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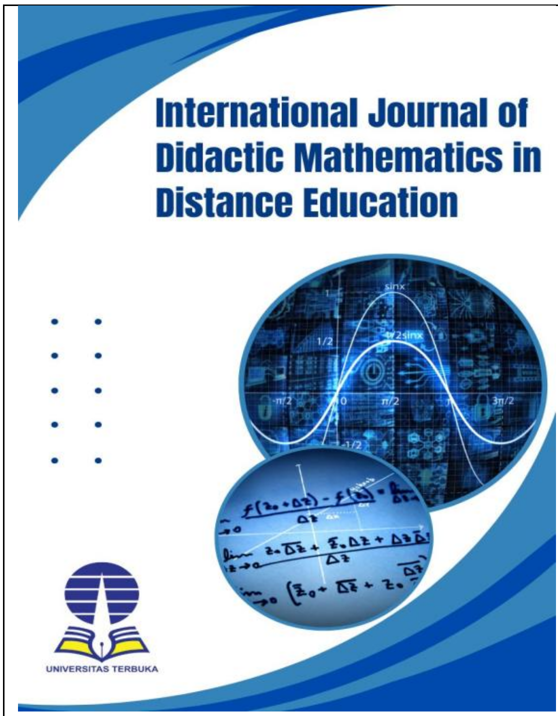

Creative thinking of female high school students in solving sequence and series problems: Implications for synchronous and asynchronous didactical design

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Creative thinking of female high school students in solving sequence and series problems: Implications for synchronous and asynchronous didactical design

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Abstract

This study aims to describe the creative thinking abilities of senior high school students in solving problems related to sequences and series, viewed from the perspective of their mathematical ability. Employing a qualitative descriptive approach, data were collected through classroom observation, a mathematical ability test, a creative thinking ability test, and interviews. The research subjects consisted of three Grade 10 female students from SMAN 1 Sampang, representing high, medium, and low levels of mathematical ability, selected through criterion-referenced classification and consultation with the class mathematics teacher. Data were analyzed against three creative thinking indicators: fluency, flexibility, and novelty, with time triangulation used to strengthen credibility. The findings indicate that the student with high mathematical ability satisfied all three indicators, generating fluent, flexible, and novel solution strategies. The student with medium mathematical ability satisfied only the fluency indicator, while the student with low mathematical ability satisfied none of the three. These ability-differentiated profiles suggest that creative thinking does not emerge uniformly across ability levels, and offer an initial, theoretically derived basis for informing didactical design in synchronous and asynchronous mathematics learning environments, particularly in calibrating the level and timing of real-time scaffolding required for students at each ability level.

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1. Introduction

Creative thinking is the ability of individuals to generate new ideas or solutions, either by combining existing elements or producing something relatively different from what already exists (Schoevers et al., 2019). In mathematics learning, this ability plays an important role because it enables students to explore various problem-solving strategies, especially in non-routine problems (Busyairi & Sinaga, 2021; Darmawan et al., 2025; Suherman & Vidákovich, 2022). However, empirical studies indicate that students' creative thinking abilities remain relatively low, which is partly caused by teacher centered learning and the dominance of routine problems with only one correct answer (Ibrahim & Widodo, 2020).

Although research on creative thinking has been widely conducted, most studies still focus on measuring the level of creativity without deeply examining the creative thinking process based on differences in students' mathematical abilities (Runco & Jaeger, 2012). Several studies indicate that analyses tend to merely categorize levels of creativity without exploring the underlying thinking processes (Mann, 2009; Maskur et al., 2020). In addition, previous studies rarely provide contextual evidence explaining why such research is necessary in a specific educational setting. Therefore, there is a clear research gap, namely the limited number of qualitative studies that describe how students with different levels of mathematical ability (high, medium, and low) demonstrate their creative thinking processes in solving mathematical problems, a gap that carries particular consequence for mathematics instruction delivered synchronously or asynchronously, where teachers have reduced capacity to observe and adjust to individual creative thinking processes in real time compared to a face-to-face classroom.

This study attempts to address this gap by incorporating preliminary observations conducted at SMAN 1 Sampang. The observations show that students tend to rely on a single procedure when solving problems, demonstrate limited variation in strategies, and experience difficulties when dealing with non-routine problems. These findings are consistent with previous studies indicating that students often struggle to develop diverse solution strategies in open-ended mathematical problems (Klein & Leikin, 2020). Thus, this study is not only theoretically grounded but also empirically supported by actual classroom needs.

The topic of sequences and series is selected because it allows for various solution strategies. Tasks with multiple possible solutions (multiple solution tasks) have been shown to foster students' mathematical creativity by providing opportunities to apply diverse approaches in problem solving (Leikin, 2009; Ibrahim & Widodo, 2020; Ahmad et al., 2024). Problems in this topic are not limited to a single fixed procedure but instead allow students to explore multiple solution pathways. Therefore, sequences and series provide an appropriate context for examining variations in students' creative thinking (Nurfaidah et al., 2023).

Regarding the relationship between mathematical ability and creativity, several studies indicate that students with different levels of mathematical ability may demonstrate varying levels of creativity (Uyen et al., 2021; Sitorus, 2016). This suggests

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that mathematical ability is not the sole determinant of students' creativity. Therefore, it is important to examine creative thinking processes by considering differences in students' mathematical abilities.

In this study, creative thinking is measured using three indicators: fluency, flexibility, and novelty. These indicators are widely used in mathematics education research to identify the diversity and uniqueness of students' solution strategies (Puspitasari et al., 2018; de Vink et al., 2022; Elgrably & Leikin, 2021; Hong et al., 2023). The elaboration indicator is not included because this study focuses on the diversity and originality of ideas rather than the level of detail in students' responses.

Furthermore, the assessment of novelty in this study adopts a contextual approach, in which novelty is determined based on the uniqueness of students' solution strategies compared to other participants in the same study. This approach aligns with the characteristics of open-ended problems, which allow for multiple possible solutions (Ibrahim & Widodo, 2020; Silver, 1997). Therefore, the methodological approach employed in this study remains well grounded.

This inquiry also carries relevance beyond the face-to-face classroom in which it was conducted. As mathematics instruction on sequences and series increasingly migrates to synchronous formats (live virtual classrooms, real-time collaborative sessions) and asynchronous formats (self-paced digital modules, recorded instruction) within distance and hybrid learning arrangements, understanding how students of differing mathematical ability generate fluency, flexibility, and novelty becomes a necessary precondition for designing didactical sequences suited to each modality (Brousseau, 1997). Recent evidence indicates that synchronous and asynchronous formats place distinct demands on mathematics learners: synchronous instruction sustains real-time interaction and immediate clarification, while asynchronous formats require tasks to carry their own scaffolding since teacher feedback is delayed (Mohammad et al., 2024). Similarly, hybrid didactical designs that combine both modalities have been shown to help overcome specific student learning obstacles in non-routine problem solving when the design is deliberately matched to the nature of the obstacle rather than applied uniformly (Sukarma et al., 2024; Isnawan et al., 2024). Without ability-differentiated evidence of the kind this study provides, task design for distance mathematics learning risks assuming a uniform learner, when in fact the creative thinking pathway differs substantially across ability levels.

Based on the above explanation, the novelty of this study lies in its in-depth qualitative analysis of students' creative thinking processes in solving sequences and series problems, viewed from differences in mathematical ability and supported by empirical classroom observations. Therefore, the purpose of this study is to describe high school students' creative thinking abilities in solving problems related to sequences and series in terms of their mathematical ability, and to derive from these ability-differentiated profiles an initial set of implications for didactical design in synchronous and asynchronous mathematics learning environments.

2. Method

2.1 Research Design

This study employed a descriptive research design within a qualitative approach, in which data are primarily derived from words and actions supported by written documents, and are presented systematically and accurately to describe the phenomenon under investigation (Hadar & Tirosh, 2019). This design was selected specifically because the study's purpose extends beyond measuring creative thinking levels: it aims to portray, in depth, how creative thinking processes differ across students of high, medium, and low mathematical ability, a distinction that, as argued in the Introduction, provides the ability-differentiated foundation needed to inform didactical design decisions for synchronous and asynchronous mathematics learning environments. A qualitative descriptive design accommodates this purpose because it privileges rich process description over statistical generalization, allowing the researcher to capture not merely whether students demonstrate fluency, flexibility, and novelty, but how these indicators manifest differently according to ability level.

