction

In the context of 21st-century education, mathematics learning is required to transcend mere procedural mastery and also foster the development of higher-order thinking skills, enabling students to tackle complex and contextual problems (Ulker & Celik, 2025). One approach aligned with this demand is Realistic Mathematics Education (RME), an approach to mathematics learning that leverages realistic contexts as the starting point for students to build and reconstruct their mathematical understanding (Setyaningsih et al., 2019). RME is designed to bridge the abstract nature of mathematical objects with students' concrete experiences through a gradual process of modeling and concept reinvention (Solomon et al., 2021). In its implementation, RME learning activities unfold through four levels: the situational context, model of situation, model for knowledge, and formal mathematics (Fredriksen, 2021; Gravemeijer, 1994). The progression between these levels requires students to interpret contexts, develop and revise representations, and coordinate various mathematical ideas, thus inherently requiring the engagement of higher-order thinking processes (Sutarni et al., 2024). Within this framework, creative thinking is regarded as the highest form of cognitive ability, playing a crucial role in supporting students' success in navigating the RME activity trajectory (Krulik et al., 2003).

Creative thinking in mathematics learning is understood not merely as the ability to generate diverse or original answers, but as a cognitive process involving the exploration of ideas, restructuring of understanding, and flexible decision-making when faced with problem-solving situations (Bicer et al., 2020; Kholid et al., 2024). This process is dynamic and not always linear, as students need to move between representations, connect different pieces of information, and adjust their strategies as their understanding of the problem evolves (Tolkamp et al., 2025). In a learning context that demands modeling and abstraction, such as RME, creative thinking becomes a vital prerequisite for students to navigate the learning trajectory meaningfully (Avcı & Durak, 2023). However, the complexity of this process also presents the potential for a lack of integration within the thinking structure, when the generated ideas are not coherently organized or the connections between representations are not fully formed. This lack of integration is understood by Subanji (2015) as fragmentation of the thinking structure.

Fragmentation of the thinking structure is a condition where the connections between ideas, representations, or strategies in the problem-solving process are not fully formed, resulting in reasoning that is partial or inconsistent (Subanji, 2015). Furthermore, Wibawa et al. (2017) view fragmentation not merely as a thinking error, but as a disruption in the cognitive structure that emerges when individuals face the demands of complex problem-solving. Based on the theoretical characteristics of creative thinking and the general concept of thinking fragmentation, this study conceptualizes fragmentation as the fragmentation of students' creative thinking structure, referring to disruptions in the integration of ideas, representations, and strategies during processes of idea exploration, representational transformation, and cognitive restructuring in mathematical problem solving.

In the context of mathematics education, such fragmentation can occur when students are able to access some concepts or strategies but fail to integrate them coherently to build a

meaningful solution (Kholid et al., 2024). This condition is highly relevant to the study of creative thinking, as the creative process demands high levels of flexibility and idea exploration, which can simultaneously increase the risk of severed connections between representations and concepts if not balanced by adequate restructuring of understanding (Preiss, 2022). Therefore, the fragmentation of the creative thinking structure is likely to emerge in the practice of realistic mathematics learning, particularly when students are confronted with complex and contextual problem-solving, and when instructional practices have not fully provided space for exploration, reflection, and the restructuring of mathematical ideas.

As an initial contextual illustration, preliminary classroom observations and informal interviews with a mathematics teacher at an Islamic Integrated Junior High School (SMP IT) in Sukoharjo Regency indicated that classroom practices have not yet optimally facilitated the exploration of students' thinking processes. Learning was dominated by an emphasis on analytical thinking through routine problems, with minimal space for innovative and flexible problem-solving strategies. Furthermore, the teacher prioritized the accuracy of the final answer over the solution process undertaken by the students. As an illustration, Figure 1 displays a student's answer that was deemed correct by the teacher despite containing a conceptual error in its reasoning. The student mistakenly identified the cylinder's radius as r = 20, which was actually the diameter, yet the answer was still marked as correct. This example illustrates how an outcome-oriented instructional focus may obscure students' underlying thinking processes and reduce opportunities to identify, reflect upon, and address fragmentation in creative thinking structures. This illustration highlights the relevance of investigating creative thinking fragmentation more systematically within the context of realistic mathematics learning.

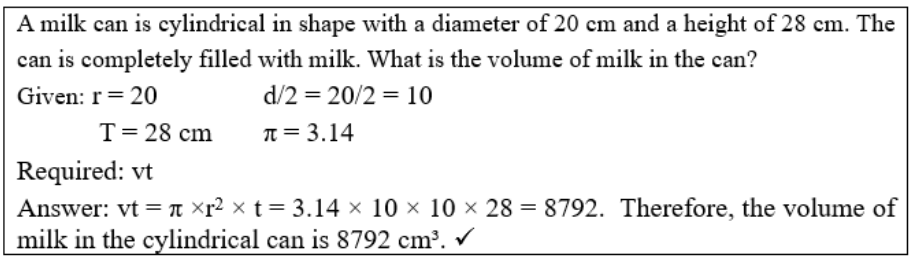

A milk can is cylindrical in shape with a diameter of 20 cm and a height of 28 cm. The can is completely filled with milk. What is the volume of milk in the can?
Given: r = 20 d/2 = 20/2 = 10
T = 28 cm π = 3.14
Required: vt
Answer: $vt = \pi \times r^2 \times t = 3.14 \times 10 \times 10 \times 28 = 8792$. Therefore, the volume of milk in the cylindrical can is 8792 cm^3. ✓

Figure 1. Student Question Answer (translated from the original student worksheet)

Several previous studies have investigated the fragmentation of students' thinking structures in mathematics education from various perspectives. These studies have examined (1) fragmentation thinking structure in general (Usodo et al., 2020; Wibawa et al., 2017; Widyaningrum et al., 2021; Wulandari et al., 2020), (2) fragmentation of pseudo thinking (Herna, 2016; Wibawa et al., 2018), (3) fragmentation of translational thinking (Wibawa, 2019), (4) fragmentation of reflective thinking (Kholid et al., 2024), and (5) fragmentation of conceptual understanding (Djannah et al., 2024). These findings consistently indicate that fragmentation is a cognitive phenomenon that impacts the quality of students' mathematical reasoning and problem-solving. Nevertheless, these studies have generally positioned fragmentation as a standalone phenomenon within a specific type of thinking, without explicitly linking it to the dynamic and multidimensional process of creative thinking. Additionally, prior research has not specifically examined how the fragmentation of the creative thinking structure

emerges and develops within the context of RME, which demands students to progress through activity levels from contextual situations to formal abstraction. Thus, a research gap remains to understand fragmentation not merely as an end product of student thinking, but as a process formed through the interaction between the cognitive demands of creative thinking and the characteristics of RME learning activities.

