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Multidimensional Patterns of Primary School Students' Difficulties in Solving Higher-Order Thinking Problems on Mixed Arithmetic Operations

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Abstract

The integration of higher-order thinking skills (HOTS) into primary mathematics education requires students to engage in complex reasoning; however, many students continue to experience significant difficulties, particularly when solving problems involving mixed arithmetic operations. This study aims to analyze the multidimensional patterns of students' difficulties by examining cognitive, affective, and pedagogical factors that influence their problem-solving processes. A qualitative descriptive design was employed, involving one mathematics teacher and three primary school students representing high, medium, and low achievement levels. Data were collected through document analysis, questionnaires, classroom observations, and in-depth interviews, and analyzed using thematic analysis with triangulation across data sources. The findings reveal that students' difficulties are inherently multidimensional. Cognitively, students demonstrate fragmented reasoning and limited relational understanding, relying on procedural strategies without fully integrating conceptual structures. Affectively, cognitive overload, anxiety, and low confidence reduce students' persistence and lead to avoidance behaviors such as guessing. Pedagogically, the dominance of procedural instruction and limited exposure to HOTS-oriented tasks contribute to algorithmic dependency and restrict the development of flexible problem-solving strategies. These dimensions interact dynamically, forming a reinforcing cycle that hinders students' ability to engage effectively with complex mathematical tasks. This study contributes to the field by proposing a multidimensional analytical framework that integrates cognitive, affective, and pedagogical perspectives in understanding students' mathematical difficulties. The findings highlight the need for instructional approaches that simultaneously support conceptual understanding, manage cognitive load, and foster positive affective engagement. Such approaches are essential for enhancing students' higher-order thinking skills and improving the quality of mathematics learning in primary education.

INTRODUCTION

The increasing demand for higher-order thinking skills (HOTS) in mathematics education has shifted the focus of primary learning from procedural fluency toward complex problem-solving and analytical reasoning. However, recent empirical evidence indicates that many primary school students still experience substantial difficulties when dealing with HOTS-oriented mathematical problems, particularly in topics requiring multi-step reasoning such as mixed arithmetic operations. These difficulties often emerge when students are required to interpret contextual problems, integrate multiple operations, and apply hierarchical rules simultaneously. The complexity of such tasks lies not only in computational accuracy but also in the ability to structure reasoning processes systematically. Studies have shown that HOTS problems inherently require non-routine thinking structures, which are often not sufficiently developed in early mathematics learning (Makmuri et al., 2021). As a result, a gap persists between instructional expectations and students' actual performance, indicating an urgent need to examine the underlying causes of these learning difficulties.

Recent studies have explored students' mathematical difficulties from various perspectives, highlighting both cognitive and instructional dimensions. Research indicates that students frequently experience misconceptions when solving HOTS problems, particularly in understanding operational hierarchies and translating problems into mathematical representations (Tanujaya & Mumu, 2020; Tabak, 2019). Moreover, large-scale analyses demonstrate that students with mathematical difficulties often struggle with solving word problems due to limitations in reasoning and representational skills (Myers et al., 2023). Instructional approaches also play a critical role, as the implementation of HOTS-oriented learning environments, such as realistic mathematics education and technology-supported instruction, has been shown to influence students' conceptual understanding and achievement (Arnellis et al., 2020; Thoriq et al., 2023; Solina et al., 2026). These findings collectively suggest that students' mathematical difficulties are shaped by a combination of conceptual, procedural, and instructional factors.

In addition to cognitive and instructional aspects, affective and domain-general cognitive factors have been identified as significant contributors to students' mathematical performance. Systematic reviews indicate that mathematical difficulties are closely related to broader cognitive processes, including working memory, attention, and executive functioning (Agostini et al., 2022). Furthermore, recent studies emphasize the heterogeneity of mathematical difficulties, suggesting that students exhibit diverse cognitive profiles that influence their problem-solving performance (Hasson & Ashkenazi, 2026). From an affective perspective, factors such as mathematics anxiety and self-efficacy play a crucial role in shaping students' engagement and persistence in solving complex problems (Zhang et al., 2019; Holenstein et al., 2022; Yang et al., 2024). These findings indicate that mathematical difficulties cannot be fully understood through a single lens but require an integrated perspective that considers cognitive, affective, and contextual dimensions simultaneously.

