

## **ANALYSIS OF ELEMENTARY SCHOOL STUDENTS' THINKING ABILITIES BASED ON SOLO TAXONOMY IN SOLVING HOTS MATHEMATICS PROBLEMS**

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### **Article Info**

#### **Article history:**

Received May 19, 2026

Revised June 18, 2026

Accepted June 28, 2026

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#### **Keywords:**

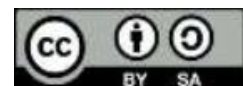
*Higher Order Thinking Skills, Elementary School Students, SOLO Taxonomy*

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### **ABSTRACT**

The low level of high-order thinking skills of elementary school students in mathematics is a problem that requires in-depth and systematic study. This study aims to: (1) describe the profile of elementary school students' thinking skills based on the Structure of Observed Learning Outcomes (SOLO) taxonomy; (2) identify the dominant level of the SOLO taxonomy achieved by students in solving Higher Order Thinking Skills (HOTS) mathematics problems; and (3) analyze the factors that influence differences in the levels of the SOLO taxonomy of elementary school students. This study uses a literature study method (library research) with a qualitative content analysis approach to ten relevant and verified scientific literature sources. The results of the study indicate that the profile of elementary school students' thinking skills is still dominated by the multistructural level, where students are able to use more than one piece of information but have not been able to integrate it comprehensively and coherently. Achievement of the relational and extended abstract levels is still very limited. Factors that influence variations in these levels include cognitive style, metacognitive abilities, initial mathematical abilities, and the learning methods applied. This study confirms that the SOLO taxonomy is an effective diagnostic instrument for mapping students' thinking quality hierarchically and comprehensively.

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## **INTRODUCTION**

Mathematics education at the elementary school level plays a strategic role in building the foundation of students' logical and analytical thinking skills from an early age. In an era of increasingly competitive global competition, higher-order thinking skills (HOTS) are essential competencies that students must master, beyond simply memorizing algorithmic procedures. However, the reality on the ground shows that most elementary school students still experience significant difficulties when faced with questions that require in-depth reasoning, analysis, and

evaluation. This condition is exacerbated by the lack of assessment instruments capable of accurately diagnosing the level of students' thinking abilities (De et al., 2025). The Structure of Observed Learning Outcomes (SOLO) taxonomy developed by Biggs and Collis offers a relevant and comprehensive theoretical framework for mapping the quality of students' thinking responses hierarchically. The SOLO taxonomy divides thinking abilities into five levels: prestructural, unistructural, multistructural, relational, and extended abstract. The advantage of this taxonomy over other instruments lies in its ability to analyze thinking processes based on the quality and complexity of students' responses, not just whether they are correct or incorrect. The application of the SOLO taxonomy in the context of mathematics has been proven to provide a more in-depth diagnostic picture of the structure of students' conceptual understanding.

Previous studies on HOTS in elementary school mathematics learning have generally focused on developing problem-solving instruments or learning strategies, but very few have integrated the SOLO taxonomy analysis as a descriptive framework for specific student thinking skills. Research conducted by (Raradhita, 2022) revealed that the majority of elementary school students were only able to reach the multistructural level in the SOLO taxonomy when working on problem-solving-based mathematics problems, while achievement at the relational and extended abstract levels remained very low. This finding indicates a significant gap between curriculum demands and students' actual thinking capacity. Furthermore, research by (Luswisandari, 2024) emphasized that elementary school students' higher-order thinking skills in mathematics need to be studied not only from the aspect of achievement scores, but also from a more holistic, structural dimension of cognitive responses.

The research gap identified in this literature review encompasses two main dimensions. First, there are not many studies that explicitly use the SOLO taxonomy as an analytical tool for elementary school students' responses to HOTS mathematics questions that are appropriate to the context of the current curriculum in Indonesia. Second, the profile of students' SOLO taxonomy levels based on differences in specific mathematical materials, such as number, geometry, and measurement, has not been adequately mapped. This study aims to fill this gap with a more specific and contextual approach. This research has novelty in integrating the SOLO taxonomy analysis with HOTS mathematics questions constructed based on the cognitive development characteristics of upper-grade elementary school students, and producing a thinking profile that can serve as the basis for more targeted learning interventions (Olaybal & Mancera, 2025).

