

Analysis of Mathematical Creative Thinking Ability Based on Solo's Taxonomy

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ABSTRACT

Purpose: This study aims to analyze high school students' mathematical creative thinking skills based on the SOLO Taxonomy and to describe the characteristics of mathematical creative thinking at each SOLO level.

Methodology: This study employed a mixed-methods design that integrated quantitative and qualitative approaches. The study participants consisted of 107 eleventh-grade students from four public high schools in Padang City, representing different school strata. The instrument used was a mathematical creative thinking test consisting of five open-ended questions, developed from indicators of mathematical creative thinking and the SOLO Taxonomy. Quantitative and qualitative analyses were conducted to describe students' mathematical creative thinking abilities and their characteristics at each SOLO level.

Findings: The study indicates that students' mathematical creative thinking skills have not yet reached the very high category. Of the four aspects of creativity, flexibility received the highest percentage (84.37%), followed by elaboration (76.27%), fluency (75.61%), and originality (70.58%). Based on the SOLO Taxonomy, students were distributed across the prestructural, unistructural, multistructural, relational, and extended abstract levels, with the majority of students (82.32%) at the multistructural level. The research findings also indicate that the higher the SOLO level achieved by students, the higher their creative thinking skills in mathematics. This suggests that students at higher levels possess better abilities to connect concepts, generate diverse ideas, and build generalizations.

Conclusion: This study contributes to mathematics education by presenting a comprehensive overview of students' mathematical creative thinking abilities at each SOLO level and demonstrating the relationship between the SOLO Taxonomy and these abilities. The findings of this study confirm that the SOLO Taxonomy can be utilized as a framework for identifying students' thinking levels and for designing HOTS-based learning and assessment strategies to enhance students' mathematical creativity.

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INTRODUCTION

Education is essential in everyone's life; through education, we begin to learn how the world works, making knowledge the most important aspect of life (Davi & Sari, 2025; Sari, Hasibuan, and Meiranti, 2025). The 2013 Curriculum is an initiative aimed at improving educational quality that has been implemented and continues to be refined. The curriculum plays a very important role in education because it is one of the interdependent components that influence other components (Adibah & Hikmawati, 2022; Azizah, D.A. et al., 2025). Progress in these quality improvements requires evaluation. Evaluation through tests is used to measure students' understanding of problem-solving. The questions used in this study are story-based questions containing information or data. Through this information or data, an expected solution is derived. Since the questions in this study are open-ended, a wide range of student responses is expected. Indirectly, this reflects students' understanding of a learning activity. Students' responses and solutions to the questions can illustrate their developmental progress. These varying developments can be grouped or classified within a specific structure. Biggs & Coils (1982) refer to these student responses as the SOLO Taxonomy. Lian & Idris (In Setiawan, R. & Mitasari, 2020) state that the SOLO Taxonomy is a cognitive psychology model that emphasizes students' internal processes and investigations in problem-solving rather than merely their correct answers.

The SOLO Taxonomy (Structure of the Observed Learning Outcome) not only measures students' learning outcomes but also allows teachers to assess the quality and nature of students' responses when solving problems. This is achieved by comparing the optimal correct answer with the students' actual responses. By analyzing these responses, teachers can classify students' abilities according to the levels of the SOLO Taxonomy. Biggs, J. B., & Coils (1982) state that the SOLO taxonomy consists of five hierarchical levels, ranging from the lowest to the highest: level (0) pre-structural, (1) unistructural, (2) multistructural, (3) relational, and (4) extended abstract.

In today's highly advanced world, students are expected to be creative. Similarly, education must work hard and strive to produce competent and creative generations. Enhancing student creativity remains one of the goals of the Merdeka Curriculum (Aliman, 2025). Student-centered learning provides students with opportunities to develop motivation, creativity, spatial skills, and critical thinking abilities; students are trained to solve real-life problems" (Sari, 2020). Istianah (2013) reports in her research that the improvement in students' mathematical creative thinking skills among those who received instruction using the MEA's approach was greater than that of students who received instruction through conventional methods.

Creative thinking is a higher-order competency that builds upon foundational competencies. It involves generating numerous relevant ideas or answers, maintaining a smooth flow of thought, producing diverse ideas – exploring different lines of reasoning, offering unconventional answers, and developing, expanding, enriching, and broadening an idea. According to (2007), "Creativity in mathematics is a higher category of ability that is distinct from attainment in conventional tests of mathematical skills, knowledge, and understanding." This means that creativity in mathematics is a higher-order ability distinct from performance on conventional tests of mathematical skills, knowledge, and understanding. Arvyati et al. (2015: 616) state that creative thinking is defined as an individual's ability to develop ideas or concepts that are fluent (smooth), flexible (adaptable), original, and elaborative. According to Permata and Yusuf (2022), mathematical creative thinking ability is a value that reflects originality and uniqueness in how students present or solve mathematical problems.

Creativity has four aspects known as the 4Ps: process, product, person, and place (Kozbelt, A., Beghetto, R. A., & Runco, 2010). Each aspect has its own focus area. The "creative person" aspect – often referred to as an individual's creative attitude – focuses on a person's habits in interacting with others or their approach to solving problems. Many students still perceive mathematics as difficult when presented with problems, leading most to doubt their own abilities (Ningsih *et al.*, 2020; Yakpi, Nurcahyono, and Mulyanti, 2023). This makes it crucial for teachers to pay attention to students' creative attitudes, which encompass independence, curiosity, openness to new experiences, self-confidence, and a willingness to take risks. Creativity can be defined as the ability to generate new ideas and solutions to problems and to perceive new relationships among existing elements (Hayat & Siswanto, 2024). Based on the above discussion, this study analyzes high

school students' mathematical creative thinking abilities using the SOLO taxonomy.