The general research procedure followed five stages: (1) preparing the research instruments; (2) consulting on and validating the instruments through expert judgment by mathematics education lecturers and/or experienced teachers, to assess their suitability with the research objectives, the indicators of creative thinking ability (fluency, flexibility, novelty), and the clarity and difficulty level of the tasks; (3) collecting data; (4) analyzing data; and (5) compiling the report. To ensure the credibility of the findings, the researcher employed time triangulation, verifying data validity with the same subjects and techniques but at different times — written test results were subsequently confirmed through interviews conducted separately. This procedural flow is illustrated in Figure 1.

Figure 1

Research Design Procedure

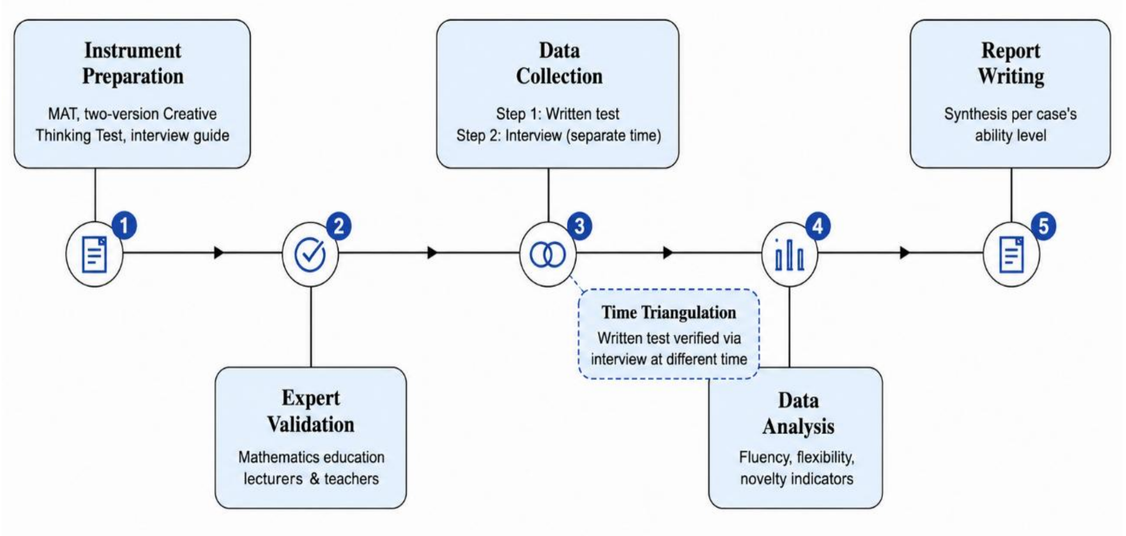

Figure 1 presents the five-stage research procedure, beginning with instrument preparation and expert validation of the Mathematics Ability Test, two-version Creative Thinking Ability Test, and interview guide. Data collection then proceeds sequentially through a written creative thinking test followed by a separate interview exploring

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participants' reasoning. This sequence supports time triangulation by comparing written and oral responses obtained at different times for consistency. The collected data are subsequently analyzed using three creative thinking indicators: fluency, flexibility, and novelty. Finally, findings are synthesized according to participants' mathematical ability levels and reported as the basis for developing ability-differentiated didactical design implications.

2.2 Participants

The research was conducted at SMAN 1 Sampang, located at Jl. Jaksa Agung Suprapto No. 73, RW II, Gn. Sekar, Sampang District, Sampang Regency, during the odd and even semesters of the 2023/2024 academic year. The research subjects were drawn from class X Merdeka 3, a heterogeneous class of male and female students. A Mathematics Ability Test (MAT) was administered to the entire class to classify students into three ability categories, high, medium, and low, using a Criterion-Referenced Assessment (Surya & Putri, 2017).

From this classification, three students (coded BMT, BMS, and BMR, representing high, medium, and low mathematical ability respectively) were selected as research subjects through purposive sampling. Subject selection was guided by three criteria: representation of each ability category, willingness to participate in interviews, and the ability to communicate reasoning and solution steps clearly — the latter determined through consultation with the class mathematics teacher regarding which students could articulate their thinking comfortably. Although each ability category was represented by only one subject, this was consistent with the study's aim of obtaining an in-depth understanding of creative thinking processes within each category, rather than pursuing statistical generalization.

2.3 Data Collection

Data were collected using two categories of instruments: a primary instrument, namely the researcher, and supporting instruments comprising the Mathematics Ability Test (MAT), a two-version Creative Thinking Ability Test on the topic of sequences and series, and a semi-structured interview guide. Each version of the creative thinking test contained three problems targeting the fluency, flexibility, and novelty indicators respectively, contextualized within real-world scenarios (e.g., visitor growth patterns and marble distribution problems) that permitted multiple valid solution strategies. All instruments underwent expert validation prior to use, as described in Section 2.1.

Data collection proceeded in two stages for each subject. First, subjects completed the Creative Thinking Ability Test individually, producing written solutions that were analyzed for evidence of fluency, flexibility, and novelty. Second, semi-structured interviews were conducted with each subject following the test, allowing the researcher to probe the reasoning behind their written solutions and to clarify ambiguous responses. This sequencing supported the time triangulation strategy described in Section 2.1, as written and oral data on the same problem were obtained at different points in time and subsequently compared for consistency.

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2.4 Data Analysis

Data analysis was conducted in three stages, corresponding to the three data sources. First, MAT results were analyzed to classify each student's mathematical ability using the Criterion-Referenced Assessment conversion proposed by Surya & Putri (2017), in which scores of 80–100, 60–79, and 0–59 correspond to high, medium, and low ability respectively. Second, Creative Thinking Ability Test results were analyzed by examining each subject's written solutions against the three creative thinking indicators, fluency, flexibility, and novelty, to obtain a descriptive profile of their creative thinking process on sequence and series problems.

Third, interview data were analyzed using the three-stage model of data reduction, data display, and conclusion drawing (Miles & Huberman, 1994). Data reduction involved summarizing responses, removing irrelevant information, and rechecking interview transcripts as data collection proceeded; data display involved presenting the information as narrative text organized around the creative thinking indicators; and conclusion drawing synthesized the descriptions of each subject's creative thinking ability into conclusions differentiated by mathematical ability level, forming the basis for the didactical design implications discussed later in this article.

2.5 Ethical Clearance

This study was conducted with attention to the ethical protection of participants, including obtaining permission from the school principal and the class mathematics teacher prior to data collection, securing informed consent from the student participants (and, given their status as minors, from their parents or guardians), and ensuring voluntary participation with the right to withdraw at any stage without consequence; participant confidentiality was maintained throughout by referring to subjects using anonymized codes (BMT, BMS, BMR) rather than their actual names.

3. Results and Discussion

3.1 Results

In this study, the data analyzed were the results of the mathematics ability test, the results of the creative thinking ability test, and the interview data. The mathematics ability test administered to class X Merdeka 3 at SMAN 1 Sampang (N = 34) showed 1 student with high mathematical ability, 1 student with moderate mathematical ability, and 32 students with low mathematical ability, indicating an uneven distribution of mathematical ability within the class. Using purposive sampling, three subjects were selected to represent each ability category, high, medium, and low, based on their willingness to participate in interviews, their ability to communicate their reasoning clearly, and the recommendation of the class mathematics teacher. Although only one student occupied the high and medium categories respectively, both were retained as subjects because this study does not pursue statistical generalization, but rather an in-depth understanding of the creative thinking process within each ability category. Data validity was established through source and time triangulation, comparing written test results against interview data collected at separate points in time.

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Based on these criteria, the three research subjects are presented in Table 1.

Table 1

Research Subjects

No	Subject Code	MAT Score	Category
1	BMT	88	High
2	BMS	68	Medium
3	BMR	1	Low

Each subject completed two versions of the Creative Thinking Ability Test on sequences and series, followed by a semi-structured interview to probe the reasoning behind their written solutions. Consistent with standard qualitative reporting practice, each indicator is presented below through three linked elements: the visual evidence (written response), an interpretation of that evidence, and a supporting interview excerpt that corroborates or nuances the written interpretation.

3.1.1 Creative Thinking of Subject BMT (High Mathematical Ability)

a) Creative Thinking Ability Test 1

In this first version of the Creative Thinking Ability Test, subject BMT was presented with three problems targeting the fluency, flexibility, and novelty indicators respectively. The analysis below presents BMT's written response to each item alongside a corroborating interview excerpt.