Based on the description above, the problem formulation in this study is: (1) What is the profile of elementary school students' thinking abilities based on the SOLO taxonomy in solving HOTS mathematics problems? (2) At which level of the SOLO taxonomy are most elementary school students when facing HOTS mathematics problems? (3) What are the factors that influence the differences in elementary school students' SOLO taxonomy levels in solving HOTS mathematics problems? The objectives of this study are: (1) To describe the profile of elementary school students' thinking abilities based on the SOLO taxonomy in solving HOTS mathematics problems; (2) To identify the distribution of the dominant SOLO taxonomy levels achieved by elementary school students in HOTS mathematics problems; (3) To analyze the factors that contribute to variations in elementary school students' SOLO taxonomy levels in the context of solving HOTS mathematics problems.

This research is expected to provide theoretical benefits in the form of enriching the knowledge of mathematics education, particularly in the use of the SOLO taxonomy as an analytical framework for higher-order thinking skills. Practically, the results of this study can serve as a reference for teachers in designing more adaptive HOTS-based learning, for curriculum developers in developing more measurable indicators of higher-order thinking achievement, and for future researchers as a foundation for developing more comprehensive studies on the cognitive abilities of elementary school students in Indonesia.

## **RESEARCH METHODS**

This research uses a literature study approach, also known as library research, which is a research method carried out by systematically identifying, collecting, reviewing, and synthesizing various relevant library sources to build an in-depth understanding of a particular phenomenon or problem. This method was chosen because it is able to produce a comprehensive conceptual analysis based on the accumulation of existing empirical and theoretical findings, without having to involve primary data collection in the field (NM Ruslim, 2022). The data sources in this study are secondary data, obtained from various types of scientific literature, including reputable national and international journal articles, mathematics education textbooks, scientific seminar proceedings, and relevant research reports. The literature search was carried out systematically through several trusted academic databases, including Google Scholar, Semantic Scholar, ERIC (Education Resources Information Center), and Garuda (Garuda Digital Reference Portal). The search keywords used include: SOLO taxonomy, HOTS mathematics, elementary school students' thinking skills, higher order thinking skills, and SOLO taxonomy elementary mathematics.

The literature inclusion criteria used included: (1) publications between 2019 and 2025; (2) direct relevance to the topics of SOLO taxonomy, HOTS, and elementary school students' mathematical thinking skills; and (3) publications in indexed journals or journals with a reputable academic reputation. Exclusion criteria included literature that lacked thematic correlation with the focus of the study or originated from sources whose scientific validity could not be verified. Data analysis was conducted through qualitative content analysis, namely by reading critically, categorizing findings, identifying patterns, and synthesizing arguments from various sources to answer the established problem formulation. The validity of the study was maintained through a source triangulation process, namely comparing and confirming information from at least three different sources for each conceptual claim proposed (Snyder, 2019).

## **RESULTS AND DISCUSSION**

### **Literature Review Results**

The literature review in this study is based on ten scientific articles relevant to the topic of analyzing students' thinking skills based on the Structure of Observed Learning Outcomes (SOLO) taxonomy in solving Higher Order Thinking Skills (HOTS) mathematics problems. Before entering into the main discussion, the following is a synthesis table of all reference sources used as the basis for the analysis.

