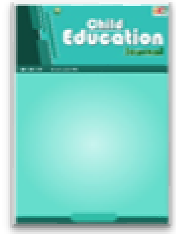

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ORIGINAL RESEARCH ARTICLE

Developing Mathematical Creativity in Early Grades: Impact Analysis of Geometric Problem Solving on Student Cognitive Levels

Ani Afifah[1*], Samuel Karim[2]

[1]Universitas PGRI Wiranegara, Pasuruan, Indonesia;
[2] Ernest Bai Koroma University of Science and Technology and College of Human Resources Development Sierra Leone

Correspondence: fifa.ani@gmail.com

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ABSTRACT

In today's digital era, critical and creative thinking skills are crucial for students to adapt to the demands of the 21st century. Creative and effective teaching, such as geometric problem solving, is considered an attractive strategy to enhance these skills. This study was conducted to evaluate the impact of geometric problem-solving teaching on students' cognitive development at the elementary level, where previous research has focused more on the development of cognitive and psychomotor skills. The main objective of this study was to analyze the level of mathematical creativity of early grade students in solving geometric problems involving triangles and quadrilaterals. Using a qualitative descriptive approach, this study involved three students with different levels of mathematical ability. Data were collected through validated problem-solving tasks, in-depth interviews, and documentation, then analyzed based on indicators of fluency, flexibility, originality, and elaboration. The results showed significant differences in students' cognitive levels: students with high ability achieved Creative Thinking Level (CTL) 4, students with medium ability achieved CTL 2, and students with low ability achieved CTL 0. The integration of non-routine geometric problems from the early grades is crucial for mapping and stimulating students' creative potential. These findings provide practical implications for educators in designing inclusive learning interventions to accelerate the achievement of basic numeracy literacy and 21st-century skills in accordance with the global mandate of the SDGs.

ABSTRAK

Di era digital saat ini, keterampilan berpikir kritis dan kreatif menjadi sangat penting bagi siswa untuk beradaptasi dengan tuntutan abad ke-21. Pengajaran yang kreatif dan efektif, seperti pemecahan masalah geometris, dianggap sebagai strategi yang menarik untuk meningkatkan keterampilan tersebut. Penelitian ini dilakukan untuk mengevaluasi dampak pengajaran pemecahan masalah geometris terhadap perkembangan kognitif siswa di tingkat dasar, di mana penelitian sebelumnya lebih banyak berfokus pada pengembangan keterampilan kognitif dan psikomotorik. Tujuan utama dari penelitian ini adalah untuk menganalisis tingkat kreativitas matematis siswa kelas awal dalam memecahkan masalah geometri yang melibatkan segitiga dan segi empat. Menggunakan pendekatan deskriptif kualitatif, penelitian ini melibatkan tiga siswa dengan tingkat kemampuan matematis yang berbeda. Data dikumpulkan melalui tugas pemecahan masalah yang tervalidasi, wawancara mendalam, dan dokumentasi, kemudian dianalisis berdasarkan indikator kelancaran, fleksibilitas, orisinalitas, dan elaborasi. Hasil penelitian menunjukkan perbedaan signifikan pada tingkat kognitif siswa: siswa dengan kemampuan tinggi mencapai Tingkat Berpikir Kreatif (CTL) 4, siswa dengan kemampuan sedang mencapai CTL 2, dan siswa dengan kemampuan rendah mencapai CTL 0. Integrasi masalah geometri non-rutin sejak kelas awal sangat penting untuk memetakan dan merangsang potensi kreatif siswa. Temuan ini memberikan implikasi praktis bagi pendidik dalam merancang intervensi pembelajaran yang inklusif untuk mempercepat pencapaian literasi numerasi dasar dan keterampilan abad ke-21 sesuai dengan mandat global SDGs.

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Keywords: *critical thinking skills, creative skills, geometric problem solving, mathematical creativity, cognitive development, inclusive education, numeracy literacy, SDGs*.