Figure 2

Response to Creative Thinking Ability Test 1 — Fluency Indicator of Subject BMT

1.) Dik :

1. 2013 : 151 orang (people)
2. 2014 : 302 orang (people)
3. 2015 : 604 orang (people)

∴ 151 , 302 , 604 , ...

$a = 151$,

$r = 302 : 151 = 2$

Dit : banyak pengunjung 4 2022 dan jumlah pengunjung 4 2013 - 2023 ?
(Find : number of visitors in 2022 and total number of visitors in 2013 - 2023 ?)

2013 = 1	2016 = 4	2019 = 7	2022 = 10
2014 = 2	2017 = 5	2020 = 8	2023 = 11
2015 = 3	2018 = 6	2021 = 9	

→ $U_{10} = a r^{n-1}$ (nth term of geometric sequence) (suku ke-n barisan geometri)

$= 151 \cdot 2^{10-1}$

$= 151 \cdot 2^{9}$

$= 151 \cdot 512$

$= 77.312$ → banyak pengunjung pada tahun 2022 adalah 77.312 orang. (number of visitors in 2022 is 77.312 people.)

→ $U_{11} = a r^{n-1}$ (nth term of geometric sequence / suku ke-n barisan geometri)

$= 151 \cdot 2^{11-1}$

$= 151 \cdot 2^{10}$

$= 151 \cdot 1024$

$= 154.624$

→ $S_n = \frac{a(r^n - 1)}{r - 1}$ (sum of first n terms of geometric sequence) (jumlah n suku pertama barisan geometri)

$= \frac{151(2^{11} - 1)}{2 - 1}$

$= 151 (2048 - 1)$

$= 151 \cdot 2047$

$= 309.097$

Jadi jumlah pengunjung dari tahun 2013 - 2023 adalah 309.097.
(Therefore, the total number of visitors from 2013 to 2023 is 309.097.)

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Subject BMT answered all sub-questions of item 1 correctly and fluently, demonstrating a clear understanding of the given information. Using the formula $U_n = ar^{n-1}$, the subject correctly determined U_{10} = 77,312 visitors; using $S_n = \frac{a(r^n - 1)}{r - 1}$, the subject correctly determined S_{11} = 309,097 visitors.

The consistency between the written solution and the subject's oral explanation confirms that BMT met the fluency indicator, providing accurate and confident responses across all sub-questions. This is consistent with Bahar and Maker (2015), who found that high-ability students can generate correct alternative answers by recognizing patterns from previously used methods, and with de Vink et al. (2022), who linked convergent-thinking accuracy in procedural steps to overall mathematical creativity performance.

Figure 3
Creative Thinking Ability Test 1 Answer of Subject BMT — Flexibility Indicator

Cara 1 (Method 1)

2.) 7, 14, 21, 28, 35, 42, 49, 56, 63, 70, 77, 84, 91, 98

Jadi $a = 7$ (So $a = 7$)
$r = 7$ (So $r = 7$)

$S_n = \frac{a + U_n}{2} \cdot n$ (Sum of first n terms of arithmetic sequence)

$S_{14} = \frac{7 + 98}{2} \cdot 14$

$= \frac{105 \times 14}{2}$

$= 105 \times 7 = 735$

(menggunakan rumus) (using the fermula)

Cara 2 (Method 2)

$7 + 14 + 21 + 28 + 35 + 42 + 49 + 56 + 63 + 70 + 77 + 84 + 91 + 98$
$= 7 + 14 + 21 + 28 + 70 + 77 + 84 + 91 + 98 + 35 + 42 + 49 + 56 + 63$
$= (7 + 98) + (14 + 91) + (21 + 84) + (28 + 77) + (35 + 70) + (42 + 63) + (49 + 56)$
$= 105 + 105 + 105 + 105 + 105 + 105 + 105$
$= 105 \times 7 = 735$

(Hitung secara manual) (Calculate manually)

For item 2, subject BMT solved the problem using two distinct and correct methods: first, applying the formula $S_n = \frac{a + U_n}{2} \cdot n$ (a = 7, n = 14, U_n = 98) to obtain 735; second, manually listing and summing the natural numbers between 1 and 100 divisible by 7, arriving at the same result.

The subject's ability to articulate both strategies during the interview, and to justify why each converges on the same result, indicates genuine flexibility rather than rote repetition, meeting the flexibility indicator. This aligns with Hong et al. (2023), whose systematic review identifies the deliberate switching between solution strategies as a core marker of mathematical flexibility distinct from mere procedural fluency.

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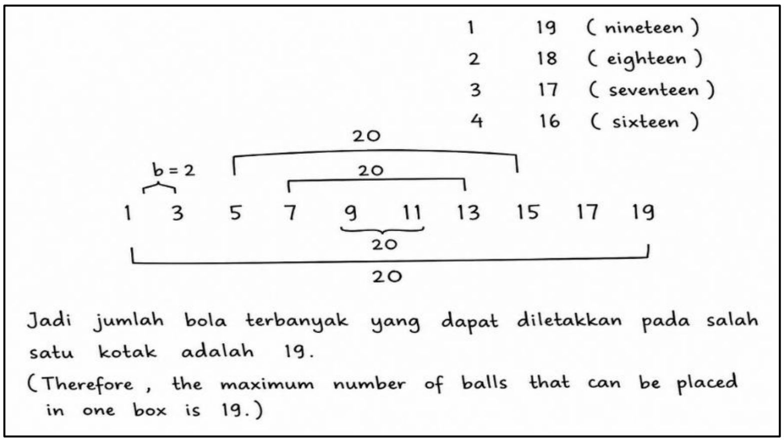
Figure 4
Creative Thinking Ability Test 1 Answer of Subject BMT — Novelty Indicator



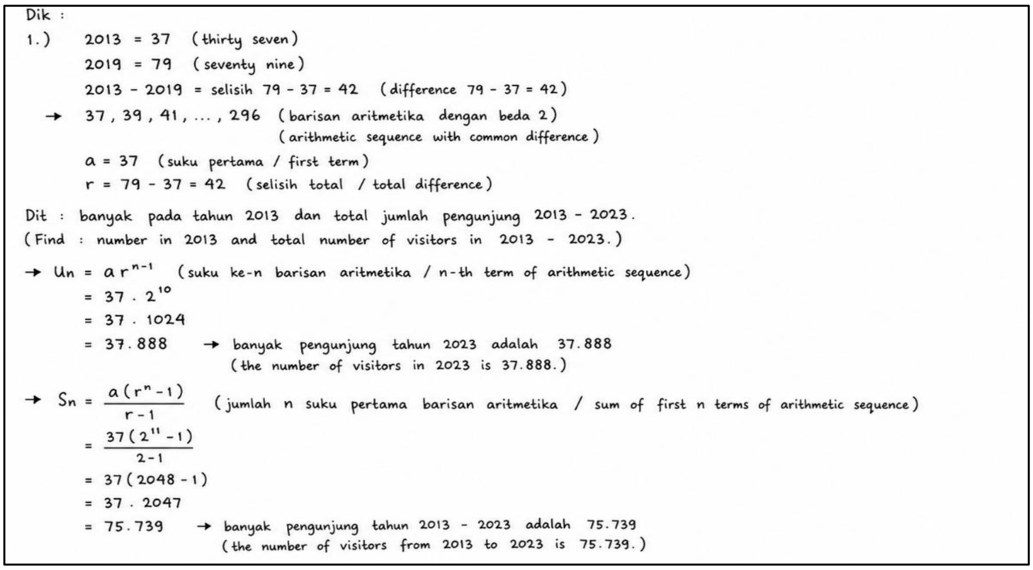
For item 3, subject BMT applied an unconventional numerical approach: dividing the total number of marbles by the number of paired boxes to ensure equal pairing, then adjusting the arithmetic difference until the sequence summed exactly to 100.

Because this pairing strategy diverged structurally from the direct formula-application approach used by most participants, and the subject could explain its origin coherently in the interview, BMT is judged to have met the novelty indicator. This corroborates Puspitasari et al. (2018) and Elgrably and Leikin (2021), who describe high-ability students' capacity to generate solution strategies uncommon among peers as a hallmark of problem-solving expertise.

b) Creative Thinking Ability Test 2

The second version of the Creative Thinking Ability Test presents a structurally parallel set of three problems, set in a different visitor-growth and marble-distribution context, to verify whether BMT's indicator achievement in Test 1 replicates under a different numerical scenario. The analysis below presents BMT's written response to each item in this second test alongside a corroborating interview excerpt.