Mathematics instruction is expected not only to develop students' conceptual understanding but also to foster higher-order thinking skills, particularly creative mathematical thinking. However, many students still struggle with solving non-routine problems and open-ended questions. Students often rely on a single solution procedure and have difficulty generating various strategies or original ideas. Consequently, students' mathematical creative thinking abilities show significant variation and require further study.

Previous studies have examined mathematical creative thinking skills, while others have used the SOLO taxonomy to classify students' understanding and learning outcomes. However, these studies generally still focus on mathematical creative thinking skills or the SOLO taxonomy separately. Research integrating mathematical creative thinking abilities with the SOLO taxonomy remains relatively limited, particularly at the high school level. Furthermore, previous studies have placed greater emphasis on learning outcomes and the accuracy of students' answers without providing an in-depth understanding of the characteristics of students' creative thinking at each level of the SOLO taxonomy.

The SOLO taxonomy provides a hierarchical framework for analyzing student responses ranging from the prestructural level to the extended abstract level. Therefore, examining mathematical creative thinking abilities through the lens of the SOLO taxonomy can provide a more comprehensive understanding of students' thought processes and the quality of their solutions. Based on these considerations, this study aims to analyze the mathematical creative thinking abilities of high school students based on the SOLO taxonomy.

METHODOLOGY

Research Design

This study employed an explanatory sequential mixed-methods design, in which quantitative data were collected and analyzed first, followed by qualitative analysis to explain and elaborate on the quantitative findings. The quantitative phase focused on assessing students' mathematical creative thinking abilities using the SOLO taxonomy and a mathematical creative thinking test. Subsequently, the qualitative phase involved analyzing students' written work documents to provide a deeper description of students' characteristics and patterns of mathematical creative thinking according to the SOLO taxonomy. The integration of both phases was intended to provide a comprehensive understanding of students' creative mathematical thinking abilities. The study was conducted from April to May 2018 in Padang City, West Sumatra.

Participants

The population of this study consisted of 3,170 Grade XI students from 12 public senior high schools in Padang City during the 2017/2018 academic year. The sample size was determined using Slovin's formula with a 10% margin of error, yielding a minimum sample size of 97 students. Accordingly, 107 students participated in this study.

A proportional stratified random sampling technique was employed. First, public senior high schools were classified into high-, medium-, and low-achievement strata based on the average mathematics scores from the 2016/2017 National Examination. Four schools were then selected proportionally to represent each stratum. Subsequently, Grade XI students from the selected schools were selected in proportion to the number of students enrolled at each school.

Data Collection

Data were collected in two sequential phases. In the quantitative phase, students completed a mathematical creative thinking test designed based on the indicators of creative thinking and the SOLO taxonomy. The test results were used to determine students' levels of mathematical creative thinking.

In the qualitative phase, students' answer sheets and written work documents were analyzed to provide detailed descriptions of their problem-solving processes and characteristics of creative thinking at each SOLO taxonomy level. The qualitative findings were used to explain and strengthen the quantitative results.

Instruments

The primary instrument used in this study was a mathematical creative thinking test developed from indicators of mathematical creative thinking and the SOLO taxonomy. The instrument consisted of five open-ended items on sequence topics designed to assess four aspects of mathematical creative thinking: fluency, flexibility, originality, and elaboration. The test was administered to all participants with a time limit of 2×45 minutes. The test blueprint was constructed according to the operational definitions of mathematical creative thinking abilities based on the SOLO taxonomy.

Prior to implementation, the instrument was validated by two experts to ensure content validity. The expert judgment indicated that the test items were appropriate for measuring students' mathematical creative thinking abilities. Furthermore, the instrument's reliability was estimated using Cronbach's alpha, yielding a reliability index of 0.803, indicating good internal consistency.

Additionally, students' written answer sheets were used as qualitative documents to provide a deeper description of students' problem-solving processes and characteristics of creative thinking at each SOLO taxonomy level. These documents served as supporting qualitative data to explain and strengthen the quantitative findings.

Data Analysis

The data analysis technique used in this study is a quantitative-qualitative approach. The analysis was conducted to describe students' mathematical creative thinking abilities when solving mathematical problems, based on the SOLO taxonomy. Before analyzing the data using a qualitative approach, a quantitative analysis was conducted to determine the results for mathematical creative thinking abilities, specifically the percentage of abilities based on the SOLO taxonomy. The purpose of the quantitative approach was to facilitate data analysis to determine students' mathematical creative thinking abilities using the SOLO taxonomy.

Qualitative data analysis was conducted on students' written responses to the mathematical creative thinking test. The analysis process involved data reduction, data display, and conclusion. Students' answers were classified according to the SOLO Taxonomy levels: unistructural, multistructural, relational, and extended abstract. The qualitative analysis focused on identifying patterns in students' thinking processes, solution strategies, the originality of responses, and the characteristics of mathematical creative thinking, demonstrated at each SOLO level. The findings from the qualitative analysis were used to support and strengthen the quantitative results.