1. INTRODUCTION

Global efforts to achieve the Sustainable Development Goals (SDGs), particularly the fourth point concerning quality education, require a transformation of the learning system that focuses not only on basic literacy but also on developing higher-order thinking skills from an early age (Ferguson, 2020; Tatto, 2021). In today's era of disruption, the ability to think creatively in mathematics is a crucial competency that must be instilled in the early stages of primary education as a foundation for students' cognitive adaptability (Simatupang & Azis, 2022). The significance of creativity in mathematics in lower elementary school grades (phases A and B) is closely related to the formation of innovative mindsets that will determine their future academic and professional success (Afifah, Ainiyah, & Dehham, 2024; Yayuk, 2020). Therefore, strengthening creativity through geometric problem-solving is a strategic agenda in global education policy to produce a generation capable of facing the complex challenges of the 21st century.

However, the reality on the ground reveals a significant challenge: mathematics learning in elementary schools is still dominated by procedural approaches and the memorization of formulas, particularly in geometric materials such as triangles and quadrilaterals (Deng, 2020; Prioste, 2020; Siswanto, Tanikawa, Alghiffari, Limori, 2024). The main problem arises when lower-grade students are often viewed as passive recipients of information, thus under-stimulating their creative potential in exploring shapes and spaces. Another challenge is the stereotype that creative thinking can only be achieved by students with high cognitive abilities (Filippetti, 2020), while students with medium and low abilities often fall behind without appropriate intervention. This situation creates disparities in learning outcomes that hinder the equitable distribution of educational quality as mandated by SDG 4 (Yang, 2020).

Several previous studies have attempted to examine this phenomenon of mathematical creativity from various perspectives. Research related to levels of creative thinking (CBT) was conducted by Siswono (2023), who validated the hierarchy of creativity in secondary school students. However, this study was flawed because it did not address the unique characteristics of children's cognition at the concrete operational stage. Furthermore, Nurutdinova et al. (2020) examined creativity in elementary education in general but failed to provide specific instruments for the geometry domain for lower grades. Wijaya et al. (2022) explored mathematical problem solving, but their focus was limited to basic numeracy skills without linking them to indicators of novelty. Research by Fitri (2023) examined geometry in elementary school students, but tended to use quantitative methods that failed to capture students' mental processes in depth. Meanwhile, Smith (2021) and Rahmawati (2020) have begun to link mathematics education to the SDGs, but neither has specifically mapped the TBK profile based on differences in mathematical ability in early grade students. A major criticism of these studies is the neglect of the potential for "originality" in ideas in children aged 7-9, who are often considered unable to think divergently in a systematic manner.

The novelty of this research lies in the adaptation of the creative thinking level (CBT) instrument developed by Siswono for specific application to lower grade elementary school students (grades 1-3). Unlike previous research, which generally targeted middle school students, this study explores how fluency, flexibility, originality, and elaboration emerge in solving geometric problems of triangles and quadrilaterals during the concrete operational development phase (Meadows & Caniglia, 2021; Qomaria, Afifah, & Manivannan, 2025). This research offers a new perspective that mathematical creativity is not a single entity, but rather a multi-layered profile that can be identified even in children just beginning formal education through visual-geometric representations.

A research gap identified is the lack of a comprehensive mapping of the creative thinking profile of lower grade students directly linked to the three levels of mathematical ability (high, medium, low) within a single qualitative analysis framework. Most existing literature separates cognitive and creativity studies or focuses solely on one ability group (Chevalier, 2020; Rahardjanto, Husamah, & Fauzi, 2019). There is a lack of empirical data on how students with low mathematical ability in early grades respond to non-routine geometric problems, and how high-ability students at that age demonstrate elaboration in their task completion. This gap is what we attempt to bridge through an in-depth analysis of the impact of problem-solving on students' cognitive levels.

The main theoretical framework (grand theory) underlying this research is Jean Piaget's Constructivism Theory, specifically the concrete operational development stage. It states that elementary school-aged children construct their knowledge through active interaction with physical and visual objects. This theory is combined with G. Wallas's creativity framework and J.P. Guilford's divergent thinking theory to explain how the incubation and illumination of ideas occur when children solve problems (Cheung, 2022). The use of these classical theories is adapted to the modern educational context to ensure that the analysis has a strong epistemological foundation in explaining students' cognitive transition from intuitive to logical-creative thinking.