Table 1. Synthesis of Literature Review Results

No	Author & Year	Study Focus	Method	Key Findings
1	(Adilawati et al., 2025)	Algebraic thinking skills & cognitive styles	Quantitative descriptive	Thinking ability is in the moderate category; FI cognitive style is superior to FD
2	(Normal, 2023)	Critical thinking in solving HOTS problems	Descriptive qualitative	Students' critical thinking skills are still below 50%
3	(Yulianto, 2023)	The influence of Accelerated Learning methods on HOTS	As if by experiment	The AL method improves critical thinking skills on HOTS questions.
4	(Prasetyo & Firmansyah, 2022)	Critical mathematical thinking on HOTS questions	Descriptive qualitative	Low students have not met any of the indicators; high students meet all indicators
5	(Izzah et al., 2025)	Item analysis based on Bloom's Taxonomy	Descriptive qualitative	92% of questions only measure C1–C2; HOTS questions are still very minimal
6	(Faiziyah & Priyambodho, 2022)	Critical thinking about HOTS from a metacognitive perspective	Qualitative descriptive	High–moderate metacognition → high critical thinking; low metacognition → low critical thinking
7	(Selvianti, 2022)	Elementary school students' ability to solve story problems (SOLO Taxonomy)	Qualitative descriptive	63.63% of students are at the multistructural level
8	(Irfana et al., 2023)	Numeracy skills based on SOLO Taxonomy	Descriptive	The majority of students are at the unistructural to relational level.
9	(Riska & Munandar, 2025)	SOLO Taxonomy-based mathematical problem solving	Descriptive qualitative	The majority of students are at the multistructural–relational level; few reach the extended abstract level.
10	(Asitah & Fatkul Anam, 2022)	Complexity of elementary school mathematics textbook questions (SOLO Taxonomy)	Qualitative (content analysis)	Dominance of relational questions (42.9%); extended abstract questions only 10.8%

Source: From various literature reviews

Based on the synthesis table above, it is clear that there is consistent finding across various studies, indicating that students' thinking skills in mathematical contexts, whether measured using the SOLO taxonomy or other HOTS indicators, remain at the lower-middle level. This strengthens the relevance of this study to further analyze the thinking profiles of elementary school students using the SOLO taxonomy framework as a systematic diagnostic instrument.

**Elementary School Students' Thinking Ability Profile Based on the SOLO Taxonomy**

The Structure of Observed Learning Outcomes (SOLO) taxonomy is a hierarchical analytical framework consisting of five levels of thinking ability: prestructural, unistructural, multistructural, relational, and extended abstract. Each level reflects the depth and complexity of a student's cognitive response to a problem (Asitah & Fatkul Anam, 2022). The thinking ability profile of elementary school students identified through this taxonomy provides a much richer diagnostic picture than conventional true-false scores. A study (Yulianto, 2023) on third-grade elementary school students showed that of the 11 subjects, 18.18% were at the prestructural level, 18.18% at the unistructural level, and 63.63% at the multistructural level. None of the students reached the relational or extended abstract levels. This condition indicates that although most students were able to identify some information from story problems, they were not yet able to fully integrate that information to construct a complete and logical solution.

Similar findings were confirmed by Irfana et al., who found that students at the unistructural level understood questions but were unable to solve problems correctly. Students at the multistructural level were able to integrate data from various sources and design a solution plan, while students at the relational level were able to accurately utilize two or more pieces of information to draw correct conclusions. This gradation of abilities confirms that the SOLO taxonomy is a continuum, and each transition between levels requires a substantial cognitive leap. Research (Riska & Munandar, 2025) extended this understanding by finding that seventh-grade students analyzed using the SOLO taxonomy simultaneously reached all five levels, but the majority were concentrated at the multistructural and relational levels. Very few students reached the extended abstract level, and they were characterized by the ability to form generalizations and apply mathematical principles to new, previously unseen situations. This finding is relevant in identifying that achieving the highest level of the SOLO taxonomy is closely correlated with abstract thinking skills, which have not yet developed evenly among students.

**The Dominant SOLO Taxonomy Level Achieved by Elementary School Students in HOTS Mathematics Questions**

Identifying the dominant level of the SOLO taxonomy in elementary school students in the context of HOTS mathematics questions is the core of this study. Based on a synthesis of various sources, the multistructural level consistently emerged as the level most frequently achieved by elementary school students. At this level, students are able to use more than one piece of information available in the question, but their use is still partial and not yet coherently integrated to produce comprehensive conclusions. This fact is closely related to the condition of the evaluation instruments used in elementary schools. A study (Irfana et al., 2023) revealed that 92% of questions used in grade II of elementary school only measured lower-level cognitive abilities, namely C1 (remembering) and C2 (understanding) based on Bloom's Taxonomy. Questions that encourage higher-order thinking skills such as C3 (applying), C4 (analyzing), and C5 (evaluating) were still very rare. This condition indirectly causes students' thinking abilities to not develop beyond the multistructural level, because the existing evaluation system does not sufficiently challenge their cognitive potential.