Despite the growing body of literature, existing studies tend to examine these dimensions in isolation, resulting in a fragmented understanding of students' difficulties in mathematics learning. Few studies have adopted a comprehensive framework that captures the interactions among cognitive processes, emotional factors, and instructional practices in authentic classroom contexts. Multidimensional analyses have been widely applied in other domains to understand complex phenomena, demonstrating the importance of integrating multiple perspectives in a single analytical framework (Aliukov & Buleca, 2022; Thurm & Barzel, 2022). In mathematics education, such an approach remains underexplored, particularly regarding primary students' difficulties in solving HOTS-based problems involving mixed arithmetic operations. This gap highlights the need for a more holistic investigation that moves beyond isolated variables and examines the interplay among multiple influencing factors.

Addressing this gap, the present study offers a multidimensional analysis of primary school students' difficulties in solving HOTS-based problems on mixed arithmetic operations by integrating cognitive, affective, and pedagogical perspectives. This study distinguishes itself by not only identifying the types of difficulties experienced by students but also examining how these difficulties emerge through the interaction of internal and external factors within real classroom settings. Drawing on insights from multidimensional educational analyses and research on mathematical cognition (Erdogan & Yemenli, 2019; Kreijkes & Greatorex, 2024; Fitria et al., 2025), this study aims to provide a more comprehensive understanding of students' problem-solving processes. Therefore, the objective of this study is to analyze the multidimensional patterns of students' difficulties and to identify how cognitive, affective, and pedagogical factors collectively influence their ability to solve HOTS-based mathematical problems. The findings are expected to contribute to the development of more effective and responsive instructional strategies that support higher-order thinking in primary mathematics education.

METHODS

This study employed a qualitative descriptive design to explore the multidimensional patterns of students' difficulties in solving higher-order thinking (HOTS) problems on mixed arithmetic operations. This approach was selected because it allows for a rich and straightforward description of participants' experiences while maintaining analytical depth in the interpretation of complex educational phenomena. Qualitative descriptive research is particularly appropriate for studies that aim to understand real-world situations without imposing excessive theoretical abstraction, making it well-suited to examining students' problem-solving processes in authentic classroom contexts (Hall & Liebenberg, 2024; Stanley, 2023). In this study, the design enabled exploration of how cognitive, affective, and pedagogical factors interact to shape students' learning difficulties.

The participants consisted of one sixth-grade mathematics teacher and three primary school students selected through purposive sampling. This sampling strategy was used to ensure that participants represented key variations relevant to the research focus, particularly differences in academic ability. The selected students exhibited high, medium, and low achievement levels, enabling a comparative understanding of diverse patterns of difficulty. Purposive sampling is widely used in qualitative research to intentionally select information-rich cases that can provide meaningful insights into the phenomenon under investigation (Ahmad & Wilkins, 2025). The teacher was included as a primary informant to provide contextual understanding of instructional practices and classroom dynamics.

Data were collected through document analysis, questionnaires, and in-depth interviews to ensure a comprehensive and multidimensional dataset. Document analysis was conducted on students' written responses to HOTS-based mixed arithmetic problems and on teacher reflective notes to identify patterns of reasoning, errors, and conceptual understanding. This method enables researchers to systematically examine existing records and artifacts to gain insights into learning processes (Kutsyuruba, 2023). In addition, questionnaires were administered to gather preliminary information on students' perceptions, motivation, and learning experiences, as e-questionnaires can support qualitative inquiry by efficiently capturing participants' perspectives (Pitura, 2023). To obtain deeper insights, in-depth interviews were conducted with both the teacher and the selected students. This method allows for the exploration of participants' experiences, interpretations, and reasoning processes in a detailed and flexible manner. Interviews focused on how students interpret problem statements, determine solution strategies, and respond to multi-step tasks, as well as how affective factors such as confidence and anxiety influence their performance. In-depth interviewing is particularly effective at uncovering complex cognitive and emotional dimensions that are not readily observable in other data sources (Eppich et al., 2019).

Data analysis was conducted using a thematic analysis approach, involving iterative processes of data reduction, coding, categorization, and interpretation. Initially, the data were organized according to the research focus, followed by systematic coding to identify recurring patterns related to students' difficulties. These patterns were then grouped into three main dimensions: cognitive, affective, and pedagogical. Thematic analysis enables researchers to identify, analyze, and interpret meaningful patterns within qualitative data, providing a structured yet flexible analytical framework (Squires, 2023). The multidimensional categorization adopted in this study aligns with broader interdisciplinary approaches that emphasize the integration of multiple perspectives in understanding complex phenomena (Pinto et al., 2019). The final stage involved synthesizing these themes to explain how different factors interact in shaping students' problem-solving difficulties.