Based on the aforementioned review and research gap, this study aims to investigate the forms of fragmentation within the creative thinking structure of students in RME. Specifically, this research focuses on how fragmentation emerges as students engage in contextual problem-solving activities that represent the RME learning trajectory. Consequently, this study positions the fragmentation of the creative thinking structure as an analytical lens to understand the dynamics of student thinking in RME, rather than merely as an error or a final product of thinking. Furthermore, the findings of this study are expected to provide pedagogical implications for the design of RME activities that are more sensitive to the potential for fragmentation in students' creative thinking.

Methods

This study employed a qualitative approach with a case study design. This design was selected because the researchers sought to investigate the types of fragmentation occurring specifically within students' creative thinking structures during RME instruction, as fragmentation is conceptualized as a processual and context-dependent cognitive phenomenon that requires in-depth, within-case analysis. Accordingly, the analysis of students' creative thinking fragmentation in this study was guided by an operational framework of fragmentation types derived from prior studies, as summarized in Table 1.

Table 1. Types of thinking structure fragmentation

Fragmentation Type	Conceptual Source	Indicators	Code
Pseudo-false fragmentation	Subanji (2015) and Wibawa et al. (2021)	Student provides an incorrect solution but is able to correct it upon reflection.	PFF
Pseudo-true fragmentation		Student provides a correct answer without conceptual justification.	PTF
Translational thinking fragmentation		Difficulty in translating between representations (verbal–symbolic, symbolic–graphical, contextual–formal) during solution processes.	TTF
Absence-of-connection fragmentation		Inability to establish connections among ideas or strategies, characterized by spontaneous and uncoordinated reasoning.	ACF
Less-strict fragmentation	Kholid et al. (2024)	Focus on partial information while ignoring interrelationships among concepts, leading to inappropriate or incomplete strategies.	LSF

Participants consisted of 18 Grade VII students from an Islamic Integrated Junior High School (SMP IT) in Sukoharjo Regency, Indonesia. Prior to data collection, informed consent was obtained from the students and their teachers, and participants' identities were anonymized to ensure confidentiality. Furthermore, using purposive sampling, a single student was chosen as the focal subject because they displayed the most extensive and varied forms of creative thinking fragmentation. This subject also exhibited all other fragmentation types found in the larger sample, albeit in unique combinations. This selection was therefore strategic, allowing for a comprehensive analysis of fragmentation patterns and ensuring the analytical transferability of the results.

This study employed two primary research instruments: a non-routine mathematics test and a semi-structured interview guide. The non-routine mathematics test was selected for its ability to elicit higher-order thinking processes, including the exploration of ideas, strategic flexibility, and the restructuring of understanding, making it highly relevant for investigating students' creative thinking structures (Kholid et al., 2024). In this study, the non-routine test was not intended to merely measure learning outcomes; rather, it served to trace students' thought processes during problem-solving, which formed the basis for identifying fragmentation within their creative thinking structures.

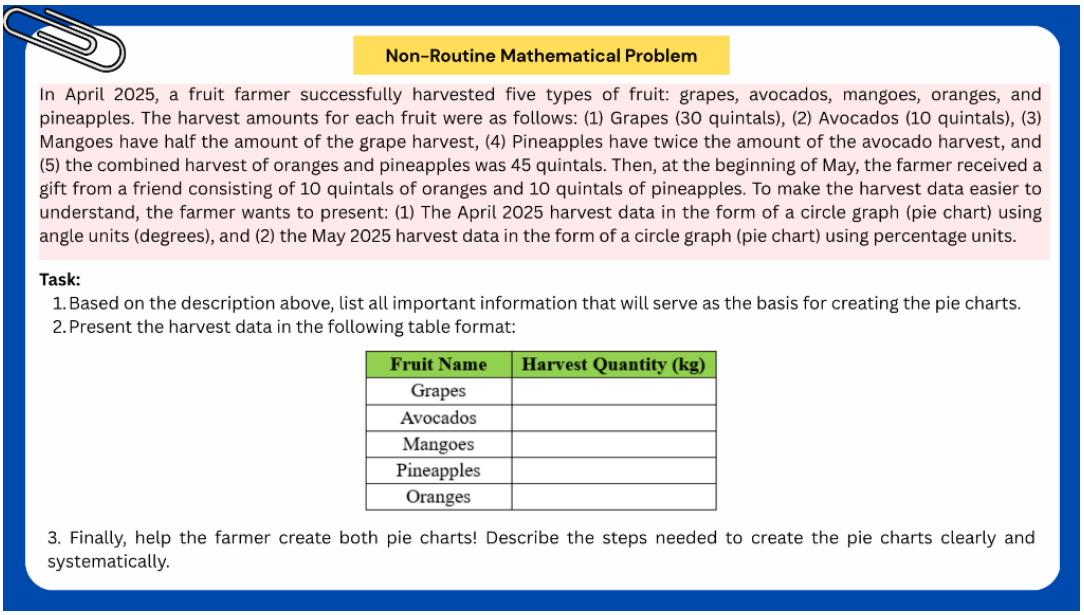
Furthermore, the items for the non-routine test were developed based on two primary foundations. First, the aspects of creative thinking that constitute the analytical focus of this study, as presented in Table 2. Second, the characteristics of RME activities, represented through the four levels of RME: (1) Situation, where students engage with realistic contexts; (2) Model of Situation, involving informal representations; (3) Model for Knowledge, where models are generalized; and (4) Formal Mathematics, which uses abstract concepts (Gravemeijer, 1994). Consequently, each problem was designed to prompt students to transition between the RME activity levels, thereby allowing for the emergence of creative thinking dynamics and the potential for fragmentation within this process. The complete test instrument is presented in Figure 2.

Table 1. Apects and indicators of creative thinking (Kholid et al., 2024)

Aspects	Indicators
Fluency	Able to generate answers from different points of view. Able to produce various responses to a problem.
Flexibility	Able to understand the problem. Able to solve problems using various strategies or patterns that have been formulated.
Originality	Able to provide unique and different answers from others. Able to develop innovative ideas or solutions for problem-solving. Able to connect unusual concepts or ideas to find new solutions.
Elaboration	Able to add details or additional relevant information when explaining answers. Able to solve problems using detailed steps. Able to recheck answers

In addition, semi-structured interviews were employed as a supplementary instrument to deepen the analysis of students' creative thinking structures. The interviews focused on

clarifying the students' problem-solving steps, the rationale behind their strategy selection, and the connections between representations they employed during the problem-solving process. This interview instrument served to verify and enrich the findings from the written test analysis, particularly in identifying types of fragmentation that were not fully apparent through the written responses alone.



Non-Routine Mathematical Problem

In April 2025, a fruit farmer successfully harvested five types of fruit: grapes, avocados, mangoes, oranges, and pineapples. The harvest amounts for each fruit were as follows: (1) Grapes (30 quintals), (2) Avocados (10 quintals), (3) Mangoes have half the amount of the grape harvest, (4) Pineapples have twice the amount of the avocado harvest, and (5) the combined harvest of oranges and pineapples was 45 quintals. Then, at the beginning of May, the farmer received a gift from a friend consisting of 10 quintals of oranges and 10 quintals of pineapples. To make the harvest data easier to understand, the farmer wants to present: (1) The April 2025 harvest data in the form of a circle graph (pie chart) using angle units (degrees), and (2) the May 2025 harvest data in the form of a circle graph (pie chart) using percentage units.