FINDINGS

Students' Mathematical Creative Thinking Ability

Mathematical Creative Thinking Ability by School Stratum

This study was conducted in 4 sample schools: 1 from the high stratum, 2 from the medium stratum, and 1 from the low stratum. The high-strata school was selected based on the results of a sampling conducted prior to the study. Students' mathematical creative thinking abilities were described based on an analysis of their test results, which comprised four aspects: fluency, flexibility, originality, and elaboration. The overall data on students' mathematical creative thinking abilities across each school stratum are presented in Table 1

Table 1. Description of Students' Mathematical Creative Thinking Ability Data by School Stratum

Description	High Stratum	Medium Stratum	Low Stratum	Overall
Category	High	High	Moderate	High
Average Score	28.6 (79.44%)	25.96 (72.11%)	24.33 (67.58%)	26.2 (72.78%)
Standard Deviation	2.02	4.98	7.46	5.4
Highest Possible Score	36	36	36	36
Lowest Possible Score	0	0	0	0
Highest Score Achieved	32	35	36	39
Lowest Score Achieved	23	14	9	9

Table 1 presents information on high school students' mathematical creative thinking abilities, based on the average of their responses to five problems assessing it. Each school stratum has a different average, although no students in Padang City achieved the "very high" category. This indicates that students struggle to solve mathematical creative thinking problems.

Creative thinking ability in the high stratum meets the high criteria, with an average of 28.6. The highest score achieved by students was 32, and the lowest was 23. Schools in the medium stratum are in the high category, but with an average of 25.96. The highest score achieved by students was 35, and the lowest was 14. This differs slightly from the results obtained by schools in the low stratum, which were 24.33, but places schools in the low stratum within the "adequate" category. The highest score achieved by students was 36, and the lowest was 9.

Distribution of Students' Mathematical Creative Thinking Ability

The frequency and percentage of students in each criterion of mathematical creative thinking ability were calculated according to the predetermined score ranges, as shown in Table 2.

Table 2. Frequency Distribution (Percentage) of Students' Mathematical Critical Thinking Ability Criteria by School Stratum

Stratum	Very High	High	Moderate	Low	Very Low	Total
High	9 (33.33%)	17 (62.96%)	1 (3.7%)	0 (0%)	0 (0%)	27 (100%)
Medium	13 (24.53%)	25 (47.17%)	7 (13.21%)	7 (13.21%)	1 (1.89%)	53 (100%)
Low	8 (29.63%)	6 (22.22%)	7 (25.93%)	2 (7.41%)	4 (14.81%)	27 (100%)
Total	30 (28%)	48 (45%)	15 (14%)	9 (8%)	5 (5%)	107 (100%)

Table 2 presents information on the frequency and percentage of students' mathematical creative thinking abilities across the school strata included in the study sample. There were only 5 students in Padang City who fell into the very low category: 1 student from a school in the medium stratum and 4 students from the low stratum. There were 27 research subjects in high-strata schools, with 9 in the very high category, 17 in the high category, and 1 in the adequate category. In medium-strata schools, there were 53 subjects, with 13 in the very high category, 25 in the high category, 7 in the medium category, and 7 in the low category. In the low-tier school, 8 students were in the very high category, 6 in the high category, 7 in the moderate category, and 2 in the low category. Furthermore, the percentage distribution of Overall Mathematical Creative Thinking Ability is also illustrated in the following histogram:

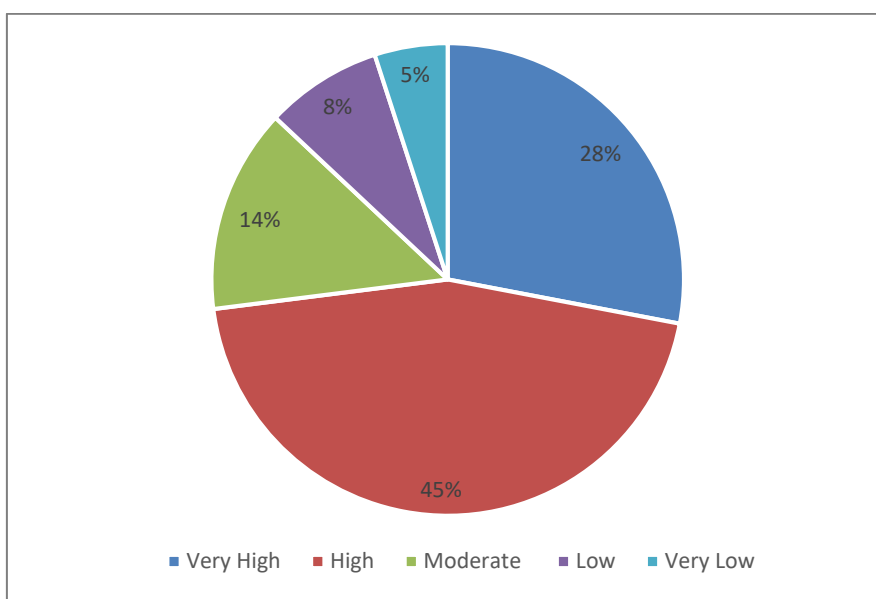


Figure 1. Percentage Diagram of Overall Mathematical Creative Thinking Ability

Based on the histogram presented above, there were 107 students as research subjects, with the majority (45%, or 48 students) falling into the high category. This aligns with the overall sample average of 26.2, which falls within the high category. Since the average for students in Padang City reached the high category, it can be concluded that students' mathematical creative thinking skills are good.

