

# STUDENTS' MATHEMATICAL CREATIVE THINKING PROFILE IN ALGEBRA OLYMPIAD PROBLEMS THROUGH PROJECT-BASED ASSESSMENT: A QUALITATIVE CASE STUDY

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## Abstract

Mathematical creative thinking is a higher-order thinking competency that is essential in developing mathematics olympiads because it requires the ability to produce non-routine solutions flexibly, originally, and elaborately. This study aims to describe in depth the mathematical creative thinking profile of students on the mathematics olympiad team at the junior high school level through the application of project-based assessment on the subject of algebra olympiads. The study used a qualitative descriptive approach with a case study design. The research subjects consisted of three students on the mathematics olympiad team who were selected purposively. Data collection was carried out through open-ended algebra tests, project assignments, observations, and semi-structured interviews. Data analysis focused on four indicators of mathematical creative thinking: fluency, flexibility, originality, and detail, with data validity maintained through triangulation of techniques and assessors. The results showed that each subject had a different mathematical creative thinking profile. Project-based assessment was able to facilitate the emergence of a variety of solution strategies, original solutions, and reflection on the mathematical thinking process, especially in students who were actively involved in the project implementation. These findings provide an empirical contribution to the development of authentic assessment in the context of developing mathematics olympiads and enrich the study of mathematical creative thinking in algebraic material.

***Keywords: mathematical creative thinking: project-based assessment: math olympiad: algebra.***

## INTRODUCTION

Within the framework of modern education, mathematical creativity is seen as a crucial foundation for the development of higher-order reasoning and complex problem solving. Leikin and Pitta-Pantazi (2021) and the OECD (2019) emphasize that mathematical creative thinking is a key 21st-century competency that needs to be systematically developed in mathematics learning. This ability is not only related to producing correct answers but also encompasses the ability to explore diverse ideas, use flexible strategies, and construct original and logically elaborated solutions. In the context of advanced mathematics learning, particularly in mathematics olympiads, mathematical creative thinking is a crucial competency. Students in olympiads are faced with non-routine problems that cannot be solved solely using standard algorithmic procedures but instead require the exploration of alternative strategies, flexible symbolic manipulation, and the ability to discern patterns in depth (Sriraman, 2020; Pratiwi & Suryadi, 2023). Therefore, students' success in mathematics competitions is not solely determined by conceptual mastery but also by the quality of their creative thinking processes.

Students' mathematical creative thinking profiles are generally analyzed through four main indicators: fluency, flexibility, originality, and elaboration (Mann, 2018; Yuniarti & Siswono, 2020). Fluency refers to the ability to generate multiple ideas or strategies, flexibility relates to the variety of approaches used, originality indicates the novelty of the solution, and elaboration reflects the depth and clarity of the mathematical explanation. These four indicators are multidimensional and do not always appear simultaneously in every individual (Leikin, 2021). However, various studies show that the development of students' mathematical creative thinking, including those with high abilities, has not been optimally facilitated in Olympiad learning practices and coaching. Olympiad coaching in many schools and Islamic schools still focuses on routine practice problems, intensive drilling, and speed-of-completion targets, leaving relatively limited room for idea exploration and reflection on thought processes (Suripah & Sthephani, 2021; Miatun & Nurafni, 2023).

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Assessment plays a strategic role in shaping how students learn and think. Assessments that solely emphasize outcomes tend to encourage students to seek the quickest answers, while authentic, process-oriented assessments can create opportunities for students to explore strategies, test ideas, and reflect more deeply on their thinking (Suherman & Vidákovich, 2022). One form of authentic assessment widely recommended in the mathematics education literature is project-based assessment (Bell, 2018; Krajcik et al., 2020). Previous research has shown that project-based assessment can encourage deeper exploration of strategies, mathematical communication, and reflection on students' thinking processes compared to conventional assessments, including in the context of advanced mathematics learning (Putri & Zulkardi, 2021; Hasanah & Utami, 2021). In the context of mathematics, this approach has proven effective in revealing variations in students' strategies and creative thinking skills, particularly when assignments are designed in the form of open-ended and challenging questions (Nurjanah & Hidayat, 2022). However, empirical studies specifically investigating the application of project-based assessment in the context of mathematics olympiad coaching, particularly at the junior high school level and algebra material, are still relatively limited. Therefore, this study focuses on describing the mathematical creative thinking profile of students on the mathematics olympiad team through the application of project-based assessment to algebra olympiad problems.