To ensure the trustworthiness of the findings, this study applied triangulation of sources and methods. Data obtained from students, the teacher, and documents were compared to enhance credibility, while multiple data-collection techniques enabled cross-validation of findings. The research process was systematically documented to maintain consistency and transparency in data analysis. Ethical considerations were carefully addressed throughout the study. Prior to data collection, permission was obtained from the school, the teacher, and the students' parents. All participants were informed about the purpose of the study, and their confidentiality was strictly maintained. Students' identities were anonymized in all reports to ensure privacy and to create a supportive environment for participation.

RESULT

Multidimensional Patterns of Students' Difficulties

The analysis of students' written work, questionnaires, teacher reflective notes, and interview data reveals that students' difficulties in solving HOTS-based problems on mixed arithmetic operations are inherently multidimensional. These difficulties are systematically categorized into three interrelated dimensions: cognitive, affective, and pedagogical. The findings indicate that students' errors are not isolated incidents but emerge from the interaction between internal processing constraints and external instructional conditions. This multidimensional structure was consistently identified across all data sources through thematic coding and triangulation.

Cognitive Difficulties: Fragmented Reasoning and Weak Operational Structuring

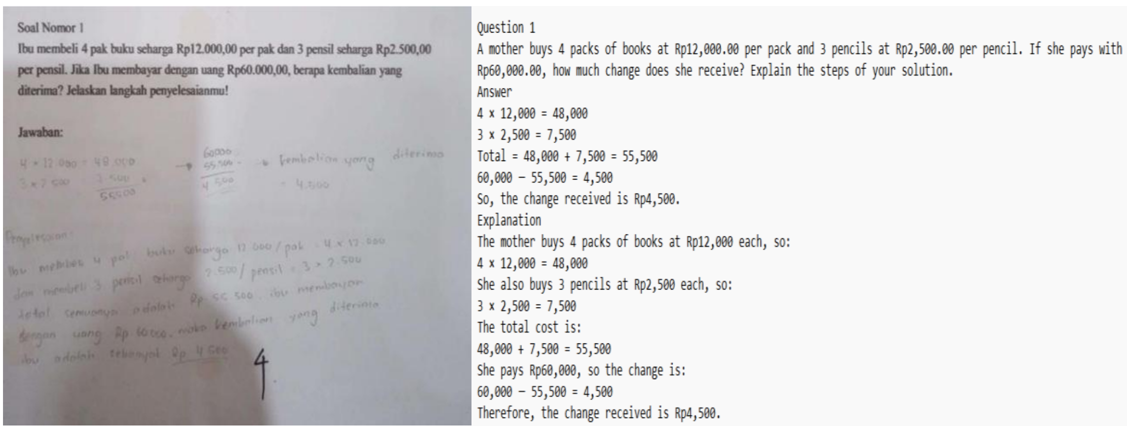

Figure 1. Student's written response to a HOTS-based mixed arithmetic problem

The student's written response provides critical insight into the structure of mathematical reasoning during problem-solving. At an initial stage, the student successfully identifies relevant quantitative information, as indicated by the correct computation of:

$$4 \times 12{,}000 = 48{,}000$$
$$3 \times 2{,}500 = 7{,}500$$

These steps demonstrate that the student possesses basic procedural competence in multiplication and can extract key numerical elements from the problem context. Furthermore, the student correctly aggregates the total cost (48,000 + 7,500 = 55,500) and determines the change (60,000 – 55,500 = 4,500), indicating that the final answer is mathematically accurate. However, a deeper analysis reveals several critical limitations in the student's reasoning structure. First, the solution is presented in a fragmented, non-systematic format, with intermediate steps written without clear logical sequencing or explicit justification. The absence of structured representation (e.g., organized equations or step-by-step modeling) suggests that the student relies on intuitive procedural execution rather than explicit mathematical reasoning.

Second, although the student arrives at the correct answer, the written explanation shows limited evidence of relational understanding between operations. The student does not explicitly articulate why multiplication is performed before addition, nor how the operations are interconnected in the problem context. This indicates that the student's understanding remains at a surface procedural level, without fully internalizing the hierarchical structure of mixed operations. Third, the explanatory section reflects a tendency toward reproductive reasoning, where the student restates the problem in narrative form rather than constructing a conceptual model. This suggests that the student is able to follow familiar patterns but may struggle when confronted with variations in problem structure. This evidence demonstrates that correct answers do not necessarily indicate deep understanding. Instead, the student's performance reflects a procedural success-but-conceptual-fragility pattern, in which accuracy is achieved without robust cognitive structuring.