Achievement of Mathematical Creative Thinking Aspects

The achievement of the Creative Thinking Indicators for each school stratum is presented.

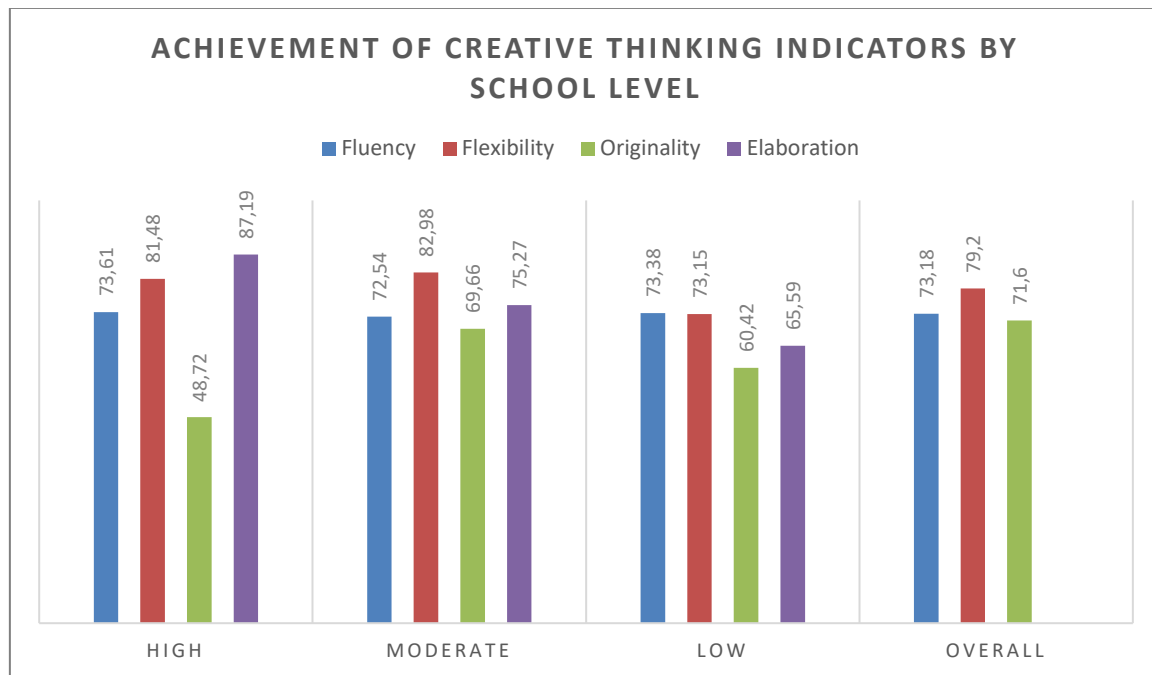


Figure 2. Achievement of Creative Thinking Indicators by School Stratum

Based on Figure 2, it is evident that in high-tier schools, the highest achievement on the elaboration indicator was observed among students, with an average of 87.19, while the fluency indicator showed the lowest achievement, with an average of 73.61. However, in contrast to schools in the middle stratum, the highest achievement, 79, was obtained in the flexibility indicator, with an average of 87.98, and the lowest, 69.66, was obtained in the originality indicator. In schools in the low stratum, the scores for the fluency and flexibility indicators were very close. However, flexibility remained the highest, with an average of 73.38, while students scored the lowest on the originality indicator, with an average of 60.42. Figure 2 also shows the average range of mathematical creative thinking skills across all strata. When viewed as a whole, the flexibility indicator had the highest achievement, nearly matching that of schools in the middle stratum. The lowest achievement was in the originality indicator, similar to the middle and low strata.

Table 3. Average Mathematical Creative Thinking Ability by School Tier

Aspects	School Stratum			Overall
	High	Moderate	Low	
Fluency	79.5	68.08	79.25	75.61
Flexibility	88	91.96	73.15	84.37
Originality	91.5	59.82	60.42	70.58
Elaboration	94.17	69.05	65.59	76.27

Table 3. presents the average level of students' mathematical creative thinking ability by aspect and school stratum. In high-stratum schools, the elaboration aspect ranks highest among the aspects, while the fluency aspect ranks lowest. In medium-stratum schools, the highest-scoring aspect is flexibility, and the lowest is originality. In low-stratum schools, students' highest achievement was in fluency and their lowest in

originality. Overall, flexibility represents the highest student achievement, with an average of 84.37. The lowest achievement in the mathematical creative thinking ability test was in the originality aspect, with an average of 70.58.

Students' Mathematical Creative Thinking Ability Based on the SOLO Taxonomy

Students' Achievement at Each SOLO Level

Students' mathematical creative thinking skills were classified based on an analysis of test responses that incorporated SOLO taxonomy indicators. The SOLO taxonomy indicators included in the test comprised four categories: unistructural, multistructural, relational, and extended abstract. Data on students' overall performance in mathematical creative thinking across each SOLO taxonomy category are presented in Table 4.