Figure 5
Creative Thinking Ability Test 2 Answer of Subject BMT — Fluency Indicator



Dik :
1.) 2013 = 37 (thirty seven)
2019 = 79 (seventy nine)
2013 - 2019 = selisih 79 - 37 = 42 (difference 79 - 37 = 42)
→ 37 , 39 , 41 , ... , 296 (barisan aritmetika dengan beda 2)
(arithmetic sequence with common difference)
a = 37 (suku pertama / first term)
r = 79 - 37 = 42 (selisih total / total difference)

Dit : banyak pada tahun 2013 dan total jumlah pengunjung 2013 - 2023.
(Find : number in 2013 and total number of visitors in 2013 - 2023.)

→ $U_n = a r^{n-1}$ (suku ke-n barisan aritmetika / n-th term of arithmetic sequence)
$= 37 \cdot 2^{10}$
$= 37 \cdot 1024$
$= 37.888$ → banyak pengunjung tahun 2023 adalah 37.888
(the number of visitors in 2023 is 37.888.)

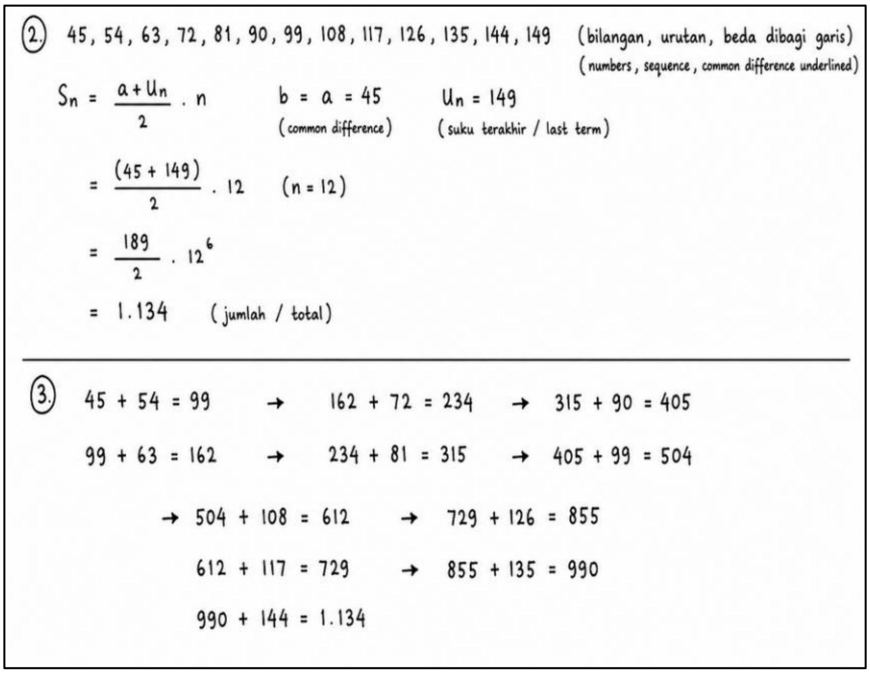
→ $S_n = \frac{a(r^n - 1)}{r - 1}$ (jumlah n suku pertama barisan aritmetika / sum of first n terms of arithmetic sequence)
$= \frac{37(2^{11} - 1)}{2 - 1}$
$= 37(2048 - 1)$
$= 37 \cdot 2047$
$= 75.739$ → banyak pengunjung tahun 2013 - 2023 adalah 75.739
(the number of visitors from 2013 to 2023 is 75.739.)

Subject BMT again answered all sub-questions of item 1 correctly, determining U_{11} = 37,888 and S_{11} = 75,739 using the same formulas as in Test 1, applied to a different visitor-growth scenario.

The replication of accurate, confident performance across both test versions strengthens the credibility of the fluency finding for BMT. Sipahi & Erbas (2025), similarly found that high-ability students meet the fluency indicator through the confident application of commonly known procedures.

Figure 6

Creative Thinking Ability Test 2 Answer of Subject BMT — Flexibility Indicator


2. 45, 54, 63, 72, 81, 90, 99, 108, 117, 126, 135, 144, 149 (bilangan, urutan, beda dibagi garis)
(numbers, sequence, common difference underlined)

$S_n = \frac{a + U_n}{2} \cdot n$ $\quad b = a = 45$ (common difference) $\quad U_n = 149$ (suku terakhir / last term)

$= \frac{(45 + 149)}{2} \cdot 12$ (n = 12)

$= \frac{189}{2} \cdot 12^{6}$

$= 1.134$ (jumlah / total)

3. 45 + 54 = 99 → 162 + 72 = 234 → 315 + 90 = 405

99 + 63 = 162 → 234 + 81 = 315 → 405 + 99 = 504

→ 504 + 108 = 612 → 729 + 126 = 855

612 + 117 = 729 → 855 + 135 = 990

990 + 144 = 1.134

For item 2, BMT again produced two valid methods — the arithmetic series formula $S_n = \frac{a + U_n}{2} \cdot n$ (a = 45, n = 12, U_n = 144, result 1,134) and a manual summation approach yielding the identical result, indicating pattern recognition and flexible control of mathematical representations across problem contexts.

The subject's ability to transfer the same dual-strategy approach to a structurally similar but numerically distinct problem reinforces that BMT's flexibility is a stable, transferable disposition rather than a one-off response. This is in line with Uyen et al. (2021) and Weiss and Wilhelm (2022), who argue that flexibility reflects an underlying capacity to reorganize strategies across related problem contexts, distinct from fluency or originality alone.

Figure 7

Creative Thinking Ability Test 2 Answer of Subject BMT — Novelty Indicator

3.)

a	+	b	=	U_n	
3	+	39	=	42	→ (suku ke-1 / first term)
7	+	35	=	42	
11	+	31	=	42	
15	+	27	=	42	
19	+	23	=	42	

$S_{10} = \frac{a + U_n}{2} \cdot n$ (rumus jumlah n suku pertama barisan aritmetika) (formula for the sum of the first n terms)

$= \frac{3 + 42}{2} \cdot 10$ (n = 10)

$= \frac{(45)}{2} \cdot 10$

$= 22{,}5 \cdot 10$

$= 225.$

Jadi, jumlah 10 suku pertama barisan tersebut adalah 225.
(So, the sum of the first 10 terms is 225.)

For item 3, BMT again applied the pairing-and-adjustment strategy used in Test 1, correctly determining the maximum number of marbles per box until the sequence summed to 210.

The consistent, independently-derived use of this uncommon strategy across two separate testing occasions provides stronger evidence for the novelty indicator than a single instance would. Sipahi & Erbas (2025) similarly note that high-ability students meet the novelty indicator by consistently applying unconventional methods uncommon among peers.

3.1.2 Creative Thinking of Subject BMS (Moderate Mathematical Ability)

As with subject BMT, subject BMS was presented with three problems on sequences and series targeting the fluency, flexibility, and novelty indicators. The analysis below examines whether BMS's moderate mathematical ability translates into a similarly complete indicator profile as observed for BMTa) Creative Thinking Ability Test 1

Figure 8

Creative Thinking Ability Test 1 Answer of Subject BMS — Fluency Indicator

1. Misal : $U_1 = 2013 = 151$ (tahun 2013 = 151 pengunjung / year 2013 = 151 visitors)
$U_2 = 2014 = 302$ (tahun 2014 = 302 pengunjung / year 2014 = 302 visitors)
$U_3 = 2015 = 609$ (tahun 2015 = 609 pengunjung / year 2015 = 609 visitors)

Dit : jumlah pengunjung pada tahun 2022 ? → 2022 = U_{10} dan 2023 = U_{11}
(Find : number of visitors in 2022 ? → 2022 = U_{10} and 2023 = U_{11})
– total jumlah pengunjung dari tahun 2013 – 2023 ? total $U_1 - U_{11}$
(total number of visitors from 2013 to 2023 ? total $U_1 - U_{11}$))

$U_n = a \cdot r^{n-1} \rightarrow r = \frac{U_n}{U_{n-1}} = \frac{302}{151} = 2$ (rasio / common ratio)

$U_n = a \cdot r^{n-1}$

$U_{10} = 151 \cdot 2^9$

$= 151 \cdot 512$

$= 77.312$ → jumlah pengunjung tahun 2022 adalah 77.312
(the number of visitors in 2022 is 77.312)

$S_n = \frac{a \cdot (r^n - 1)}{r - 1}$ (jumlah n suku pertama / sum of first n terms)

$S_{11} = \frac{151\,(2^{11} - 1)}{2 - 1}$

$= \frac{151\,(2048 - 1)}{1}$

$= 151\,(2047)$

$= 151 \cdot 2047$

$= 309.097$ → jadi jumlah total dari tahun 2013 – 2023 adalah 309.097
(so, the total number of visitors from 2013 to 2023 is 309.097)

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Subject BMS correctly determined U_{10} = 77,312 and S_{11} = 309,097 using the same standard formulas as BMT, answering all sub-questions accurately.