Table 1. Analytical Breakdown of Student's Mathematical Reasoning in Solving a HOTS-Based Mixed Arithmetic Problem

Aspect	Evidence	Interpretation
Computation	Correct multiplication and subtraction	Procedural competence
Representation	Unstructured steps	Weak mathematical modeling
Explanation	Narrative repetition	Low conceptual understanding

Affective Difficulties: Cognitive Overload, Avoidance Behavior, and Reduced Persistence

Interview data, supported by questionnaire responses and students' written work, indicate that affective factors play a critical role in shaping students' engagement with HOTS-based problems. These factors are not merely emotional reactions but function as mediating variables that influence how students process, sustain, and regulate their cognitive efforts during problem solving.

A student in the medium-ability category stated:

"I need to read the problem several times because there is too much information to process."

This statement is consistent with observable behavior during task completion, where the student repeatedly revisited the problem text before initiating any mathematical operation. Such behavior indicates cognitive overload at the comprehension stage, where working memory is taxed by the simultaneous processing of multiple pieces of information. As a result, the transition from problem interpretation to strategy formulation is delayed, reducing overall efficiency in problem-solving. This pattern suggests that the difficulty lies not only in understanding the content but also in managing informational complexity within limited cognitive capacity.

A more pronounced pattern is observed in the low-ability student, who reported:

"The hardest part is when all operations are mixed together. I often get confused and just guess the answer."

This response reflects a shift from cognitive struggle to affective-driven avoidance behavior. The student's tendency to guess indicates a breakdown in problem-solving persistence, where confusion triggers disengagement rather than strategic effort. Analysis of the student's written work further supports this finding, showing incomplete solution steps and an abrupt termination of reasoning. This alignment between interview data and written evidence strengthens the interpretation that affective responses directly influence cognitive engagement, particularly in complex tasks. Questionnaire data further reinforce these findings, with several students reporting feelings of anxiety, uncertainty, and lack of confidence when dealing with long or multi-step problems. These emotional responses are consistently associated with observable patterns such as hesitation, delayed initiation, and reliance on superficial strategies. Rather than engaging in systematic reasoning, students tend to simplify the task by guessing or skipping steps, indicating reduced cognitive persistence.

Interestingly, even high-performing students demonstrated difficulty maintaining accuracy under increased cognitive demand. Although they applied the correct procedures, minor inconsistencies and calculation errors were observed in tasks requiring sustained attention across multiple steps. This suggests that affective factors such as pressure and uncertainty can disrupt otherwise stable cognitive processes, leading to performance fluctuations. Taken together, these findings indicate that affective difficulties are not independent of cognitive processes but are dynamically intertwined with them. Cognitive overload, when combined with low confidence and anxiety, reduces students' ability to sustain effort, regulate strategies, and complete problem-solving tasks effectively. Therefore, students' failure to solve HOTS-based problems should be understood not solely as a lack of knowledge but as a consequence of reduced cognitive endurance under affective pressure and perceived task complexity.

Pedagogical Factors: Procedural Dominance and Limited Exposure to HOTS-Oriented Learning

Classroom observations, teacher reflective notes, and questionnaire data collectively indicate that instructional practices play a decisive role in shaping students' difficulties in solving HOTS-based problems. The observed lessons were predominantly structured around teacher-led explanations followed by routine exercises, with limited opportunities for students to engage in analytical reasoning or non-routine problem solving. During instruction, the teacher typically demonstrated procedural steps, after which students were asked to replicate similar patterns, suggesting a strong emphasis on procedural transmission rather than conceptual exploration.

This instructional pattern is empirically reflected in students' written work, where solutions tend to follow memorized procedures without explicit justification or adaptation to problem context. Students rarely construct their own representations (e.g., diagrams or structured equations) and instead rely on direct numerical manipulation. This indicates that classroom practices implicitly reinforce algorithmic dependency, where students prioritize rule application over meaning-making. Teacher reflections further reveal that HOTS-oriented tasks are infrequently implemented due to perceived constraints such as limited instructional time and students' readiness levels. As a consequence, students have minimal exposure to complex, multi-step problems that require interpretation, strategy selection, and evaluation. This limited exposure restricts the development of cognitive flexibility, particularly when students encounter unfamiliar problem structures that cannot be solved through routine procedures.