## LITERATURE REVIEW

Mathematical creative thinking is a high-level thinking ability that reflects an individual's capacity to generate diverse, flexible, original, and logically elaborated mathematical ideas, strategies, and solutions to solve non-routine problems (Leikin & Pitta-Pantazi, 2021; Suherman & Vidákovich, 2022). From a contemporary mathematics education perspective, creativity is not viewed as an innate ability alone, but rather as a cognitive competency that can be developed through learning experiences and an environment that supports exploration and reflection (Sriraman, 2020). Therefore, mathematical creativity requires the integration of divergent thinking to generate various possible solutions and convergent thinking to ensure the mathematical validity of the resulting solutions. Conceptually, mathematical creative thinking is multidimensional and is generally analyzed through four main indicators: fluency, flexibility, originality, and elaboration. Fluency refers to the ability to generate multiple relevant ideas or alternative strategies, while flexibility relates to the ability to use conceptually different approaches to solving mathematical problems (Yuniarti & Siswono, 2020; Leikin, 2021). Originality refers to the novelty of the resulting strategy or solution, while elaboration reflects the ability to explain the solution process coherently, systematically, and in-depth (Nurjanah & Hidayat, 2022). These four indicators do not always appear simultaneously, so each student's mathematical creative thinking profile may vary.

In the context of the Mathematics Olympiad, mathematical creative thinking is a very essential competency because the characteristics of Olympiad questions require non-routine problem-solving skills, abstract reasoning, and high strategic flexibility (Sriraman, 2020; Rahmawati et al., 2022). Olympiad team students are required not only to understand concepts but also to construct and evaluate various solution approaches reflectively. However, several studies show that Olympiad coaching in schools and Islamic schools still tends to be oriented towards procedural and speed training, so opportunities for developing mathematical creativity are not fully optimized (Suripah & Sthephani, 2021; Miatun & Nurafni, 2023). Assessment plays a strategic role in shaping how students learn and think. Project-based assessment is a form of authentic assessment that assesses the learning process and product through complex and meaningful mathematical tasks, allowing students to explore strategies, integrate concepts, and reflect on their thinking processes (Bell, 2018; Krajcik et al., 2020). In mathematics learning, project-based assessment has been shown to be effective in uncovering variations in students' strategies and indicators of mathematical creative thinking, especially when project assignments are designed in the form of open-ended and contextual questions (Nurjanah & Hidayat, 2022; Suherman & Vidákovich, 2022).

Algebra is a relevant mathematical domain for studying mathematical creative thinking because it demands the ability to manipulate symbols, abstract reasoning, and representational flexibility. In the context of the Olympiad, algebraic material—particularly factoring and describing algebraic forms—provides opportunities for various solution strategies with varying levels of complexity, thus enabling in-depth analysis of students' mathematical creative thinking profiles (Suripah & Sthephani, 2021; Pratiwi & Suryadi, 2023). Thus, the application of project-based assessment to algebraic material provides a strong theoretical foundation for uncovering and developing mathematical creative thinking in students on the Mathematics Olympiad team.

## METHOD

This study uses a qualitative descriptive approach with a case study design, which aims to deeply reveal the profile of students' mathematical creative thinking in the context of mathematics olympiad coaching. The research

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subjects consisted of three students from the MTs Abadiyah mathematics olympiad team who were selected by purposive sampling based on their mathematical ability, active participation in coaching, and willingness to participate in the entire research series. The selection of a limited number of subjects was intended to allow for in-depth and contextual data exploration. The research instruments included an open-ended algebra test, an authentic assessment-based project assignment, an observation sheet, and a semi-structured interview guide. Prior to use, the test and project instruments underwent a content validity test through expert judgment by two mathematics education lecturers and one mathematics olympiad coach. The feasibility test focused on the suitability of the questions to the research objectives, the characteristics of the olympiad questions, and indicators of mathematical creative thinking, namely fluency, flexibility, originality, and detail (Leikin & Pitta-Pantazi, 2021). Instrument reliability in a qualitative context was maintained through consistency of analysis indicators and inter-rater agreement.