The accuracy and confidence demonstrated in both the written response and the interview indicate that BMS met the fluency indicator. This is consistent with Nufus et al. (2024), whose Heliyon study likewise found that students with moderate self-regulated learning and moderate ability can perform procedural mathematics tasks accurately even where higher-order creative indicators remain unmet.

Figure 9

Creative Thinking Ability Test 1 Answer of Subject BMS — Flexibility and Novelty Indicators

2. Jadi bilangan asli antara 1–100 adalah =
(Thus, the natural numbers between 1–100 are =)

7, 14, 21, 28, 35, 42, 49, 56, 63, 70, 77, 84, 91, 98.

dan jumlah seluruh bilangan adalah n bilangan.
(and the total number of all the numbers is n numbers.)

(cara 1 : U_1 = 7, b = 7)
(method 1: U_1 = 7, b = 7)

$U_n = a + (n-1)b$ (suku ke-n)
(the n-th term)

$98 = 7 + (n-1)7$

$98 = 7 + (n-1)7$

$98 = 7n$

$14 = n$ (jumlah suku)
(number of terms)

$S_n = \frac{n}{2}(2a + (n-1)b)$ (jumlah n suku pertama)
(sum of first n terms)

$= \frac{14}{2}(2(7) + (14-1)7)$

$= \frac{14}{2}(14 + 91)$

$= \frac{14}{2}(105)$

$= 7 \times 105$

$= 735.$ (jumlah seluruh bilangan)
(total sum of all the numbers)

For item 2, BMS produced only a single method, the formula $S_n = \frac{n}{2}(2a + (n-1)b)$, arriving at the correct result of 735, but did not attempt an alternative approach. For item 3, BMS was unable to produce a solution at all.

The subject's reliance on a single, previously taught procedure, and the inability to attempt item 3 despite understanding its context, indicate that BMS did not meet either the flexibility or the novelty indicator. This is consistent with Yayuk et al. (2020), who found that moderate-ability students typically demonstrate fluency and partial flexibility, but rarely produce solutions judged as novel relative to peers.

b) Creative Thinking Ability Test 2

The second test administration presents a parallel set of problems in a different numerical context, allowing the researcher to check whether BMS's Test 1 profile, fluency met, flexibility and novelty unmet, remains stable. Any deviation from this pattern would suggest inconsistency rather than a genuine ability-based ceiling.

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Figure 10

Creative Thinking Ability Test 2 Answer of Subject BMS — Fluency Indicator

1. Misal : $U_1 = 2013 = 37$ (tahun 2013 = 37) (*year 2013 = 37*)
$U_2 = 2019 = 79$ (tahun 2019 = 79) (*year 2019 = 79*)
$U_9 = 2016 = 296$ (tahun 2016 = 296) (*year 2016 = 296*)

1.a Ditanya : banyak pengunjung pada 2023 (U_{11}).
(Find : number of visitors in 2023 (U_{11}).)
- total jumlah pengunjung dari tahun 2013 – 2023.
(total number of visitors from 2013 to 2023.)

Jawab (Solution):

Rumus suku ke-n barisan aritmetika : $U_n = a \cdot r^{n-1}$ (*Formula for the n-th term of an arithmetic sequence*)

Diketahui (Given): $U_1 = 37 \Rightarrow a = 37$

$U_2 = 79 \Rightarrow r = \frac{U_2}{U_1} = \frac{79}{37} \approx 2$

$U_n = a \cdot r^{n-1}$

$U_{11} = 37 \cdot 2^{11-1} = 37 \cdot 2^{10}$
$= 37 \cdot 1.024$
$= 37.888$

Jadi, banyak pengunjung pada tahun 2023 adalah 37.888.
(So, the number of visitors in 2023 is 37.888.)

Rumus jumlah n suku pertama : $S_n = \frac{a\,(r^n - 1)}{r - 1}$ (*Formula for the sum of the first n terms*)

$S_{11} = \frac{37\,(2^{11} - 1)}{2 - 1} = 37\,(2^{11} - 1)$
$= 37\,(2.048 - 1)$
$= 37\,(2.047)$
$= 37 \times 2.047$
$= 75.739$

Jadi, total jumlah pengunjung dari tahun 2013 – 2023 adalah 75.739.
(*So, the total number of visitors from 2013 to 2023 is 75.739.*)

---

2. Ditanya : Misal 2013 = tahun ke-1.
(*Find : Let 2013 = the first year.*)

Selisih = Membagi jumlah orang pada tahun berikutnya dengan jumlah orang pada tahun sebelumnya.
(*The difference ratio = dividing the number of people in the next year by the number of people in the previous year.*)

2019 = tahun ke-2 (*year 2019 = the 2nd year*) $g = \frac{79}{37} \approx 2,135$

2016 = tahun ke-9 (*year 2016 = the 9th year*) $g = \frac{296}{79} \approx 3,747$

2023 = tahun ke-11 (*year 2023 = the 11th year*) $g = \frac{37.888}{296} \approx 128,01$

Dan ditanya pada tahun ke-11. Etb dapat menghitung mundur dengan cara mengalikan 2 jumlah orang pada tahun sebelumnya.
(*And asked for the 11th year. So we can calculate backward by multiplying the previous year's number by the ratio.*)

Tahun ke 9 = 296 × 2
Tahun ke 6 = 1.189 . (1.189)
Tahun ke 7 = 2.368 . (2.368)
Tahun ke 8 = 4.736 . (4.736)
Tahun ke 9 = 9 . 472 . (9.472)
Tahun ke 10 = 18 . 944 . (18.944)
Tahun ke 11 = 37 . 888 . (37.888)

BMS again correctly determined U_{11} = 37,888 and S_{11} = 75,739, replicating the accurate procedural performance shown in Test 1. This replication across both test versions supports the conclusion that BMS reliably meets the fluency indicator, consistent with Mann (2009).

Figure 11
Creative Thinking Ability Test 2 Answer of Subject BMS — Flexibility and Novelty Indicators

2. Jadi bilangan asli antara 49 – 195 yang habis dibagi 9 adalah
(Thus, the natural numbers between 49 and 195 that are divisible by 9 are)

95, 59, 63, 72, 81, 90, 99, 108, 117, 126, 135, 144, 153, 162, 171, 180, 189.

Dan jumlah seluruh bilangan adalah 12 bilangan.
(And the total number of those numbers is 12 numbers.)

Cara 1 : $U_1 = 95$, $b = 9$ (*cara 1 :* $U_1 = 95$, $b = 9$) (*method 1:* $U_1 = 95$, $b = 9$)

$U_n = a + (n-1)b$ (rumus suku ke-n barisan aritmetika) (*formula for the n-th term of an arithmetic sequence*)

$$195 = 95 + (n-1)9$$
$$195 = 95 + 9n - 9$$
$$195 - 95 + 9 = 9n$$
$$99 + 9 = 9n$$
$$108 = 9n$$
$$12 = n$$

(banyak suku / *number of terms*)

$$S_n = \frac{n}{2}(2a + (n-1)b)$$

(rumus jumlah n suku pertama barisan aritmetika) (*formula for the sum of the first n terms*)

$$= \frac{12}{2}[2(95) + (12-1)9]$$
$$= 6[190 + (11)(9)]$$
$$= 6[190 + 99]$$
$$= 6(289)$$
$$= 1.734.$$

(jumlah seluruh bilangan / *total sum of the numbers*)

Cara 2 : Menggunakan cara manual. Membuat baris bilangan asli antara 49 – 195 yang habis dibagi 9,
(Using the manual method. List the natural numbers between 49 and 195 that are divisible by 9,)

95, 59, 63, 72, 81, 90, 99, 108, 117, 126, 135, 144, 153, 162, 171, 180, 189.

dan dihitung manual jumlah bilangan asli tersebut.
(and then add them manually.)