Task:

1. Based on the description above, list all important information that will serve as the basis for creating the pie charts.
2. Present the harvest data in the following table format:

Fruit Name	Harvest Quantity (kg)
Grapes	
Avocados	
Mangoes	
Pineapples	
Oranges	

3. Finally, help the farmer create both pie charts! Describe the steps needed to create the pie charts clearly and systematically.

Figure 2. Non-routine mathematical problems

Furthermore, data collection proceeded in three main phases: (1) Implementation of RME-based mathematics instruction using the four activity levels, covering statistics with a focus on pie charts; (2) Administration of the non-routine mathematics test to all participants; and (3) Conducting interviews with students who demonstrated flawed problem-solving processes and obtained the lowest scores, aiming to explore creative thinking structure fragmentation further.

To ensure the credibility of the data, this study employed methodological triangulation by combining the analysis of written tests with in-depth interviews. This triangulation was used to verify the consistency between the students' creative thinking structures identified from their written responses and their verbal explanations provided during the interviews (Creswell & Creswell, 2017). Specifically, the triangulation focused on the identification process of creative thinking structure fragmentation by comparing the solution steps, use of representations, and inter-idea connections evident in the written answers with the reasoning students articulated verbally.

Following the data validation process, qualitative data analysis was conducted using the framework proposed by Miles et al. (2014), which comprises three stages: data reduction, data display, and conclusion drawing. Data reduction involved selecting the non-routine test responses and interview transcripts from 18 students, from which one student exhibiting the most dominant and representative fragmentation of their creative thinking structure was chosen for in-depth analysis. During this stage, a coding process was undertaken to identify and label

segments of the student's responses that represented creative thinking processes at each RME activity level. This coding was based on the theoretical framework of thinking structure fragmentation by Subanji (2015), along with its subsequent developments by Wibawa et al. (2021) and Kholid et al. (2024) (see Table 1). The data were subsequently presented through analytical narratives and tables that mapped the relationships between RME activity levels, aspects of creative thinking, and the identified types of thinking structure fragmentation. This presentation revealed the dynamics of the emergence, shift, and persistence of fragmentation as it progressed from contextual situations to formal mathematics. The final stage, conclusion drawing, involved interpreting the coding results to conceptualize the fragmentation of the creative thinking structure as a processual phenomenon. This phenomenon is understood to be formed through the interaction between the demands of creative thinking and the characteristics of RME learning activities.

Results

Based on the analysis of the data, five types of fragmentation in creative thinking were identified, each emerging during specific stages of RME activities. These fragmentation types include: (1) Less-strict Fragmentation in the Fluency aspect during the Situation stage, (2) Translation Fragmentation (text to symbol) in the Originality aspect during the Situation stage, (3) Pseudo-False Fragmentation in the Flexibility aspect during the Model of Situation stage, (4) Translation Fragmentation (text to visual) in the Flexibility aspect during the Model for Knowledge stage, and (5) Pseudo-True Fragmentation during the Formal Mathematics stage. Table 3 summarizes the identified types and manifestations of creative thinking fragmentation.

Table 3. Types and forms of creative thinking fragmentation

Type of Fragmentation	Aspects of Creative Thinking	Forms of Fragmentation	RME Stage
Less-Strict	Fluency	The student is unable to fully comprehend all the information provided in the mathematical problem, particularly regarding the harvest data for May.	Situation
Translational (text to symbol)	Originality	The student is unable to correctly translate the information about the fruit harvest from the problem into mathematical symbols.	Situation
Pseudo-False	Flexibility	The student makes an error by assuming that a quintal is equivalent to a kilogram.	Model of Situation
Translational (text to visual)	Flexibility	The student is unable to connect textual numerical information (in this case, angles in degrees) to visual representation (pie chart) proportionally.	Model for Knowledge
Pseudo-True	Elaboration	The student cannot provide justification for the reasoning behind multiplying the quantity of a particular type of fruit by 360° in relation to the total number of fruits.	Formal Mathematic

Situation stage

The student' creative thinking processes in the Situation stage began with repeatedly reading a mathematical problem related to data representation. After comprehending the problem context, the student started identifying and selecting key information provided in the question. The recognized information was then noted and visualized by the students, as illustrated in Figure 3.

Based on Figure 3, the student represented each type of fruit using letter symbols: A for grapes, L for avocados, M for mangoes, N for pineapples, and J for oranges. Since some quantitative information was not explicitly stated in the problem (e.g., the number of mangoes being half the number of avocados), the student employed algebraic representations to determine the unknown values. The student formulated several symbolic equations to represent the relationships among the available data. Nevertheless, the student's work indicates that not all crucial information from the problem was recorded and utilized. Specifically, the information regarding the quantity of fruit for May, which was necessary for constructing the pie chart for that month, was omitted by the student. To clarify this matter, a follow-up interview was conducted with the student.

R: "From the information you wrote down, do you think you've included all the important points?"

S: "Umm, I think so, Sir."

R "Are you sure there's no other information besides what you wrote?"

S: "(thinks for a moment) I don't think there's anything else, Sir."

Based on Figure 3 and the interview results, it is evident that the student did not fully integrate all the information presented in the problem. The student focused only on a portion of the information while disregarding other relevant details. Furthermore, Figure 3 also reveals errors in translating verbal information into mathematical symbols. The student wrote the equation 1/2M = A, which they interpreted as "the number of mangoes is half the number of grapes," and the equation 2N = L, interpreted as "the number of pineapples is twice the number of avocados." However, according to the problem statement, the correct relationships were that the number of mangoes is half the number of avocados (M = 1/2L), and the number of pineapples is twice the number of avocados (N = 2L). This error demonstrates the student's inaccuracy in converting textual statements into symbolic representations.

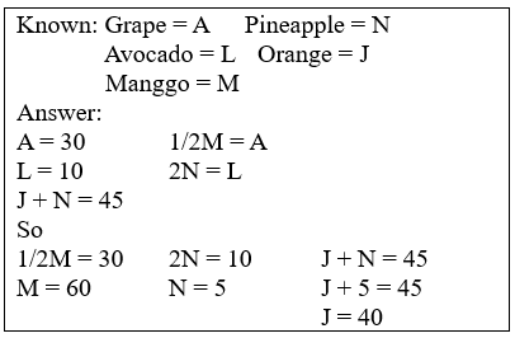


Figure 3. Informations the student understood (translated from the original student worksheet)

Overall, the findings at the Situation stage indicate that fragmentation emerged in two forms. First, less-strict fragmentation occurred when the student focused only on partial information without integrating the entire problem conditions holistically. Second, translation fragmentation arose when verbal information from the problem was not accurately transformed into symbolic representations. This fragmentation pattern is further illustrated in Figure 4. Furthermore, the Situation stage within the RME framework successfully elicited indicators of creative thinking, specifically fluency and originality. Fluency was reflected in the student's ability to generate multiple symbolic relationships to represent the problem situation, while originality was evident in the use of non-routine algebraic representations. However, this creative engagement was not accompanied by an adequate process of verification and information coordination. Consequently, these two types of fragmentation did not stem from a low creative thinking ability, but rather from a desynchronization between creative exploration and representational accuracy during the initial phase of the RME activity.