Table 4. Students' Mathematical Creative Thinking Abilities Based on the SOLO Taxonomy

Descriptions		School Level			Overall
		High	Moderate	Low	
Unistructural	Correct Answer	84.62	97.36	87.50	80.37
	Incorrect Answer	15.38	2.64	12.50	19.63
Multistructural	Criteria	High	Very High	High	High
	Correct Answer	96.15	86.64	73.72	82.32
	Incorrect Answer	3.85	13.36	26.28	17.68
Relational	Criteria	Very High	High	High	High
	Correct Answer	84.94	59.55	69.55	69.00
	Incorrect Answer	15.06	40.45	30.45	31.00
Extended abstract	Criteria	High	Moderate	Moderate	Moderate
	Correct Answer	57.21	51.51	57.21	60.51
	Incorrect Answer	42.79	48.49	42.70	39.49
	Criteria	Moderate	Moderate	Moderate	Moderate

Students achieved the highest percentage at the multistructural level (82.32%), followed by the unistructural level (80.37%). Lower percentages were found at the relational level (69.00%) and the extended abstract level (60.51%).

Relationship between SOLO Taxonomy Levels and Creative Thinking Aspects

Table 5. Percentage of Students' Creative Thinking Skills by SOLO Taxonomy

SOLO Taxonomy	Creative Thinking	School Level			Overall
		High	Moderate	Low	
Unistructural	Fluency	86.26	85.60	84.26	85.37
	Fluency	92.13	82.08	68.52	85.52
Multistructural	Originality	93.52	75.47	61.11	76.40
	Elaboration	92.59	82.86	70.99	82.32
Relational	Originality	81.79	66.98	60.19	69.00
	Elaboration	81.79	66.98	60.19	69.00
Extended abstract	Fluency	50.93	59.43	57.41	56.78
	Flexibility	81.48	66.51	73.15	80.37

Table 5 presents students' mathematical creative thinking abilities across the SOLO taxonomy levels. Overall, the highest percentage is found in the fluency aspect of mathematical creative thinking at the multistructural level of the SOLO taxonomy. Mathematical creative thinking abilities can be observed across each school stratum. Students in high-stratum schools, on average, score highly at the multistructural level of the SOLO taxonomy. However, at the unistructural level, they have the lowest percentage compared to students in other school strata.

Characteristics of Students' Mathematical Creative Thinking at Each SOLO Level

Unistructural Level

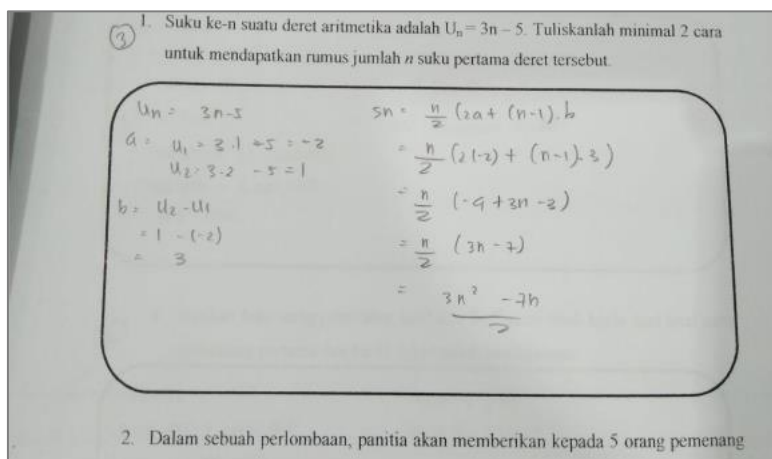


Figure 3. Unistructural Level

Students at the unistructural level tend to focus on a single piece of relevant information and use a single procedure they consider correct to solve mathematical problems. Based on the results of this study, mathematical creative thinking ability at the unistructural level showed an overall percentage of 85.37%, indicating that fluency begins to emerge at this level. Students are generally able to identify known information and apply formulas or procedures they have learned to obtain the correct answer. This finding is supported by the results of the analysis of students' answers on the fluency aspect, in which students were able to solve problems correctly but used only one method, even though the problem required more than one. This indicates that students' thinking is still centered on a single representation or a single path to a solution.

Nevertheless, flexibility and originality at this level remain relatively limited. Students are not yet able to generate a variety of alternative strategies and tend to rely on the standard procedures taught by their teachers. The ideas that emerge are still routine and do not yet show any effort to find new ways that differ from the usual. Thus, the main characteristic of students at the unistructural level is the beginning of fluency in problem-solving. However, the ability to develop various strategies and generate original ideas has not yet reached its full potential.

Multistructural Level

At the multistructural level, students were able to use several relevant pieces of information to solve problems, but they still processed that information separately. The research results showed that this level had the highest average percentage among the SOLO levels, particularly in the fluency aspect, at 85.52%. In addition, the aspects of originality and elaboration began to develop, with percentages of 76.40% and 82.32%, respectively. Students have been able to present solution steps in greater detail and use more than one piece of available information to arrive at the correct answer.

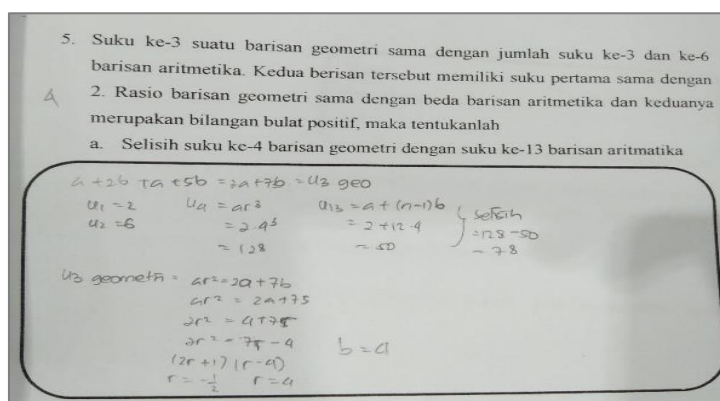


Figure 4. Aspect of Flexibility

Nevertheless, students still struggle to connect this information into a coherent whole. They can identify some of the concepts needed to solve problems, but they do not yet have a deep understanding of the relationships between these concepts. As a result, the problem-solving process is carried out in a step-by-step and fragmented manner. This situation indicates that fluency is the most dominant characteristic at the multistructural level. At the same time, the ability to generate more original ideas and develop detailed solutions begins to emerge, even though the integration of ideas has not yet fully formed.