Jadi terdapat 12 bilangan asli yang habis dibagi 9 di antara 49 – 195.
(Thus, there are 12 natural numbers that are divisible by 9 between 49 and 195.)

For item 2, BMS attempted two approaches, the formula $S_n = \frac{n}{2}(2a + (n-1)b)$ yielding a correct sum of 1,134, and a manual listing of qualifying numbers, but did not complete the summation in the second method, indicating a lapse in carefulness rather than genuine strategic diversity. For item 3, BMS again could not produce a solution.

Because the second method was left incomplete, it does not constitute a genuinely alternative, correct strategy, so BMS is judged not to have met the flexibility indicator, a finding that differs somewhat from Bahar and Maker (2015), who reported moderate-ability students capable of two distinct correct methods. The unmet novelty indicator is consistent with Rahayuningsih et al. (2021), who found moderate-ability students typically demonstrate only fluency and partial flexibility, but not originality or elaboration.

3.1.3 Creative Thinking of Subject BMR (Low Mathematical Ability)

a) Creative Thinking Ability Test 1

For subject BMR, the same three-item test was administered to examine how low mathematical ability manifests in the creative thinking process. Particular attention is paid to the point at which the subject's solution attempt breaks down, since this indicates whether the limiting factor is conceptual understanding or strategic variety.

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Figure 11

Creative Thinking Ability Test 1 Answer of Subject BMR — Fluency Indicator

1.) **Diketahui** (*Given*) : $U_1 = 151$ (tahun 2013 = 151 pengunjung / year 2013 = 151 *visitors*)
$U_2 = 302$ (tahun 2014 = 302 pengunjung / year 2014 = 302 *visitors*)
$U_3 = 609$ (tahun 2015 = 609 pengunjung / year 2015 = 609 *visitors*)

Misalkan (*Let*) : $U_n = a + (n-1)b$ (rumus barisan aritmetika / *formula of arithmetic sequence*)

Maka (*Then*) :

$$\begin{aligned} U_2 &= a + b = 302 \\ U_3 &= a + 2b = 609 \\ \hline 2b &= 609 - 302 \\ 2b &= 307 \\ b &= \frac{307}{2} = 153{,}5 \end{aligned} \qquad \begin{aligned} a + b &= 302 \\ a + 153{,}5 &= 302 \\ a &= 302 - 153{,}5 \\ a &= 148{,}5 \end{aligned}$$

Jadi, $U_n = 148{,}5 + (n-1)153{,}5$. (*So*, $U_n = 148.5 + (n-1)153.5$.)

Tahun (*Year*)	$U_n = a + (n-1)b$ (Pengunjung / *Visitors*)	**Perhitungan** (*Calculation*)	**Hasil** (*Result*)
2013 ($n=1$)	$U_1 = 148{,}5 + (1-1)153{,}5$	$= 148{,}5$	151
2014 ($n=2$)	$U_2 = 148{,}5 + (2-1)153{,}5$	$= 148{,}5 + 153{,}5$	302
2015 ($n=3$)	$U_3 = 148{,}5 + (3-1)153{,}5$	$= 148{,}5 + 307$	609
2016 ($n=4$)	$U_4 = 148{,}5 + (4-1)153{,}5$	$= 148{,}5 + 460{,}5$	$609 + 153{,}5 = 762{,}5 \rightarrow 762$
2017 ($n=5$)	$U_5 = 148{,}5 + (5-1)153{,}5$	$= 148{,}5 + 614$	$762 + 153{,}5 = 915{,}5 \rightarrow 916$
2018 ($n=6$)	$U_6 = 148{,}5 + (6-1)153{,}5$	$= 148{,}5 + 767{,}5$	$916 + 153{,}5 = 1.069{,}5 \rightarrow 1.070$
2019 ($n=7$)	$U_7 = 148{,}5 + (7-1)153{,}5$	$= 148{,}5 + 921$	$1.070 + 153{,}5 = 1.223{,}5 \rightarrow 1.224$
2020 ($n=8$)	$U_8 = 148{,}5 + (8-1)153{,}5$	$= 148{,}5 + 1.074{,}5$	$1.224 + 153{,}5 = 1.377{,}5 \rightarrow 1.378$
2021 ($n=9$)	$U_9 = 148{,}5 + (9-1)153{,}5$	$= 148{,}5 + 1.228$	$1.378 + 153{,}5 = 1.531{,}5 \rightarrow 1.532$
2022 ($n=10$)	$U_{10} = 148{,}5 + (10-1)153{,}5$	$= 148{,}5 + 1.381{,}5$	$1.532 + 153{,}5 = 1.685{,}5 \rightarrow 1.686$

Jadi, banyak pengunjung pada tahun 2022 adalah 77.312.
(*So, the number of visitors in 2022 is 77.312.*)

Subject BMR correctly determined the number of visitors in 2022 (77,312) using a manual calculation method, but was unable to determine the total number of visitors from 2013–2023 (S_{11}). Items 2 and 3 were also left unsolved.

The partial completion of item 1 and the inability to attempt items 2 and 3 indicate that BMR did not meet the fluency, flexibility, or novelty indicators. This is consistent with Bahar and Maker (2015), who found low-ability students tend to apply familiar approaches without reaching correct final results, who similarly found low-ability subjects unable to produce varied alternative answers.

b) Creative Thinking Ability Test 2

The second test presents an equivalent problem set in a different numerical context to verify whether BMR's difficulty in Test 1 reflects a stable conceptual gap rather than an isolated error specific to the first scenario. The analysis below examines whether this same breakdown point recurs under the new numerical scenario.

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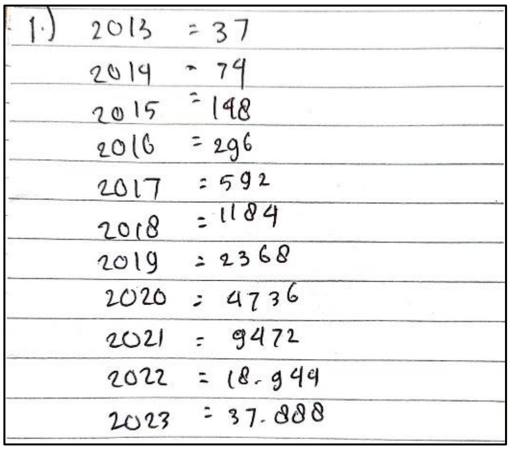
Figure 12
Creative Thinking Ability Test 2 Answer of Subject BMR — Fluency Indicator



BMR again correctly determined the number of visitors in 2023 (37,888) using a manual method but could not determine the total from 2013–2023. Items 2 and 3 were again left unsolved.

The repeated pattern across both test versions, partial success on the first sub-question, no attempt on subsequent items, confirms that BMR did not meet any of the three creative thinking indicators. This aligns with Maskur et al (2020), who found low-ability students struggle when problems cannot be solved with standard formulas, who classified such profiles as non-creative on all three indicators.

3.2 Discussion

Read together, the three subjects' results reveal that creative thinking does not decline uniformly with mathematical ability but follows a specific, stepwise pattern: fluency is retained down to moderate ability and is lost only at the low-ability level, while flexibility and novelty are already lost at the moderate-ability level. Subject BMT, representing high mathematical ability, met all three indicators consistently across both test administrations. In both tests, BMT accurately interpreted the problem and applied the correct formula to determine the nth term and the sum of the sequence without difficulty, consistent with Bahar and Maker (2015), who found that high-ability students generate correct alternative answers by recognizing patterns from previously used methods, and with de Vink et al. (2022), who linked strong convergent-thinking accuracy in procedural steps to overall mathematical creativity performance. BMT also produced two distinct, correct methods for each flexibility item across both tests, indicating a stable rather than incidental capacity to shift between solution strategies, a pattern Hong et al. (2023) identify as the defining feature of mathematical flexibility, and one Weiss and Wilhelm (2022) argue reflects a competency genuinely separable from fluency or originality. For the novelty indicator, BMT consistently applied a pairing-and-adjustment strategy that diverged structurally from the dominant formula-based approach used by most participants, satisfying the predefined criteria of novelty, uniqueness relative to peers and deviation from standard procedure. This is consistent with Puspitasari et al. (2018) and reinforced by Elgrably and Leikin (2021), who found that problem-solving expertise in high-achieving students manifests precisely in the capacity to generate uncommon, self-initiated solution paths, and by Sipahi and Erbas (2025), who similarly found gifted students meet fluency and novelty indicators through the confident, repeated application of unconventional strategies across problem variants. This profile also aligns with the classification proposed by Kholid et al. (2024), whose recent study of non-routine mathematical problem-solving similarly identified a subgroup of students capable of flexible, elaborative solution paths distinct from the majority who rely on a single direct procedure.