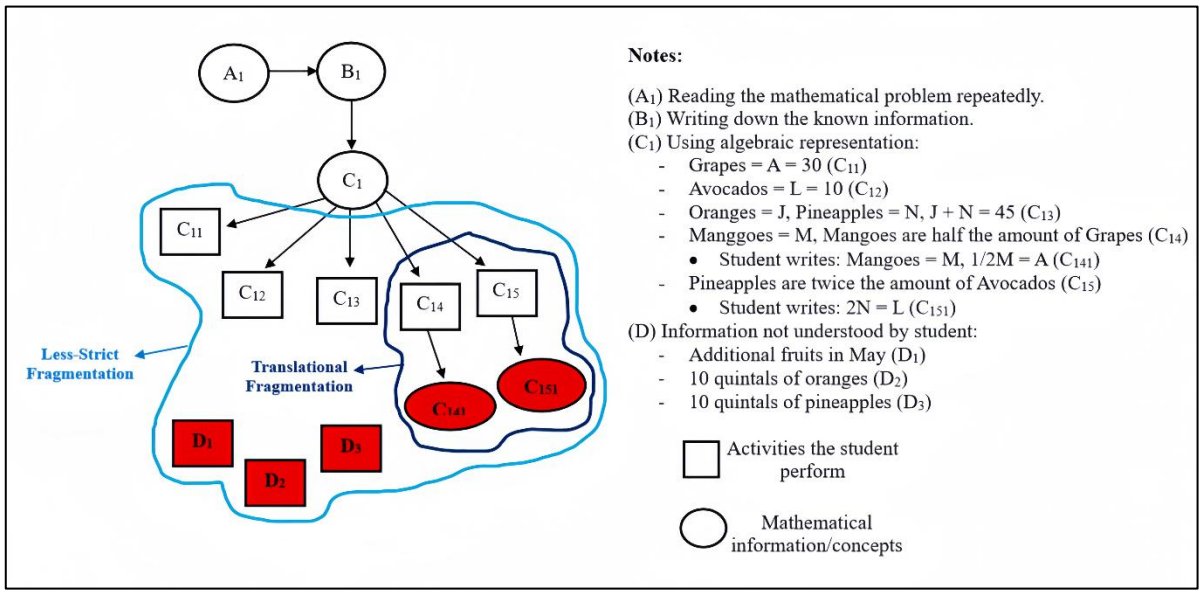


Figure 4. Fragmentation of students' creative thinking structure in the situation stage

Model of situation stage

The student' thinking process in the Model of Situation stage began by recording all fruit harvest data for April into a provided table. The table specified harvest quantities in kilograms (kg). The student's response is shown in Figure 5. Figure 5 reveals that the student made errors in determining the harvest quantities of mangoes, pineapples, and oranges. These errors stemmed from fragmentation in creative thinking structure that originated in the Situation stage, particularly affecting the Fluency and Originality aspects. This incoherence in thinking subsequently impacted the accuracy of later problem-solving stages.

Table

Fruit Name	Harvest Quantity (kg)
Grapes	30
Avocados	10
Manggoes	60
Pineapples	5
Oranges	40

Figure 5. Student answers regarding the harvest results table (translated from the original student worksheet)

Additionally, Figure 5 also reveals an inaccuracy in the use of units. Although the table explicitly listed kilograms (kg) as the unit, the student recorded the harvest data using quintals. To investigate the reason behind this use of units, a follow-up interview was conducted with the student.

R: "Are you confident with your answers in this harvest data table?"
S: "Umm… is it wrong, Sir? I thought it was correct."
R "In the problem, what unit was used to state the weight of the fruits?"
S: "(thinks for a moment) It was in quintals, Sir."
R: "Well, in this table, is it also asking for the data in quintals?"
S: "In the table, there's something written in parentheses, kg, I think. That's kilograms, right?"
R: "If you already knew it says kilograms, why did you still write it in quintals?"
S: "Isn't it the same, Sir? As far as I know, kg and quintals are the same."
R: "Have you ever learned about weight units like tons, quintals, kilograms, hectograms, decagrams, and so on?"
S: "(thinks for a moment) I think I have, Sir, back in elementary school."

The interview results showed that the student considered a quintal to be equivalent to a kilogram. In fact, mathematically, one quintal is equivalent to 100 kilograms. This error indicates that the student's knowledge of weight units, despite having been previously learned, was not activated appropriately in the context of solving this problem.

This condition demonstrates that the student had difficulty adjusting their mathematical representation to the demands of the given context. At this stage, the relevant creative thinking indicator is flexibility, defined as the ability to adapt and coordinate representations according to situational needs. The inaccuracy in unit usage reflects that the flexibility aspect did not function adaptively, even though the student possessed the necessary conceptual knowledge. Therefore, this condition is categorized as pseudo-false fragmentation, a situation where a student produces an incorrect response not due to a lack of knowledge, but rather due to a failure to activate and coordinate relevant conceptual schemas. This fragmentation pattern is further detailed in Figure 6.

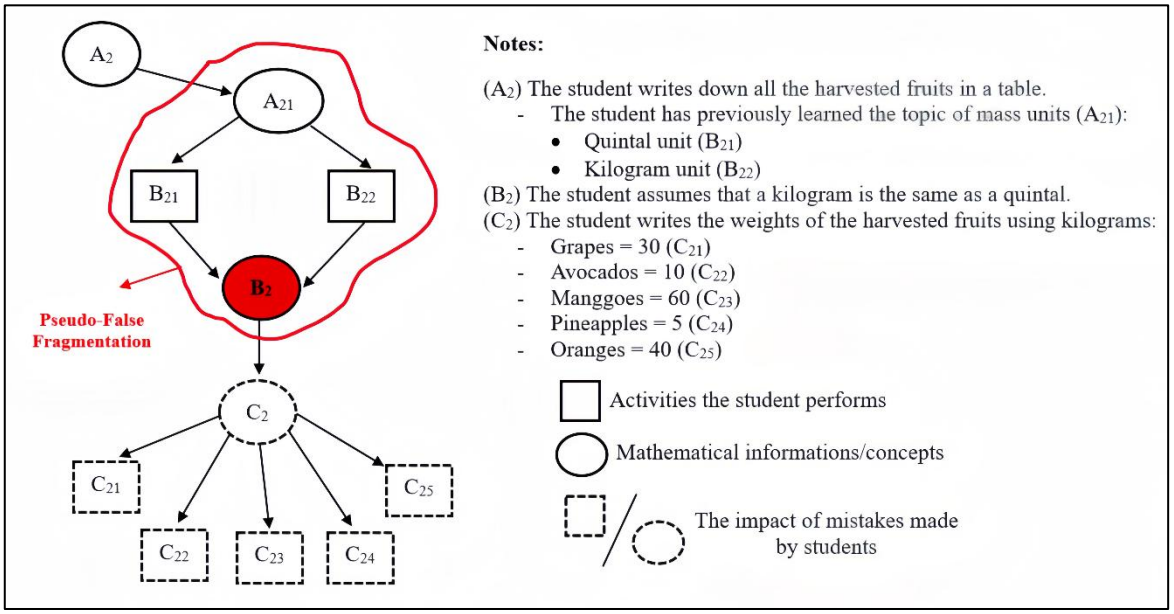


Figure 6. Fragmentation of students' creative thinking structure in the model of situation stage