The concepts used in this study refer to the four pillars of mathematical creativity: fluency, flexibility, originality, and elaboration, which are integrated into Polya's problem-solving steps (Darmayanti, In, Afifah, Verliana, & Nurmaltasari, 2023). Fluency is measured by students' ability to generate multiple correct solutions (Baiduri, 2020; Pathuddin, 2024), flexibility in the variety of strategies used, originality in the uniqueness of ideas generated compared to peers, and elaboration in the extent to which students are able to detail the solution steps. The concept of Creative Thinking Levels (CBT) from level 0 (not creative) to level 4 (very creative) serves as the primary measuring tool for classifying students' cognitive performance in response to assigned geometry tasks (Suherman, 2024).

A compelling aspect of this study, and therefore crucial for its investigation, is the highly visual and manipulative nature of geometry materials, making them an excellent "laboratory" for observing young children's creativity before they become overwhelmed by abstract algebraic symbolism. Understanding creativity profiles from the early grades allows educators to detect potential mathematical talent early and design interventions for students experiencing cognitive challenges (Botting, 2020). This research is crucial because its findings will provide empirical evidence that investing in creativity in primary education is key to achieving inclusiveness and quality global education, as mandated by the SDGs.

Based on this background, this study aims to describe the profile of lower grade elementary school students' creative thinking levels in solving problems involving triangles and quadrilaterals. Specifically, this study aims to identify differences in achievement in aspects of creativity between students with high, medium, and low mathematical abilities. The results of this study are expected to serve as a reference in developing a more adaptive and innovative mathematics curriculum at the primary school level to enhance students' competitiveness internationally.

2. RESEARCH METHODS

This study uses a qualitative approach with a descriptive analytical design to deeply explore students' cognitive phenomena in solving geometry problems (Wark, 1992). The use of this method aims to provide a comprehensive picture of the profile of mathematical creativity at the concrete operational level, in line with the focus of the (Sujiva et al., 2020) pedagogical innovation and cognitive excellence in early childhood (Darmayanti, 2022; Inganah et al., 2023). This entire series of methodologies is designed to address the challenges of numeracy literacy within the framework of 21st-century skills and the mandate of SDGs 4 regarding quality education for all levels of student ability (Afifah et al., 2024; Ferguson, 2020).

2.1. Research Design

This research design focuses on qualitative-descriptive analysis aimed at dissecting students' divergent thinking processes when interacting with non-routine geometry problems. This design selection is highly relevant for capturing mental dynamics that cannot be measured statistically, such as originality of ideas and flexibility in manipulating geometric shapes (Wijaya, 2021; Yang, 2020). This study positions the researcher as a key instrument, conducting participant observation and clinical interviews to detect students' cognitive transitions from basic stages to more complex creative thinking. Empirically, this approach has proven effective in mapping the cognitive potential of early childhood through exploratory tasks that stimulate Higher Order Thinking Skills (HOTS) (Kristiantari et al., 2023; Purnomo, 2022). By describing each student's response in detail, this study is able to identify cognitive barriers as well as opportunities for developing mathematical talent from an early age (Simatupang & Azis, 2022; Siswanto et al., 2024). See Figure 1.

Figure 1. Research Procedure Flow

Figure 1 illustrates a systematic cycle that begins with the conceptualization stage based on literature studies and ends with the final profile mapping stage. The instrument development stage (TKBK) is crucial to ensure the presented problem can trigger all four creativity indicators, while subject selection through purposive sampling ensures representation of each level of cognitive ability (high, medium, and low) for comparative analysis.

2.2 Data Collection

Data collection techniques relied on triangulation methods, consisting of the Creative Thinking Ability Test (CBT), in-depth clinical interviews, and documentation of work results. The CBT test served as the primary stimulus for observing students' visual-spatial responses to the attributes of triangles and quadrilaterals, while interviews were used to explore the logical justification behind emerging solutions (Darmayanti, 2022; Purnomo, 2022). The use of documentation in the form of process recordings and student scribbles provided strong empirical evidence regarding the development of elaboration and idea fluency indicators (Wijaya, 2021; Siswanto et al., 2024). This strategy aligns with the needs of early childhood research, which requires engaging communication media and simple language to avoid bias in the results (Afifah et al., 2024; Kristiantari et al., 2023). Through this triangulation, researchers can ensure the validity of cognitive information collected from various mutually reinforcing data sources.