Furthermore, a study (Prasetyo & Firmansyah, 2022) of fifth-grade elementary school mathematics textbooks found that the distribution of problem complexity based on the SOLO taxonomy was dominated by the relational level at 42.9%, followed by multistructural at 32%,

unistructural at 14.1%, and extended abstract at only 10.8%. Although the problems in the textbooks had reached the relational level, in reality, students' actual responses in the classroom tended to be lower than the questions' demands. This indicates a significant gap between the cognitive demands of the problems and students' actual thinking capacity. This phenomenon is further reinforced by the finding that students' critical thinking skills in dealing with HOTS problems were still below 50%, with only focus and reasoning indicators being adequately achieved, at 64% and 50%, respectively. This figure reflects that the majority of students are only at the surface level of understanding, which aligns with the characteristics of the unistructural to multistructural levels in the SOLO taxonomy.

### **Factors Influencing Differences in Elementary School Students' SOLO Taxonomy Levels**

The variation in the SOLO taxonomy levels achieved by students does not occur randomly, but is influenced by a number of interrelated cognitive, pedagogical, and instructional factors. Understanding these factors is crucial for designing targeted learning interventions. First, students' cognitive styles have been shown to significantly influence mathematical thinking capacity (Izzah et al., 2025). Students with a Field Independent (FI) cognitive style consistently display higher-order thinking skills than students with a Field Dependent (FD) cognitive style, with a contribution of 16.70%. FI students tend to be better able to organize information independently and analyze problems structurally, characteristics that strongly support achievement of the relational and extended abstract levels in the SOLO taxonomy.

Second, metacognitive abilities play a crucial role in determining the quality of students' higher-order thinking. (Faiziyah & Priyambodho, 2022) showed that students with high and moderate metacognition were able to achieve high levels of critical thinking skills in solving HOTS problems, while students with low metacognition still demonstrated limited critical thinking processes. In the context of the SOLO taxonomy, strong metacognition enables students to monitor their own thinking processes, identify gaps in understanding, and integrate various information more effectively—competencies that are prerequisites for reaching the relational and extended abstract levels. Third, students' prior mathematical abilities are a crucial factor. (Selvianti, 2022) demonstrated that low-ability students did not meet the critical thinking indicators at all in HOTS problems, while high-ability students were able to meet all indicators well. This finding directly correlates with students' position in the SOLO taxonomy hierarchy, where strong prior abilities serve as the foundation for building more complex and integrated cognitive responses.

Fourth, the learning methods applied by teachers also contribute to the development of students' thinking levels. Empirically, the application of the Accelerated Learning for the 21st Century method can significantly improve students' mathematical critical thinking skills in solving HOTS problems compared to conventional approaches, both in high-, medium-, and low-ability students. The implication is that learning strategies that actively stimulate higher-order thinking processes will encourage students to move from the multistructural level to a higher level in the SOLO taxonomy. Overall, these four factors work synergistically in shaping students' SOLO taxonomy level profiles. Effective interventions need to consider the whole holistically, starting from adjusting teaching strategies based on students' cognitive styles, strengthening metacognitive abilities, paying attention to initial abilities, to selecting learning methods that explicitly target the development of higher-order thinking skills.

**CONCLUSION**

This study yields three main conclusions. First, the profile of elementary school students' thinking skills based on the SOLO taxonomy shows an uneven distribution, with most students still concentrated at the pre-structural to multi-structural levels, with only a small proportion able to reach the relational or extended abstract levels. Second, the multi-structural level is the dominant level achieved by elementary school students in solving HOTS mathematics problems, indicating that students are able to use more than one piece of information but are not yet able to integrate it coherently. Third, differences in the levels of the SOLO taxonomy are influenced by cognitive style, metacognitive abilities, initial mathematical abilities, and the applied learning methods. The implications of these findings call for more systematic pedagogical reform, particularly in designing evaluation questions that progressively demand higher-order thinking skills. As a recommendation, teachers are advised to integrate the SOLO taxonomy as a diagnostic framework in assessing elementary school mathematics learning, and to implement learning strategies that explicitly target the development of relational and extended abstract thinking skills through a contextual and adaptive problem-based approach.

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