Overall, the findings at the Model of Situation stage show that the transitional function of this stage within the RME framework, namely, organizing contextual information into a more formal representational model, becomes a crucial point for the stability of students' creative thinking. The fragmentation that appeared in the previous stage not only persisted but also manifested in the form of errors in quantity and units. This suggests that the fragmentation of creative thinking in RME learning is not solely caused by knowledge limitations, but rather by the obstruction of activation and coordination of conceptual schemas as students transition from contextual exploration to more structured mathematical modeling.

Model for knowledge stage

The student's thinking process in the Model for Knowledge stage commenced with calculating the central angle for each fruit type to construct a pie chart. However, due to incomplete comprehension of the problem information, specifically regarding May's fruit quantities, the solution focused solely on April's data. After determining the angles, the student sketched the pie chart (see Figure 7).

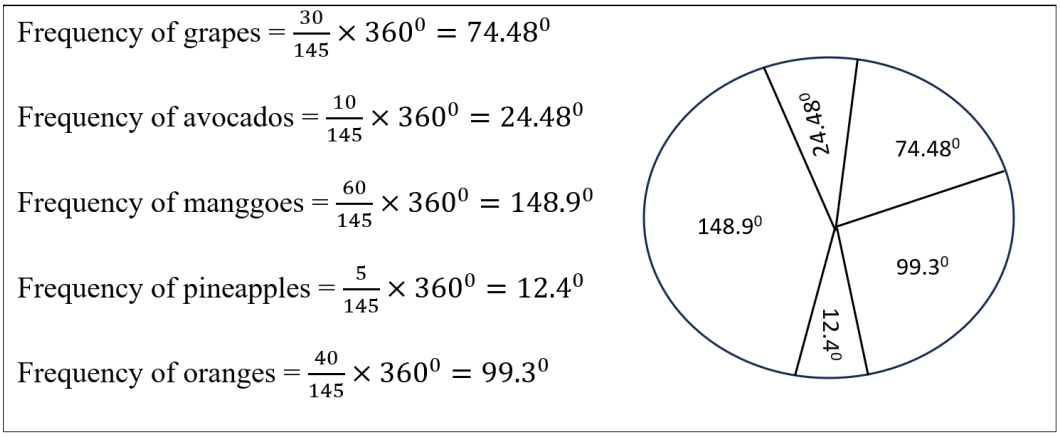


Figure 7. Students' answers related to pie chart construction (translated from the original student worksheet)

Figure 7 confirms the student correctly calculated angles using the principle: specific fruit quantity/total quantity)×360°. The calculation of the angles was performed in accordance with correct mathematical procedures. However, in the visual representation of the pie chart, the sectors measuring 12.40° and 24.80° were drawn of nearly equal size, even though mathematically, the 24.80° sector should have appeared twice as large as the 12.40° sector. To clarify this discrepancy, a follow-up interview was conducted with the student.

R: "You've already determined the angle for each type of fruit. For pineapples and avocados, you got 12.40° and 24.80°, respectively. So, between 12.40° and 24.80°, which one is greater?"

S: "Umm, 24.80° is greater, Sir. That's obvious."

The interview results indicated that the student conceptually understood the quantitative relationship between the two angles. Nevertheless, this understanding was not proportionally reflected in the pie chart they constructed. This discrepancy between numerical understanding and visual representation signifies the occurrence of translation fragmentation, defined as the failure to transform numerical and symbolic information proportionally into a visual representation. In the context of the Model for Knowledge stage, this fragmentation is associated with the aspect of flexibility, wherein the student was unable to adjust the form of the visual representation to align with the quantitative relationship they had comprehended. The structure of this thinking fragmentation at this stage is further illustrated in Figure 8.

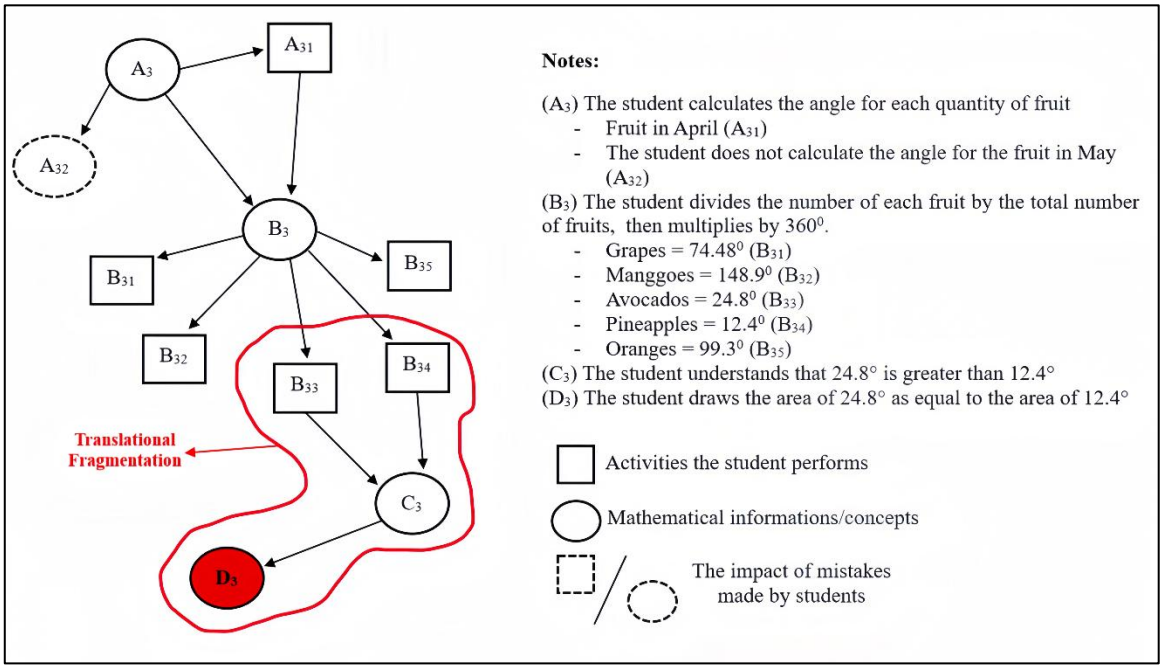


Figure 8. Fragmentation of students' creative thinking structure in the model for knowledge stage

Formal mathematics stage

Furthermore, students should systematically write down the steps in making a circle diagram at the formal mathematics stage (see Figure 7). However, students have not listed these steps on the answer sheet. Therefore, the researchers conducted interviews to explore further students' understanding of the procedures they used to compile pie charts. This is related to the creative thinking aspect of elaboration.