Relational Level

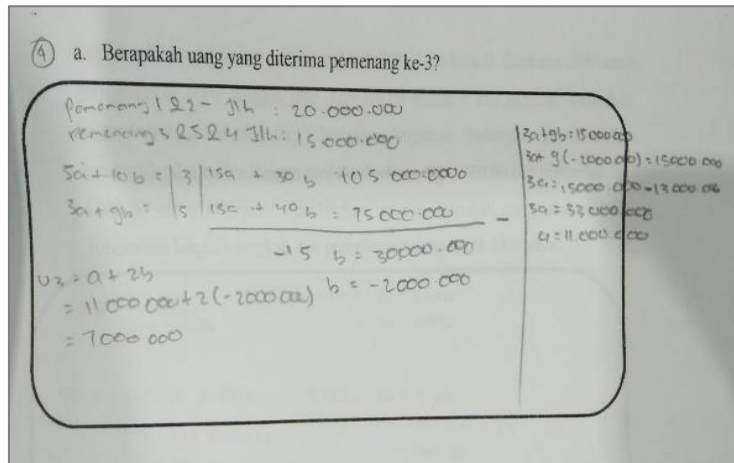


Figure 5. Relational Level

Students at the relational level demonstrate greater ability because they can connect several mathematical concepts involved in a problem. Based on the research results, the aspects of originality and elaboration at this level account for 69.00% in total. These findings indicate that students' ability to develop ideas and explain the problem-solving process in greater depth is becoming stronger. Students are not only able to identify available information but also to understand the relationships between concepts, thereby producing more systematic and logical solutions.

This is evident in the responses of students who can connect the concepts of arithmetic and geometric sequences when solving problems. Unlike students at the multistructural level, who still view information in isolation, students at the relational level have been able to establish clear relationships between concepts, making their thinking process more structured. Thus, the main characteristics of the relational level are a stronger emphasis on originality and elaboration, along with the ability to identify and connect relevant concepts in problem-solving.

Extended Abstract Level

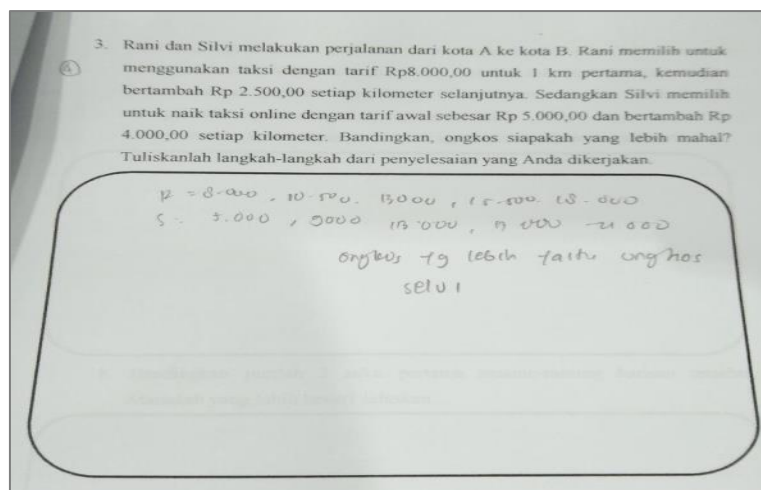


Figure 6. Extended Abstract Level

The extended abstract level is the highest in the SOLO taxonomy, indicating more complex mathematical creative thinking skills. In this study, flexibility was the most prominent characteristic, with an overall percentage of 80.37%, while fluency had a lower percentage, at 56.78%. These findings indicate that students at this level focus not only on the number of answers produced but also on their ability to develop a variety of problem-solving strategies. Students can view problems from multiple perspectives and are not confined to a single procedure.

In addition, students' responses at the extended abstract level tend to be more innovative and demonstrate the ability to generalize concepts they have already understood. Students can modify the strategies they use, compare alternative solutions, and apply mathematical concepts to broader contexts. Therefore, the main characteristics at this level are greater flexibility, the ability to generate diverse approaches, and a tendency to provide more creative and innovative solutions. This level represents the highest form of mathematical creative thinking ability according to the SOLO taxonomy, as students have moved beyond routine procedures to construct more abstract and complex ideas.

The research subjects – 11th-grade students at a public high school in Padang – exhibit mathematical creative thinking abilities at the *unistructural*, *multistructural*, *relational*, and *extended abstract* levels. On average, students demonstrate creative mathematical thinking in the high category; however, according to the SOLO taxonomy, the average student remains at the *multistructural* level. The following figure presents information on students' responses according to the SOLO taxonomy.