Project-based assessment was conducted during two Olympiad coaching sessions. Students were asked to solve Olympiad algebra problems with the following requirements: (1) using more than one strategy if possible, (2) explaining the rationale for their strategy selection, and (3) writing a reflection on their mathematical thinking process. The project products consisted of written worksheets and oral presentations, which were analyzed to identify students' mathematical creative thinking profiles (Bell, 2018; Nurjanah & Hidayat, 2022). Data were collected through tests, project outcome analysis, observations, and semi-structured interviews. Data analysis was conducted through data reduction, data presentation, and conclusion drawing, with a focus on meeting the indicators of mathematical creative thinking. Data validity was maintained through technical and assessor triangulation, ensuring high credibility and trustworthiness of the research results (Suherman & Vidákovich, 2022).

**Figure 1. Algebra Problem**

1. Faktorkan bentuk aljabar berikut dengan dua cara berbeda. Tunjukkan setiap langkah-langkahnya secara lengkap!

$$x^2 + 2xy + 3y^2 - 4x - 6y + 2$$

**Table 1. Indicators of Mathematical Creative Thinking**

Indicator	Operational Description
Smoothness	Generate more than one relevant solution
Flexibility	Using a variety of different strategies or approaches
Authenticity	Generating uncommon solutions or strategies
Details	Explain the completion steps in a coherent and detailed manner

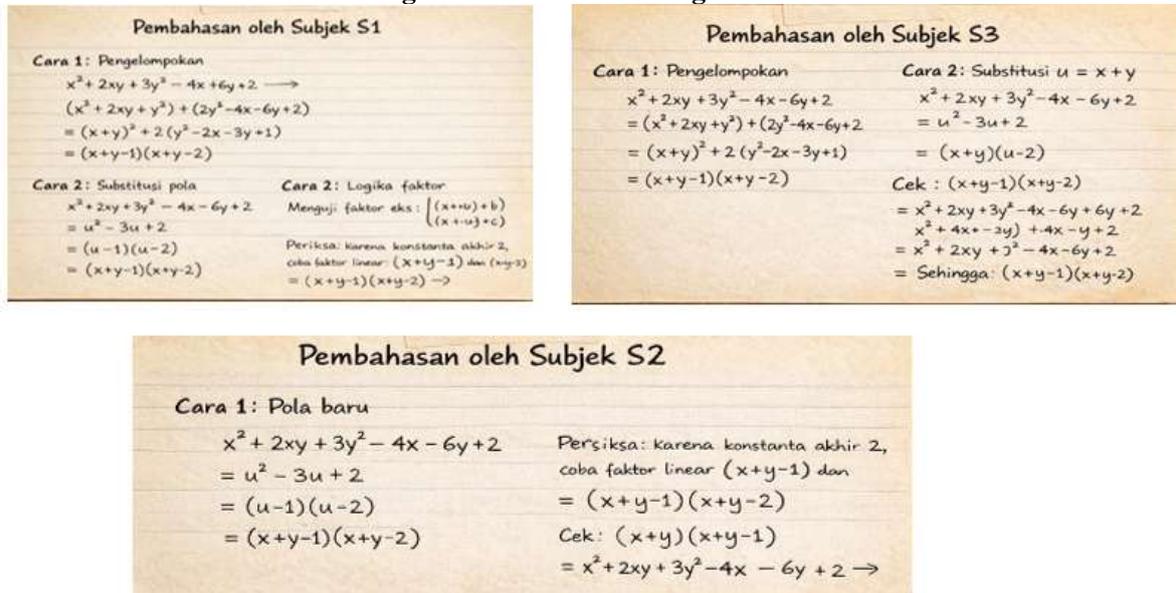
**Table 2. Data Collection Techniques**

Technique	Objective
Open algebra test questions	Identifying variations in strategies and solutions
Project assignment	Revealing the creative thinking process in depth
Observation	Recording student activities and engagement
Interview	Exploring the reasons and reflections of mathematical thinking

RESULTS AND DISCUSSION

The results of the study indicate that the mathematical creative thinking profiles of the Olympiad team students are diverse and not homogeneous, even though all three subjects have high mathematical abilities. This variation is evident in the fulfillment of the indicators of fluency, flexibility, originality, and detail, which appear differently in each subject. These findings confirm that mathematical creativity is a multidimensional cognitive construct that does not develop uniformly across individuals (Leikin & Pitta-Pantazi, 2021; Suherman & Vidákovich, 2022).