R: You've already made the pie chart. Now, using your own words, your own explanation, how do you actually draw a pie chart from raw data?"
S: "Umm (thinks for a moment). Well, Sir, usually there's a set of data. For example, grapes this much, mangoes that much. So first, you add them all up to get the total. Then... (thinks again) oh right, you find the angle for each fruit, Sir."
R "Is it always fruit?"
S: "No, it depends on the problem, Sir."
R: "Okay, then how do you determine the angle?"
S: "So, if it's about fruit, for example, you take the amount of one type of fruit, divide it by the total amount, then multiply by 360^0, Sir."
R: "Wait a minute, why did you multiply by 360^0?"
S: "Umm... (thinks for a long time). Well, that's just how it's usually done, right Sir? You're supposed to multiply by 360^0."

Based on the interview results, it was seen that students could correctly determine the angle size by multiplying the result of dividing the number of fruits and the total of all fruits by 360°. However, when asked to justify why the calculation result is multiplied by 360°, students cannot explain it.

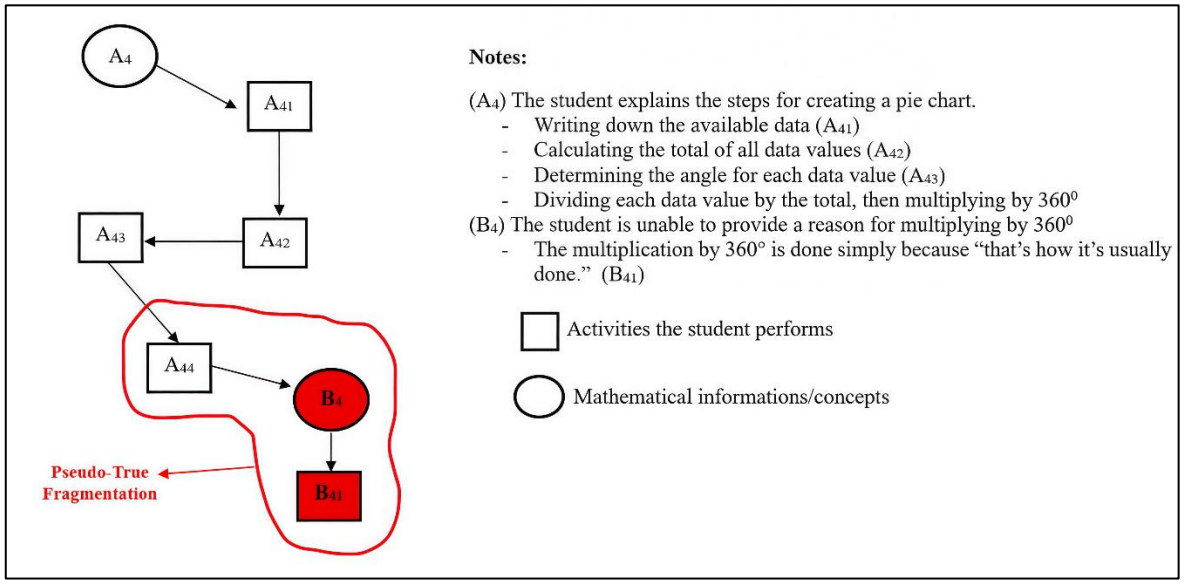


Figure 9. Fragmentation of students' creative thinking structure in the fornal mathematics stage

This finding indicates that although the student successfully applied the formula procedurally correct, their conceptual understanding of 360° as a representation of a full circle's rotation was not yet fully formed. This condition suggests the occurrence of Pseudo-True Fragmentation in the aspect of elaboration, which is a situation where a student is able to produce an operationally correct answer but is unable to elaborate on or justify the steps through mathematical reasoning. Analytically, this suggests that the transition from modeling activities to formal mathematical justification within the RME framework was not fully achieved. At this stage, RME requires students not only to execute procedures but also to connect each step with its underlying mathematical principles. Therefore, the emerging fragmentation is not caused by computational weaknesses, but rather by the lack of integration between procedural fluency and formal mathematical meaning-making. Furthermore, this fragmentation is visualized in Figure 9.

Discussion

In this study, the Situation stage within the RME framework is understood as the initial phase emphasizing contextual exploration and the construction of informal representations, which, in the context of the analyzed case, facilitates the emergence of fluency and originality aspects in creative thinking (Gravemeijer, 1994; Sitorus & Masrayati, 2016). In line with research findings in various educational contexts, both in Europe and Southeast Asia, including Indonesia, studies indicate that the Situation stage naturally facilitates creative thinking through exploratory activities and non-routine approaches (Fredriksen, 2021; Hasibuan et al., 2024; Samaniego et al., 2024). However, a study by Abdu et al. (2025) showed that creative engagement at this initial stage is often accompanied by cognitive instability when the processes of coordination and verification have not yet optimally developed.

Within the framework of thinking structure fragmentation (Subanji, 2015), the fragmentation that emerged at the Situation stage in this case's analysis manifested in the forms of less-strict fragmentation and translation fragmentation from text to symbols, caused by selective attention to problem elements and a misalignment between contextual meaning and symbolic representation. This type of fragmentation is understood as temporary fragmentation, a cognitive development phenomenon reflecting the tension between the demands of creative exploration and the need for representational accuracy (Kholid et al., 2024; Wibawa, 2019). Similar findings have been reported in RME-based research in the Netherlands and Vietnam, where initial representational inconsistencies can be reduced through pedagogically facilitated conceptual reintegration in subsequent stages (Nguyen et al., 2025; Zanten & Heuvel-Panhuizen, 2021). Thus, based on the analytical findings of this study, fragmentation at the Situation stage is not positioned as a pathological phenomenon, but rather as a condition requiring targeted scaffolding to prevent its continuation into subsequent stages.

Nevertheless, the results of this study indicate that in the context of the analyzed case, when scaffolding is not optimally implemented, fragmentation can persist into the Model of Situation stage. At this stage, pseudo-false fragmentation emerges, affecting the aspect of flexibility in creative thinking. This is evident in the student's inability to adapt mathematical representations to contextual demands and conventions, particularly in the use of units of measurement. This condition aligns with the findings of Wibawa et al. (2017) and Grajzel et al. (2023), who showed that students often possess adequate conceptual knowledge but fail to activate it adaptively during the modeling process. In this study, the emergence of pseudo-false fragmentation marks a shift from temporary to potentially persistent fragmentation. Furthermore, Kholid et al. (2024) explained that such fragmentation is caused not by a lack of knowledge, but by the obstruction of activation and coordination of conceptual schemas as students transition from contextual exploration to mathematical modeling. Analytically, this finding indicates that unresolved fragmentation at the Model of Situation stage can form a fragile representational foundation, such that in subsequent stages, students may exhibit procedural success that is not fully accompanied by representational integration.