In addition, observational data show a lack of scaffolding strategies during instruction. Teachers rarely decompose complex problems into manageable stages or provide guided questioning to support students' reasoning processes. The absence of visual representations, contextual modeling, and interactive learning media further constrains students' ability to connect abstract mathematical operations with real-world meaning. As a result, students often approach problems superficially, focusing on numerical computation rather than conceptual understanding.

Questionnaire responses provide additional support for these findings, indicating that learning support outside the classroom is limited. Most students reported minimal parental involvement in discussing mathematical reasoning, with support typically limited to checking answers rather than guiding problem-solving. This lack of reinforcement reduces opportunities for students to revisit concepts, clarify misunderstandings, and develop deeper reasoning skills. These findings suggest that pedagogical factors contribute to students' difficulties through a reinforcing cycle: instructional practices emphasize procedural fluency, which leads to algorithmic dependency, while limited exposure to HOTS tasks restricts the development of analytical reasoning. Without adequate scaffolding and contextual support, students are not equipped to construct meaningful understanding, resulting in persistent difficulties when engaging with complex mathematical problems.

Triangulation of Findings

The integration of multiple data sources strengthens the validity of these findings. Patterns identified in written work—such as disorganized solution structures and incorrect operation sequencing—are consistent with interview responses indicating confusion and repeated reading behavior. Similarly, classroom observations align with students' reported reliance on procedural strategies, confirming the influence of instructional practices. To summarize the multidimensional findings, the following table presents the alignment between empirical evidence and analytical interpretation:

Table 2. Multidimensional Analysis of Students' Difficulties Based on Empirical Evidence and Analytical Interpretation

Dimension	Empirical Evidence	Analytical Interpretation
Cognitive	Misordered operations, fragmented written steps	Weak schema and limited relational understanding
Affective	"Confused", "need to reread", guessing answers	Cognitive overload and low confidence
Pedagogical	Routine teaching, limited HOTS exposure	Procedural dependency and lack of analytical training

Comparative Patterns Across Student Ability Levels

A comparative analysis across ability levels reveals distinct patterns of difficulty. High-achieving students demonstrate procedural accuracy but still experience inconsistencies in maintaining solution coherence. Medium-achieving students show partial understanding but require additional time and support to structure their reasoning. In contrast, low-achieving students exhibit fundamental difficulties in both comprehension and execution, often accompanied by avoidance behaviors. These findings suggest that students' difficulties exist along a continuum, where differences in performance reflect variations in how cognitive, affective, and pedagogical factors interact rather than differences in a single ability dimension.

DISCUSSION

The findings of this study demonstrate that students' difficulties in solving HOTS-based problems on mixed arithmetic operations are inherently multidimensional, arising from the dynamic interaction between cognitive, affective, and pedagogical factors. This result aligns with broader perspectives in mathematics education that conceptualize learning difficulties as complex phenomena shaped by multiple interrelated dimensions rather than isolated deficits (Fritz et al., 2019). In this regard, students' problem-solving performance should be understood as an outcome of interacting processes involving knowledge structures, emotional regulation, and instructional conditions.

From a cognitive perspective, the findings indicate that students experience fundamental challenges in constructing coherent mathematical representations from contextual problems. Although many students demonstrate procedural competence, their reasoning often lacks structural organization and relational coherence. This pattern reflects limitations in schema development, where students fail to integrate individual operations into a unified problem-solving structure. The development of problem-solving schemata is closely related to experience and structured engagement in complex tasks, suggesting that insufficient exposure to such tasks limits students' ability to organize knowledge effectively (Dimitrova et al., 2023). Furthermore, difficulties in processing and organizing information during problem-solving can be explained by limitations in cognitive processing systems, in which ineffective information integration leads to fragmented reasoning (Rahmawati, 2026).

These cognitive constraints are further intensified by affective factors, particularly cognitive overload, anxiety, and reduced self-efficacy. The findings show that students frequently experience difficulty during the initial comprehension phase, where multiple pieces of information must be processed simultaneously. This condition is consistent with cognitive load theory, which posits that excessive informational demand can exceed working memory capacity and hinder problem-solving performance (Barbieri & Rodrigues, 2025). When cognitive load is not effectively managed, students tend to rely on inefficient strategies or disengage from the task altogether. In addition, affective variables such as self-efficacy and anxiety play a critical role in mediating students' engagement. Students with lower confidence are more likely to avoid challenging tasks, while those experiencing anxiety demonstrate reduced persistence and accuracy (Kohen et al., 2022; Zhu et al., 2024). This interaction suggests that cognitive and affective processes are deeply intertwined, where emotional responses can either support or inhibit cognitive performance. Moreover, instructional interventions incorporating multimedia and interactive elements have been shown to reduce mathematics anxiety and improve problem-solving ability, highlighting the importance of addressing affective dimensions in learning design (Mondal & Vijaykumar, 2025).