Figure 2: Problem Solving Results



Subject S1 shows the dominance of fluency and flexibility indicators. S1 is able to produce more than two algebraic factoring strategies and switch strategies reflectively when the initial strategy is deemed less efficient. This is reinforced by the following interview statement:

"I tried several methods. If one method felt too long, I switched to another, faster method." (W-S1-01).

This statement indicates strategic flexibility and metacognitive awareness in selecting a solution approach, which are key characteristics of mathematical creative thinking in non-routine problems (Leikin, 2021). However, S1's written explanation was not fully elaborated conceptually, so the detail indicator fell into the moderate category. Subject S2 demonstrated significant strength in the originality indicator. S2 used an unconventional approach by first transforming the algebraic form to find hidden patterns before factoring. This is reflected in the interview statement:

"I change the shape first so that the pattern can be seen, then factor it in." (W-S2-01).

This strategy is rarely used by other subjects and demonstrates the ability to creatively see algebraic structures. However, S2 was less able to explain the solution steps in detail, resulting in a less developed detailed indicator of detail. This finding aligns with Yuniarti and Siswono (2020), who stated that originality of ideas is not always accompanied by strong mathematical elaboration skills. Subject S3 exhibited a different profile, with a predominance of detail indicators. S3 wrote down the solution steps in a coherent and systematic manner, emphasizing the importance of procedural clarity. This was reinforced by the interview results:

"I wrote down the steps one by one so that they could be checked and not made any mistakes." (W-S3-01).

However, the variety of strategies used by S3 was relatively limited, resulting in low fluency and flexibility indicators. This profile reflects a tendency toward convergent and procedural thinking, as reported in research by Mann (2018) and Rahmawati et al. (2022). The relationship between the indicators of mathematical creative thinking and interview data for the three subjects is presented in Table 1.

**Table 1. Matrix of Relationships between Mathematical Creative Thinking Indicators and Interview Data**

Subject	Smoothness	Flexibility	Authenticity	Details	Key Interview Quotes
S1	✓ ✓	✓ ✓	✓	✓	"I tried several ways..." (W-S1-01)
S2	✓	✓	✓ ✓	✗	"I changed the shape first..." (W-S2-01)
S3	✗	✗	✓	✓ ✓	"I wrote down the steps one by one..." (W-S3-01)

Information: ✓ ✓ = dominant, ✓ = just appear, ✗ = does not appear optimal yet.

Based on this matrix, it is clear that each subject has distinct strengths in indicators, so no single subject optimally fulfills all indicators of mathematical creative thinking. This reinforces the view that mathematical creativity is not simply a level of ability, but rather a thinking profile influenced by learning experiences and individual character (Leikin & Pitta-Pantazi, 2021). Overall, project-based assessment has proven effective in uncovering students' mathematical creative thinking processes more comprehensively. Through project assignments, students are encouraged to explore various strategies, reflect on their thinking processes, and communicate their mathematical reasoning explicitly. Thus, project-based assessment serves not only as an evaluation tool but also as a means of developing mathematical creativity in the context of Olympiad coaching. These findings support the work of Bell (2018), Krajcik et al. (2020), and Nurjanah and Hidayat (2022), who emphasized the importance of authentic assessment in mathematics education.

## CONCLUSION

Based on the analysis results summarized in Table 1, it can be concluded that the mathematical creative thinking profiles of the Olympiad team students are diverse and not homogeneous, even though all subjects have high mathematical abilities. Each subject shows a different dominance of mathematical creative thinking indicators. Subject S1 excels in the fluency and flexibility indicators, which are reflected in their ability to generate and select various solution strategies reflectively. Subject S2 shows a major strength in the originality indicator, through the use of an unconventional algebraic approach, but is still weak in the aspect of explanatory detail. Meanwhile, subject S3 excels in the detail indicator, with coherent and systematic solutions, but shows limitations in strategy variation.

These findings confirm that mathematical creative thinking is a multidimensional construct, where the four indicators—fluency, flexibility, originality, and elaboration—do not always appear simultaneously in a single individual. Furthermore, the results of this study indicate that project-based assessment is effective in revealing differences in students' mathematical creative thinking profiles in greater depth than conventional written tests, as it provides space for exploration of strategies, reflection on thought processes, and mathematical communication. Thus, project-based assessment has the potential to be a relevant and strategic authentic assessment approach in developing mathematics olympiads, particularly in algebra.

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