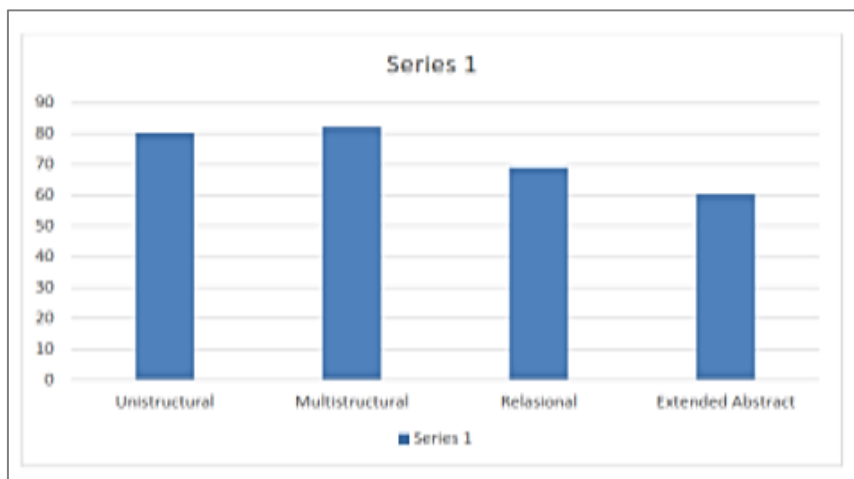


Figure 7. Students' Mathematical Creative Thinking Abilities Based on the SOLO Taxonomy

When viewed as a whole, the scores for students' mathematical creative thinking abilities based on the SOLO taxonomy show little difference between the *unistructural* and *multistructural* levels. However, it can be generalized that students' overall mathematical creative thinking abilities form a hierarchy, such that students with higher scores answer easier problems more readily than problems perceived as more difficult. The great perceived difficulty at the *relational* and *extended abstract* levels meant that only some students were able to solve them. Since students' mistakes varied, the interventions provided by teachers also differed. Appropriate and timely interventions can help students understand the lesson material. Therefore, teachers need to identify where students' misunderstandings or errors lie in solving problems so that the assistance provided is precise.

DISCUSSION

Overview of Students' Mathematical Creative Thinking Ability

The research findings indicate that the mathematical creative thinking ability of high school students in Padang City remains suboptimal, despite variations across school strata. No stratum achieved the "very high" category, highlighting the need for serious attention to its development. Differences in achievement across schools indicate that the quality of instruction, access to learning resources, and teachers' pedagogical approaches

also influence these abilities. Nevertheless, the presence of relatively high maximum scores in the moderate and low strata suggests that students' creative potential is widespread but has not yet been fully supported in the learning process. This aligns with studies in Mathematics Education that emphasize the importance of instructional designs that encourage exploration and open-ended problem-solving.

From a creative thinking perspective, flexibility is the aspect that shows the greatest achievement, indicating that students are able to generate a variety of solutions and perspectives. However, the aspect of originality remains only moderate, suggesting that the ideas generated are not yet fully innovative. Additionally, the fluency aspect falls into the moderate category, indicating students' limited ability to generate numerous ideas, likely due to a lack of practice with open-ended problems. Meanwhile, the elaboration aspect is fairly good, though not yet in-depth. Overall, these results suggest that learning remains procedure-oriented, thereby failing to foster students' mathematical creativity fully.

The Relationship Between the SOLO Taxonomy and Mathematical Creative Thinking Skills

Higher-order thinking skills cannot be acquired instantly but require strong, professional human resources in education (Sari & Arini, 2024). Creative thinking skills are essential for every student (Hanifah et al., 2024). From a creative thinking perspective, flexibility is the aspect with the highest achievement, indicating that students have been able to generate a range of alternative solutions and perspectives. However, originality remains in the moderate category, suggesting that the ideas generated are not yet fully innovative. Additionally, fluency is in the moderate category, suggesting that students still face limitations in generating numerous ideas, possibly due to a lack of experience solving open-ended problems. Meanwhile, the elaboration aspect is fairly good, though it has not yet demonstrated in-depth solution development. Overall, these results indicate that the current learning process remains procedure-oriented and thus has not fully facilitated the optimal development of students' mathematical creativity.

The SOLO taxonomy can be used as an effective tool for identifying students' levels of thinking (Riyani et al., 2023; Riska & Munandar, 2025). The SOLO taxonomy is used to accurately analyze students' responses in solving mathematical problems (Setiawan et al., 2022). Additionally, the SOLO taxonomy provides a framework for measuring and analyzing students' levels of thinking, identifying errors, and designing effective assessment instruments (Irfana et al., 2024). Based on the SOLO taxonomy, most students' abilities are at the multistructural level, indicating that they can understand several concepts separately but have not yet integrated them comprehensively or made generalizations. Students tend to succeed on low-difficulty questions but still struggle with higher-order thinking skills (HOTS). This situation indicates that current instruction has not fully accommodated the development of HOTS.

The findings of this study indicate that the higher the SOLO taxonomic level achieved by students, the higher their creative thinking skills in mathematics. There is a gradual progression from the prestructural, unistructural, and multistructural levels to the relational and extended abstract levels, reflecting improvements in students' ability to understand information, connect concepts, generate diverse ideas, and build generalizations. In other words, higher SOLO levels tend to indicate higher levels of mathematical creative thinking ability.