Subject BMS, representing moderate mathematical ability, met only the fluency indicator in both tests, correctly interpreting the problem and applying appropriate procedures to determine the nth term and sum, while recognizing the underlying numerical pattern. This indicates that BMS's performance is characterized by procedural fluency combined with emerging pattern recognition rather than by the generation of multiple solution strategies, a finding corroborated by Nufus et al. (2024), whose qualitative case study similarly found that students with moderate self-regulated learning and moderate mathematical ability could perform structured procedures accurately while higher-order creative indicators remained underdeveloped. In contrast to BMT, BMS used only one method in Test 1 and left a second method incomplete in Test 2, and was unable to solve either novelty item in both tests. This plateau after fluency is consistent with Yayuk et al. (2020), who found moderate-ability students frequently demonstrate fluency and partial flexibility but stall before producing genuinely alternative strategies, and with Rahayuningsih et al. (2021), who identified originality as the indicator moderate-ability students most consistently fail to meet in open-ended problem-solving tasks. Sadak et al. (2022) offer a plausible explanation for this specific ceiling, showing that the transition from flexible problem-solving to genuinely novel problem-posing represents a distinct and more demanding creative competency, one that moderate-ability students, despite adequate procedural skill, do not yet reliably exhibit.

Subject BMR, representing low mathematical ability, did not meet any of the three indicators in either test. BMR partially understood the problem, correctly determining the nth term, but could not determine the sum of the sequence, and did not attempt the flexibility or novelty items at all. This is consistent with Maskur et al. (2020), who found low-ability students struggle specifically when problems cannot be solved through standard formulas, reflecting a conceptual rather than a purely strategic limitation. BMR's visible confusion during the interview when asked to revisit the problems further suggests that this difficulty reflects incomplete conceptual understanding rather than a lack of creative strategy alone, a pattern also consistent with Niu et al. (2022), who found that the level of perceived learning support students receive is associated with their creative thinking outcomes independently of raw mathematical achievement, implying that BMR's difficulty may reflect not only ability but also the degree of structured, real-time scaffolding available during problem-solving.

Taken as a whole, this stepwise pattern, rather than a simple high-low dichotomy, is the ability-differentiated evidence anticipated as the empirical basis for didactical design decisions in synchronous and asynchronous mathematics learning environments. For

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high-ability students such as BMT, whose flexibility and novelty appear self-sustaining and require little external prompting, asynchronous formats, self-paced, open multiple-solution tasks, are well suited, since these students independently generate and justify alternative strategies without real-time scaffolding. For moderate-ability students such as BMS, whose fluency is intact but whose flexibility stalls at a single method, the critical didactical intervention point lies precisely at the transition from a correct procedure to an alternative one, a transition better suited to synchronous, real-time prompting than to asynchronous self-paced formats where a first correct answer may otherwise end the student's engagement with the problem. For low-ability students such as BMR, whose difficulty originates in incomplete conceptual understanding, Sukarma et al. (2024) suggest that sustained, synchronous conceptual scaffolding, rather than creative-thinking tasks themselves, should precede any attempt at flexibility- or novelty-oriented instruction. This is consistent with Mohammad et al. (2024), who found that asynchronous mathematics tasks must carry their own scaffolding in the absence of immediate teacher feedback, suggesting that low-ability students are the group most at risk of disengagement in a purely asynchronous distance mathematics environment. As Leikin and Pitta-Pantazi (2013) observe in their review of the state of the art in mathematical creativity research, the field has long called for instructional design that responds to how creativity actually varies across learners rather than treating a classroom as a uniform audience; the ability-differentiated findings of this study, and the didactical design implications drawn from them, offer one concrete response to that call within the specific context of synchronous and asynchronous mathematics learning.

Limitations

This study is subject to several limitations that should be considered when interpreting its findings. First, the number of research subjects was limited to three, one representing each category of mathematical ability (high, medium, and low), drawn from a single class at one school (SMAN 1 Sampang), which restricts the generalizability of the findings beyond the specific context studied. Second, mathematical ability was determined using a single administration of the Mathematics Ability Test, without accounting for the possibility that a student's ability profile may vary across topics or over time. Third, the study focused exclusively on the topic of sequences and series, so the ability-differentiated pattern of creative thinking identified here may not extend uniformly to other mathematical topics with different structural characteristics. Finally, and most importantly for the didactical design implications proposed in this study, all data were collected in a face-to-face classroom setting; the implications drawn for synchronous and asynchronous mathematics learning environments are theoretically derived from the observed ability-based patterns and have not been empirically tested within an actual distance or hybrid learning context.

Future Study

Future research should address these limitations in several ways. Studies involving a larger and more balanced number of subjects across multiple schools and classes would strengthen the generalizability of the ability-differentiated creative thinking profiles identified here, and could further examine whether the pattern holds across other mathematical topics beyond sequences and series. Most importantly, the didactical design implications proposed in this study, particularly the differentiated use of synchronous and asynchronous instructional formats across ability levels, warrant empirical validation through actual implementation in distance or hybrid mathematics learning environments, ideally using a quasi-experimental or design-based research approach that can measure their effect on students' creative thinking outcomes directly.

4. Conclusion

This study set out to describe how high school students' creative thinking in solving sequence and series problems differs according to their level of mathematical ability. The findings show that this difference is not a simple high–low dichotomy but follows a specific, stepwise pattern: the student with high mathematical ability met all three creative thinking indicators (fluency, flexibility, and novelty) consistently across both test versions; the student with moderate mathematical ability met only the fluency indicator, showing procedural competence without strategic variety; and the student with low mathematical ability met none of the three indicators, reflecting an incomplete grasp of the underlying concepts rather than a lack of creative strategy alone.

Beyond describing this pattern, the study contributes an ability-differentiated empirical basis for didactical design decisions in synchronous and asynchronous mathematics learning environments. Specifically, the findings suggest that high-ability students are well suited to asynchronous, self-paced open-ended tasks; moderate-ability students require synchronous, real-time scaffolding at the precise point where a single correct method must be deliberately unsettled to provoke flexibility; and low-ability students require sustained synchronous conceptual support before creative-thinking tasks are introduced at all, regardless of delivery mode. In this way, the study offers mathematics educators and instructional designers a concrete, ability-differentiated starting point for calibrating the level and timing of support across creative thinking tasks delivered synchronously and asynchronously, contributing to the broader effort of designing distance mathematics instruction that responds to genuine differences in how students think rather than treating them as a uniform audience.

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Author Contributions

Author 1: Conceptualization, Writing – Original Draft, Editing, and Visualization.
Author 2: Validation and Supervision.
Author 3: Writing, Review & Editing, and Methodology.
Author 4: Writing, Review & Editing
Author 5: Review

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Conflict of Interest

The authors declare that they have no conflicts of interest related to this study.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available to protect the privacy and confidentiality of the study participants.

AI Use Declaration

Generative artificial intelligence tools were used solely to support language refinement, improve grammatical clarity, and enhance the readability of the manuscript. AI tools were not used to generate or manipulate research data, conduct statistical analyses, or determine the study findings and conclusions. All AI-assisted content was critically reviewed and verified by the authors, who take full responsibility for the accuracy, integrity, and final content of the manuscript.

5. References

Ahmad, A., Maruf, A. H., & Yudha, C. B. (2024). Effectiveness of digital-based mathematics learning media on sequence and series material. *Polyhedron International Journal in Mathematics Education*, *2*(2), 69–78. https://doi.org/10.59965/pijme.v2i2.163

Bahar, A., & Maker, C. J. (2015). Cognitive backgrounds of problem solving: A comparison of open-ended vs. closed mathematics problems. *Eurasia Journal of Mathematics, Science and Technology Education*, *11*(6), 1531-1546. https://doi.org/10.12973/eurasia.2015.1410a

Brousseau, G. (1997). *Theory of didactical situations in mathematics*. Kluwer Academic Publishers.