In addition to internal factors, the findings emphasize the significant influence of pedagogical practices in shaping students' difficulties. The dominance of teacher-centered instruction and routine exercises contributes to the development of procedural dependency, limiting students' opportunities to engage in higher-order thinking processes. This finding is consistent with multidimensional models of teaching, which emphasize that effective instruction must integrate cognitive, motivational, and contextual elements to support meaningful learning (Metsäpelto et al., 2022). The absence of scaffolding strategies and structured guidance further exacerbates students' difficulties, as they must manage complex tasks without adequate support. Research shows that scaffolding interventions, particularly those supported by digital or mobile technologies, can reduce cognitive load and enhance students' problem-solving performance by guiding their reasoning processes (Karabay & Meşe, 2024). Similarly, integrating self-regulated learning strategies into instruction can improve students' confidence and reduce anxiety, enabling them to engage more effectively with complex mathematical tasks (Han et al., 2025).

The interaction among cognitive, affective, and pedagogical dimensions reveals a reinforcing cycle of difficulty. Instructional practices that emphasize procedural fluency without conceptual support lead to weak schema development, which increases cognitive load when students encounter complex problems. This heightened cognitive demand triggers affective responses such as anxiety and low confidence, which in turn reduce persistence and engagement. Over time, this cycle reinforces students' reliance on surface-level strategies and limits the development of higher-order thinking skills. Therefore, students' difficulties should be understood not as isolated weaknesses but as outcomes of systemic interactions within the learning environment.

These findings have important implications for mathematics education. Instructional design must move beyond procedural teaching toward approaches that explicitly support schema development, cognitive load management, and affective engagement. The integration of scaffolding, visual representations, and problem-based learning can help students construct meaningful understanding and improve flexibility in problem solving. In addition, addressing affective factors through supportive learning environments and confidence-building strategies is essential to sustain students' engagement. By adopting a multidimensional approach, educators can more effectively address the complexity of students' learning difficulties and foster the development of higher-order thinking skills.

CONCLUSIONS

This study demonstrates that students' difficulties in solving HOTS-based problems involving mixed arithmetic operations are inherently multidimensional, involving interactions among cognitive, affective, and pedagogical factors. From a cognitive perspective, students exhibit fragmented reasoning and limited relational understanding, indicating that procedural competence is not accompanied by well-developed conceptual schemas. From an affective perspective, cognitive overload, low confidence, and anxiety reduce students' persistence and disrupt their ability to sustain problem-solving processes. From a pedagogical perspective, the dominance of procedural instruction and limited exposure to HOTS-oriented tasks contribute to the development of algorithmic dependency and restrict opportunities for analytical reasoning. The findings further reveal that these dimensions do not operate independently but form a reinforcing system. Weak conceptual structuring increases cognitive load, which in turn triggers negative affective responses such as confusion and avoidance. These responses reduce engagement and persistence, ultimately limiting the effectiveness of learning experiences. At the same time, instructional practices that emphasize routine procedures without sufficient scaffolding fail to support the development of flexible problem-solving strategies. This interaction explains why students may produce correct answers in some cases yet still exhibit unstable and inconsistent reasoning. This study contributes theoretically by providing a multidimensional analytical framework that integrates cognitive, affective, and pedagogical perspectives in understanding students' mathematical difficulties. Unlike previous approaches that focus on isolated factors, this study highlights the importance of examining the dynamic interplay among these dimensions to obtain a more comprehensive understanding of students' problem-solving processes. In practice, the findings suggest that improving students' HOTS abilities requires a shift in instructional design toward approaches that simultaneously support conceptual understanding, cognitive load management, and affective engagement. The use of scaffolding, structured problem decomposition, visual representations, and contextual learning can help students develop more coherent reasoning. In addition, creating supportive learning environments that reduce anxiety and enhance confidence is essential to sustain students' engagement with complex tasks. This study is limited by its small sample size and qualitative scope, which may restrict generalizability. Future research is recommended to examine the effectiveness of specific instructional interventions, such as problem-based learning, technology-enhanced scaffolding, or multimodal learning environments, in addressing multidimensional difficulties across broader educational contexts.

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