These results are consistent with the theory proposed by Biggs and Collis (1982), which explains that cognitive development proceeds hierarchically from simple responses toward integrated and abstract thinking. Students at higher SOLO levels possess more complex cognitive structures, enabling them to generate more varied and meaningful solutions. These findings also support the research results of Riyani et al. (2023), Setiawan et al. (2022), and Irfana et al. (2024), which indicate that the SOLO taxonomy can describe students' thinking processes and is closely related to higher-order thinking skills. Therefore, learning innovations such as problem-based learning, contextual learning, and ethnomathematics-based approaches are needed and should be supported by teachers, who play an adaptive role in identifying students' errors, so that progress toward higher SOLO levels can be achieved and students' mathematical creative thinking skills can improve.

Characteristics of Mathematical Creative Thinking Abilities at Each SOLO Level

According to Biggs and Collis (1982), the development of students' thinking skills proceeds hierarchically

through five levels: prestructural, unistructural, multistructural, relational, and extended abstract. The results of this study indicate that the characteristics of students' mathematical creative thinking skills become increasingly complex as their SOLO achievement level increases.

Unistructural Level

Students at the unistructural level tend to focus on a single piece of information and can follow a single correct procedure. At this level, fluency begins to emerge as students can provide correct answers. However, the flexibility and novelty remain relatively limited. This indicates that students have begun to understand a concept but are not yet able to connect it to other information. These characteristics align with the description of the unistructural level proposed by Biggs and Collis (1982).

Multistructural Level

Most of the students in this study were at the multistructural level. At this level, students were able to understand some information and use more than one problem-solving procedure, but they still understood these concepts in isolation. As a result, their flexibility and elaboration began to develop more fully, while their ability to handle novel situations remained relatively low. This finding supports previous research indicating that students at the multistructural level can generate several problem-solving strategies but have not yet fully integrated various concepts.

Relational Level

At the relational level, students have been able to connect various concepts and organize information into a coherent structure. Therefore, the four aspects of mathematical creative thinking begin to emerge more clearly. Students demonstrate greater fluency in generating ideas, flexibility in selecting solution strategies, and more in-depth elaboration when explaining the steps of the solution. These findings align with the theory proposed by Biggs and Collis (1982), which holds that relational-level thinking involves integrating multiple components into a meaningful whole.

Extended Abstract Level

Students at the extended abstract level demonstrate the highest level of mathematical creative thinking. They are not only able to integrate various concepts but also to generalize and develop new ideas. At this level, originality is more prominent, as students can produce unique and innovative solutions. According to Biggs and Collis (1982), the extended abstract level is a form of abstract thinking and generalization closely related to creativity and higher-order thinking skills. Therefore, students at this level demonstrate the most comprehensive characteristics of mathematical creative thinking.

Dominant Aspects of Mathematical Creative Thinking Ability

Based on Table 3, flexibility received the highest percentage (84.37%), followed by elaboration (76.27%), fluency (75.61%), and originality (70.58%). These results indicate that students have been relatively able to use various problem-solving strategies and view problems from different perspectives. These findings suggest that mathematics instruction has provided students with opportunities to explore various problem-solving procedures, although it has not yet fully fostered the emergence of truly novel ideas.

On the other hand, originality had the lowest percentage. This indicates that students still struggle to generate truly new ideas and tend to rely on previously familiar procedures. This finding aligns with various previous studies showing that novelty is the most difficult to develop, as conventional learning is generally still procedure-oriented and does not provide students with sufficient opportunities to explore through open-ended problems.

Why Most Students Are at the Multistructural Level?

Based on Table 4, the majority of students (82.32%) are at the multistructural level. According to Biggs and Collis (1982), students at this level can understand some information but are not yet able to integrate it into a coherent whole. Consequently, students can solve routine problems and use several problem-solving procedures

but still experience difficulties with problems that require conceptual connections, reasoning, and generalization skills.

The predominance of the multistructural level indicates that current mathematics instruction does not fully facilitate the development of higher-order thinking skills. Students tend to succeed on low-cognitive-demand problems but struggle with more complex and non-routine ones. These findings align with previous research indicating that many students remain at the multistructural level because procedural and teacher-centered approaches still dominate the current learning process. Therefore, learning innovations such as problem-based learning, contextual learning, and ethnomathematics-based learning are needed to encourage students' development toward the relational and extended abstract levels.

CONCLUSION

The results of the study indicate that the mathematical creative thinking skills of high school students in Padang City remain in the suboptimal category, with flexibility as the most dominant aspect, followed by elaboration, fluency, and originality, which show the lowest achievement levels. Based on the SOLO taxonomy, students' abilities are distributed across five levels of thinking: prestructural, unistructural, multistructural, relational, and extended abstract, with the majority of students (82.32%) at the multistructural level. This indicates that students can understand some information and use certain problem-solving procedures, but are not yet capable of integrating concepts comprehensively or making generalizations. The findings of this study indicate that the higher the SOLO taxonomy level achieved by students, the higher their ability in mathematical creative thinking. There is a positive relationship between the development of thinking levels according to the SOLO taxonomy and students' mathematical creative thinking ability. Students at higher levels demonstrate stronger abilities to generate diverse ideas, connect concepts, provide more detailed explanations, and construct generalizations. Therefore, the SOLO taxonomy can be utilized by teachers as a framework to identify students' thinking levels, analyze learning difficulties, and design instruction and assessment aligned with students' cognitive development. To enhance mathematical creative thinking skills, teachers need to provide learning experiences that encourage higher-order thinking through non-routine and open-ended problems, problem-based learning, contextual learning, and an ethnomathematics-based approach that allows students to explore various solution strategies, connect concepts, and develop more original ideas so that students can progress toward the relational and extended abstract levels.

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