Busyairi, A., & Sinaga, P. (2021). Test instruments development of ideation-explanation model to measure. *Jurnal Pijar MIPA*, *16*(1), 57–63. https://doi.org/10.29303/jpm.v16i1.1700

Darmawan, P., Salsabiila, A. S., & Olivero-Acuña, R. R. (2025). PAPUTRI (Trigonometric Rotating Board) as an innovation to enhance mathematics learning in trigonometry. *Panicgogy International Journal*, *3*(2), 39–53. https://doi.org/10.59965/pij.v3i2.170

de Vink, I. C., Willemsen, R. H., Lazonder, A. W., & Kroesbergen, E. H. (2022). Creativity in mathematics performance: The role of divergent and convergent thinking. *British Journal of Educational Psychology*, *92*(2), 484–501. https://doi.org/10.1111/bjep.12459

Elgrably, H., & Leikin, R. (2021). Creativity as a function of problem-solving expertise: Posing new problems through investigations. *ZDM – Mathematics Education*, *53*, 891–904. https://doi.org/10.1007/s11858-021-01228-3

Hadar, L. L., & Tirosh, M. (2019). Creative thinking in mathematics curriculum: An analytic framework. *Thinking Skills and Creativity*, *33*, 100585. https://doi.org/10.1016/j.tsc.2019.100585

Hong, W., Star, J. R., Liu, R. D., & Zhang, D. (2023). A systematic review of mathematical flexibility: Concepts, measurements, and related research. *Educational Psychology Review*, *35*(4), 1–33. https://doi.org/10.1007/s10648-023-09825-2

Ibrahim, I., & Widodo, S. A. (2020). Advocacy approach with open-ended problems to mathematical creative thinking ability. *Infinity Journal*, *9*(1), 93-102. https://doi.org/10.22460/infinity.v9i1.p93-102

Isnawan, M. G., Belbase, S., & Yanuarto, W. N. (2024). Implementation of a hybrid mathematics module to minimize students' learning obstacles when interpreting fractions. *International Journal of Didactic Mathematics in Distance Education*, *1*(2), 83–101. https://doi.org/10.33830/ijdmde.v1i2.9555

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

Klein, S., & Leikin, R. (2020). Opening mathematical problems for posing open mathematical tasks: what do teachers do and feel? Klein S., Leikin R. *Educational Studies in Mathematics*, *105*(3), 349-365. https://doi.org/10.1007/s10649-020-09983-y

Leikin, R. (2009). Exploring mathematical creativity using multiple solution tasks. In R. Leikin, A. Berman, & B. Koichu (Eds.), *Creativity in mathematics and the education of gifted students* (pp. 129–145). Springer.

Leikin, R., & Pitta-Pantazi, D. (2013). Creativity and mathematics education: The state of the art. *ZDM*, *45*(2), 159–166. https://doi.org/10.1007/s11858-012-0459-1

Mann, E. L. (2009). The search for mathematical creativity: Identifying creative potential in middle school students. Creativity Research Journal, 21(4), 338–348. https://doi.org/10.1080/10400410903297402

Maskur, R., Sumarno, Rahmawati, Y., Pradana, K., Syazali, M., Septian, A., & Palupi, E. K. (2020). The effectiveness of problem based learning and aptitude treatment interaction in improving mathematical creative thinking skills on curriculum 2013. *European Journal of Educational Research,* *9*(1), 375-383. https://doi.org/10.12973/eu-jer.9.1.375

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). SAGE Publications.

Mohammad, N. M., Nica, M., Kraus, D., Levere, K. M., & Okner, R. (2024). Student experience using synchronous and asynchronous instruction in mathematics classes. *Pedagogical Research*, *9*(2), Article em0194. https://doi.org/10.29333/pr/14244

Niu, W., Cheng, L., Duan, D., & Zhang, Q. (2022). Impact of perceived supportive learning environment on mathematical achievement: The mediating roles of autonomous self-regulation and creative thinking. *Frontiers in Psychology*, *12*, Article 781594. https://doi.org/10.3389/fpsyg.2021.781594

Nufus, H., Muhandaz, R., Hasanuddin, Nurdin, E., Ariawan, R., Fineldi, R. J., Hayati, I. R., & Situmorang, D. D. B. (2024). Analyzing the students' mathematical creative thinking ability in terms of self-regulated learning: How do we find what we are looking for? *Heliyon*, *10*(3), Article e24871. https://doi.org/10.1016/j.heliyon.2024.e24871

Nurfaidah, N., Pujiastuti, E., Nur Cahyono, A., Sugiman, S., Kharisudin, I., & Korkor, S. (2023). Systematic literature review: mathematical creative thinking ability reviewed from self-regulated in Project Based Learning (PjBL) Model. *International Journal of Mathematics and Sciences Education*, *1*(1), 31–40. https://doi.org/10.59965/ijmsed.v1i1.8

Puspitasari, L., In'am, A., & Syaifuddin, M. (2018). Analysis of students' creative thinking in solving arithmetic problems. *International Electronic Journal of Mathematics Education*, *14*(1). https://doi.org/10.12973/iejme/3962

Rahayuningsih, S., Sirajuddin, S., & Ikram, M. (2021). Using open-ended problem-solving tests to identify students' mathematical creative thinking ability. *Participatory Educational Research*, *8*(3), 285-299. https://doi.org/10.17275/per.21.66.8.3

Runco, M. A., & Jaeger, G. J. (2012). The standard definition of creativity. *Creativity Research Journal*, *24*(1), 92–96. https://doi.org/10.1080/10400419.2012.650092

Sadak, M., Incikabi, L., Ulusoy, F., & Pektas, M. (2022). Investigating mathematical creativity through the connection between creative abilities in problem posing and problem solving. *Thinking Skills and Creativity*, *45*, Article 101108. https://doi.org/10.1016/j.tsc.2022.101108

Schoevers, E. M., Leseman, P. P., Slot, E. M., Bakker, A., Keijzer, R., & Kroesbergen, E. H. (2019). Promoting pupils' creative thinking in primary school mathematics: A case study. *Thinking skills and creativity*, *31*, 323-334. https://doi.org/10.1016/j.tsc.2019.02.003

Silver, E. A. (1997). Fostering creativity through instruction rich in mathematical problem solving and problem posing. *ZDM Journal Mathematics Education*, *29*(3), 75–80. https://doi.org/10.1007/s11858-997-0003-x

Sipahi, Y., & Erbas, A. K. (2025). Problem-solving strategies: A comparative study of mathematically gifted and non-identified students. *Gifted and Talented International*, *40*(2), 119-139. https://doi.org/10.1080/15332276.2025.2601660

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

Suherman, S., & Vidákovich, T. (2022). Assessment of mathematical creative thinking: A systematic review. *Thinking Skills and Creativity*, *44*, 101019. https://doi.org/10.1016/j.tsc.2022.101019

Sukarma, I. K., Isnawan, M. G., & Alsulami, N. M. (2024). Research on nonroutine problems: A hybrid didactical design for overcoming student learning obstacles. *Human Behavior and Emerging Technologies*, *2024*, Article 5552365. https://doi.org/10.1155/2024/5552365

Surya, E., & Putri, F. A. (2017). Improving mathematical problem-solving ability and self-confidence of high school students through contextual learning model. *Journal on Mathematics Education*, *8*(1), 85-94. https://doi.org/10.22342/jme.8.1.3324.85-94

Uyen, B. P., Tong, D. H., & Tram, N. T. B. (2021). Developing mathematical communication skills for students in grade 8 in teaching congruent triangle topics. *European Journal of Educational Research*, *10*(3), 1287-1302. https://doi.org/10.12973/eu-jer.10.3.1287

Weiss, S., & Wilhelm, O. (2022). Is flexibility more than fluency and originality? *Journal of Intelligence*, *10*(4), Article 96. https://doi.org/10.3390/jintelligence10040096

Yayuk, E., Purwanto, As'ari, A. R., & Subanji. (2020). Primary school students' creative thinking skills in mathematics problem solving. *European Journal of Educational Research*, *9*(3), 1281–1295. https://doi.org/10.12973/eu-jer.9.3.1281