At the Model for Knowledge stage, the findings of this study show that the transition from a contextual model to more general mathematical knowledge within the RME framework demands not only procedural mastery but also the ability to coordinate various representations, which is at the core of creative thinking (Nugroho et al., 2020). Although the students' creative flexibility appeared to develop at a procedural level, this ability was not yet fully integrated at the representational level. The emergence of translation fragmentation from text to visual in this case demonstrates that creativity in RME learning does not automatically guarantee successful generalization, especially when cross-modal coordination between representations has not been explicitly facilitated (Sitorus & Masrayati, 2016). Furthermore, these findings indicate that fragmentation at the Model for Knowledge stage is not an indicator of conceptual failure, but rather reflects a tension between the demands of mathematical abstraction and the students' creative capacity to transform meaning between representations. Therefore, based on this case analysis, the Model for Knowledge stage in RME learning needs to be supported by targeted representational scaffolding, as suggested by Putra et al. (2024), to ensure that students'

creative exploration does not stop at mere formula application but evolves into the ability to represent mathematical structures proportionally, coherently, and meaningfully.

Finally, at the Formal Mathematics stage, RME requires formalization, a point where mathematical procedures are not only applied but are also justified and connected to their underlying conceptual principles (Nguyen et al., 2025). This study's findings show that a student's success in producing a correct procedure does not necessarily reflect the development of the elaboration aspect of creative thinking. The student's inability to explain the mathematical reasoning behind the procedure used indicates that the formalization process remained procedural-reproductive rather than reflective-conceptual (Schulz, 2024). The phenomenon of Pseudo-True Fragmentation that appeared at this stage affirms that fragmentation is no longer related to representation or calculation errors, but rather to a disconnection between mathematical actions and their theoretical justifications (Kholid et al., 2024; Subanji, 2015; Wibawa et al., 2021). Thus, in the formal mathematics phase, fragmentation becomes an indicator of the limit of the transformation of creative thinking: the student is able to "do mathematics" but is not yet fully "understanding the meaning of mathematics." This finding provides a crucial implication that the RME trajectory needs to explicitly facilitate reflective and argumentative activities so that creative elaboration does not stop at the execution of procedures but develops into a structured and meaningful mathematical understanding (Listyaningrum et al., 2025).

In conclusion, it must be emphasized that this study does not aim to generalize to the broader student population or RME learning contexts. The findings presented are based on an in-depth analysis of a single case, such that the generalization offered is analytical, meaning it pertains to the level of understanding the cognitive mechanisms and the dynamics of thinking structure fragmentation within the RME learning trajectory. Therefore, the results of this study are not intended as a universal representation, but rather as a conceptual framework that can be used to interpret similar phenomena in comparable learning contexts, while still considering differences in task design, pedagogical support, and learner characteristics. Further research with a multi-case and cross-contextual design is necessary to test the recurrence and variation of the fragmentation patterns identified in this study.

Conclusion

This research reveals that the creative thinking process of students in RME experiences various types of fragmentation at each stage of these learning activities, which include situation, model of situation, model for knowledge, and formal mathematics. These types of fragmentation include (1) less-strict fragmentation at the situation stage, (2) translational fragmentation from text to symbols at the situation stage, (3) pseudo-false fragmentation at the model of situation stage, (4) translational fragmentation from text to image at the model for knowledge stage, and (5) pseudo-true fragmentation at the formal mathematics stage. These fragmentations reflect the disintegration of students' creative thinking schemes, especially in fluency, originality, flexibility, and elaboration. The findings extend fragmentation theory by demonstrating that fragmentation in creative thinking is a dynamic and stage-dependent phenomenon within the

RME trajectory, rather than a static indicator of conceptual failure. Pedagogically, the results highlight the need for stage-sensitive defragmentation strategies, such as scaffolding representational coordination in early stages, activating and aligning conceptual schemas during modeling, and strengthening justification and reflection in formal mathematics. This study is limited by its single-case design and context-specific setting. Therefore, the findings are not intended for statistical generalization but offer analytical insights that may inform similar instructional contexts. Future research is encouraged to examine defragmentation mechanisms across multiple cases and learning environments to further validate and refine these insights.

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Declarations

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References

Abdu, R., Tancredi, S., Abrahamson, D., & Balasubramaniam, R. (2025). Demonstrating mathematics learning as the emergence of eye–hand dynamic equilibrium. *Educational Studies in Mathematics*, *118*(3), 505–528. https://doi.org/10.1007/s10649-023-10279-0

Avcı, Ü., & Durak, H. Y. (2023). Innovative thinking skills and creative thinking dispositions in learning environments: Antecedents and consequences. *Thinking Skills and Creativity*, *47*(1), 101225. https://doi.org/10.1016/j.tsc.2022.101225

Bicer, A., Lee, Y., Perihan, C., Capraro, M. M., & Capraro, R. M. (2020). Considering mathematical creative self-efficacy with problem posing as a measure of mathematical creativity. *Educational Studies in Mathematics*, *105*(3), 457–485. https://doi.org/10.1007/s10649-020-09995-8

Djannah, M., Setyaningsih, N., Kholid, M. N., & Reotutar, M. A. C. (2024). Defragmentation of students ' conceptual understanding in solving non-routine mathematics problems. *Jurnal Didaktik Matematika*, *11*(2), 287–301. https://doi.org/10.24815/jdm.v11i2.38383

Fredriksen, H. (2021). Exploring realistic mathematics education in a flipped classroom context at the tertiary level. *International Journal of Science and Mathematics Education*, *19*(2), 377–396. https://doi.org/10.1007/s10763-020-10053-1

Grajzel, K., Acar, S., Dumas, D., Organisciak, P., & Berthiaume, K. (2023). Measuring flexibility: A text-mining approach. *Frontiers in Psychology*, *13*(1), 1–16. https://doi.org/10.3389/fpsyg.2022.1093343

Gravemeijer, K. (1994). *Developing realistic mathematics education*. CD Press.

Hasibuan, S., Chu, C. T., & Godh, W. A. (2024). Enhancing creative thinking in circle topics through the realistic mathematics learning approach. *Interval: Indonesian Journal of Mathematical Education*, *2*(2), 106–114. https://doi.org/10.37251/ijome.v2i2.1148

Herna. (2016). *Defragmentasi struktur berpikir mahasiswa untuk memperbaiki konstruktsi pseudo benar mahasiswa dalam memahami konsep limit fungsi [Defragmenting students' thinking structures to improve students' pseudo-true constructions in understanding the concept of F]*. Unievrsitas Negeri Malang.

Kholid, M. N., Mahmudah, M. H., Ishartono, N., Putra, F. G., & Forthmann, B. (2024). Classification of students' creative thinking for non-routine mathematical problems. *Cogent Education*, *11*(1), 1–16. https://doi.org/10.1080/2331186X.2024.2394738

Kholid, M. N., Santosa, Y. T., Toh, T. L., Wijaya, A. P., Sujadi, I., & Hendriana, H. (2024). Defragmenting students' reflective thinking levels for mathematical problem solving: Does it work? *Reflective Practice*, *25*(3), 319–351. https://doi.org/10.1080/14623943.2024.2320140

Krulik, S., Milou, E., & Rudnick, J. (2003). *Teaching mathematics in middle school: A practical guide*. Pearson.

Listyaningrum, P., Retnawati, H., Harun, H., & Ibda, H. (2025). Realistic mathematics education in digital era elementary schools: A systematic literature review. *International Journal on Advanced Science, Engineering and Information Technology*, *15*(1), 67–74. https://doi.org/10.18517/ijaseit.15.1.20123

Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). *Qualitative data analysis: A methods sourcebook* (3rd ed.). SAGE Publications. https://www.ucg.ac.me/skladiste/blog_609332/objava_105202/fajlovi/Creswell.pdf

Nguyen, Q. A., Dao, N. H., Hoa, T. A., & Nguyen, N.-G. (2025). Teaching conditional probability in grade 12 using realistic mathematics education theory. *Journal on Mathematics Education*, *16*(2), 603–632. https://doi.org/10.22342/jme.v16i2.pp603-632

Nugroho, A. A., Nizaruddin, N., Dwijayanti, I., & Tristianti, A. (2020). Exploring students' creative thinking in the use of representations in solving mathematical problems based on cognitive style. *JRAMathEdu (Journal of Research and Advances in Mathematics Education)*, *5*(2), 202–217. https://doi.org/10.23917/jramathedu.v5i2.9983

Preiss, D. D. (2022). Metacognition, mind wandering, and cognitive flexibility: Understanding creativity. *Journal of Intelligence*, *10*(3), 69–81. https://doi.org/10.3390/jintelligence10030069

Putra, R. W. Y., Sutiarso, S., & Nurhanurawati, N. (2024). Using the realistic mathematics education (rme) approach with scaffolding to enhance mathematical representation ability. *Al-Jabar : Jurnal Pendidikan Matematika*, *15*(2), 535–546.

https://doi.org/10.24042/ajpm.v15i2.24560

Samaniego, M., Usca, N., Salguero, J., & Quevedo, W. (2024). Creative thinking in art and design education: A systematic review. *Education Sciences*, *14*(2), 192–224. https://doi.org/10.3390/educsci14020192

Schulz, A. (2024). Assessing student teachers' procedural fluency and strategic competence in operating and mathematizing with natural and rational numbers. *Journal of Mathematics Teacher Education*, *27*(6), 981–1008. https://doi.org/10.1007/s10857-023-09590-7

Setyaningsih, N., Rejeki, S., & Ishartono, N. (2019). Developing realistic and child-friendly learning model for teaching mathematics. *JRAMathEdu (Journal of Research and Advances in Mathematics Education)*, *4*(2), 79–88. https://doi.org/10.23917/jramathedu.v4i2.8112

Sitorus, J., & Masrayati. (2016). Students' creative thinking process stages: Implementation of realistic mathematics education. *Thinking Skills and Creativity*, *22*(1), 111–120. https://doi.org/10.1016/j.tsc.2016.09.007

Solomon, Y., Hough, S., & Gough, S. (2021). The role of appropriation in guided reinvention: establishing and preserving devolved authority with low-attaining students. *Educational Studies in Mathematics*, *106*(2), 171–188. https://doi.org/10.1007/s10649-020-09998-5

Subanji. (2015). *Teori kesalahan konstruksi konsep dan pemecahan masalah matematika [Theory of concept construction errors and mathematical problem solving]*. UM Press.

Sutarni, S., Sutama, S., Prayitno, H. J., Sutopo, A., & Laksmiwati, P. A. (2024). The development of realistic mathematics education-based student worksheets to enhance higher-order thinking skills and mathematical ability. *Infinity Journal*, *13*(2), 285–300. https://doi.org/10.22460/infinity.v13i2.p285-300

Tolkamp, G., Verwaeren, B., Vriend, T., Riekhoff, A.-J., & Nijstad, B. (2025). Creativity as it unfolds: An examination of temporality in the creative process. *Creativity Research Journal*, *37*(1), 22–43. https://doi.org/10.1080/10400419.2023.2234719

Ulker, D., & Celik, A. O. (2025). A qualitative metasynthesis: Interaction between mathematical modeling and higher order thinking. *Thinking Skills and Creativity*, *56*(1), 1–19. https://doi.org/10.1016/j.tsc.2025.101773

Usodo, B., Aulia, I. I., Wulandari, A. N., Sutopo, Setiawan, R., Kurniawati, I., & Kuswardi, Y. (2020). Fragmentation of thinking structure and its impact to students' algebraic concept construction and problem solving. *Journal of Physics: Conference Series*, *1567*(3), 1–6. https://doi.org/10.1088/1742-6596/1567/3/032006

Wibawa, K. A. (2019). Fragmentation of the thinking structure of translation in solving mathematical modelling problems. *Southeast Asian Mathematics Education Journal*, *9*(1), 25–36. https://doi.org/10.46517/seamej.v9i1.71

Wibawa, K. A., Nusantara, T., Subanji, & Nengah Parta, I. (2018). Defragmentation of student's thinking structures in solving mathematical problems based on CRA framework. *Journal of Physics: Conference Series*, *1028*(1), 1–7. https://doi.org/10.1088/1742-6596/1028/1/012150

Wibawa, K. A., Nusantara, T., Subanji, & Parta, N. (2021). *Rekonstruksi kesalahan dan perbaikan struktur berpikir dalam memecahkan masalah matematis [Error reconstruction and improvement of thinking structures in solving mathematical problems]*. CV Confident.

Wibawa, K. A., Nusantara, T., Subanji, S., & Parta, I. N. (2017). Fragmentation of thinking structure's students to solving the problem of application definite integral in area. *International Education Studies*, *10*(5), 48. https://doi.org/10.5539/ies.v10n5p48

Widyaningrum, M. S., Usodo, B., & Pratiwi, H. (2021). Fragmentation of students' thinking structure in constructing the concept of linear inequality of two variables. *Proceedings of the International Conference of Mathematics and Mathematics Education (I-CMME*

2021), *597*, 186–194. https://doi.org/10.2991/assehr.k.211122.026

Wulandari, A. N., Usodo, B., Sutopo, Setiawan, R., Kurniawati, I., Kuswardi, Y., & Aulia, I. I. (2020). Fragmentation of thinking structure: concept construction and problem solving in geometry of junior high school students. *Journal of Physics: Conference Series*, *1567*(3), 1–7. https://doi.org/10.1088/1742-6596/1567/3/032007

Zanten, M. Van, & Heuvel-Panhuizen, M. Van den. (2021). Mathematics curriculum reform and its implementation in textbooks: Early addition and subtraction in realistic mathematics education. *Mathematics*, *9*(7), 752–772. https://doi.org/10.3390/math9070752