2.3 Data Analysis

Data analysis was conducted following the interactive model of Miles, Huberman, and Saldaña, which consists of three simultaneous activity streams: data reduction, data presentation, and conclusion drawing. In the Data Reduction stage, student responses were coded based on creativity indicators, strategies were identified through doodles, and interview transcripts were transcribed (Masykur et al., 2025; Siswanto et al., 2024). The Data Presentation stage (display) was conducted by constructing a creativity profile matrix to compare performance across subjects. The indicators analyzed included: 1) Fluency (number of shape variations); 2) Flexibility (diversity of geometric shapes); 3) Originality (uniqueness of answers compared to peers); and 4) Elaboration (detailed decoration). Finally, Conclusion Drawing is done through cross-verification (triangulation) between the test results and students' oral justifications to determine an accurate Creative Thinking Level (CTL) (Afifah et al., 2024; Kristiantari et al., 2023). Data analysis was conducted following the interactive model of Miles, Huberman, and Saldaña (Masykur, Haris, & Yazid, 2025), which consists of three simultaneous activity streams:

a. Data Reduction

This stage involves selecting, focusing, and simplifying raw data from test and interview results.

1) Codification: Student responses are grouped based on creativity indicators (Fluency, Flexibility, Originality, and Elaboration).
2) Strategy Identification: Analyzing student drawings and doodles to find unique problem-solving patterns.

3) Transcription: Converting interview recordings into text to strengthen students' cognitive evidence.

b. Data Display

Data is presented in the form of a creativity profile matrix to facilitate comparisons between subjects.

c. Indicator Analysis: 1) ***Fluency***: Calculated from the number of correctly drawn geometric shapes within a problem context; 2) ***Flexibility***: Assessed by the diversity of plane shapes (e.g., combining equilateral triangles with trapezoids, not just triangles); 3) ***Originality***: Compared with answers from the same age group; if the shape created is rare (unique), then the criterion is met; 4) ***Elaboration***: Assessed by the student's ability to systematically detail or add ornamentation to the shape they created; 5) ***Creative Thinking Level Mapping***: Compiling the analysis results into a Creative Thinking Level table (Levels 0-4).

d. Conclusion Drawing/Verification

1) Triangulation: Comparing written test data with interview results. If the student draws a unique shape but cannot explain the reasoning, then the originality aspect is considered not fully met (thinking process verification).
2) Final Synthesis: Summarizing the student's creative profile and providing pedagogical recommendations to improve the quality of education (SDG 4).

Data analysis mechanisms in this study in Figure 2.

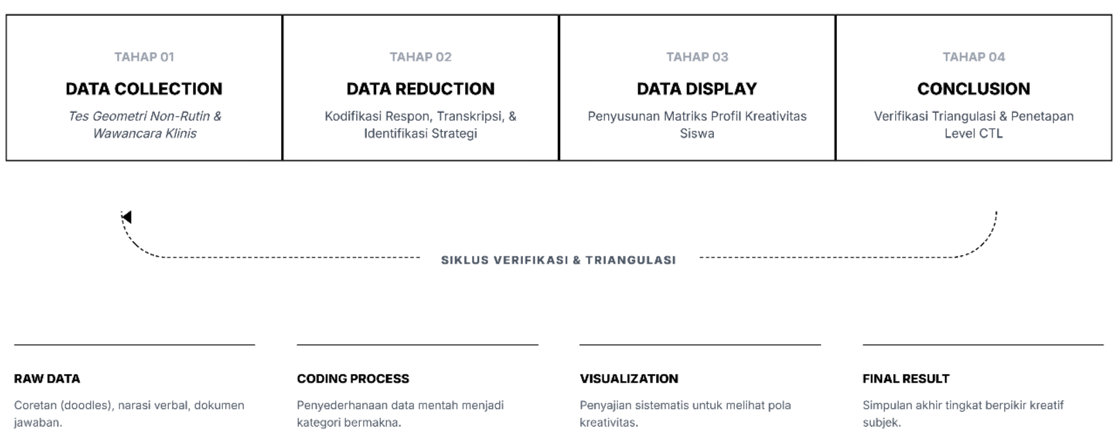

Figure 2. Data Analyss

2.4 Research Instrument

The primary instrument of this study was the Creative Thinking Ability Test (TKBK), which uses simple language and exploratory instructions to encourage thorough exploration (Kristiantari et al., 2023; Purnomo, 2022). This instrument contains engaging graphic elements consisting of three main sections: 1) Magic House (Fluency Aspect), in which students are asked to fill in a picture of an empty house with various combinations of triangles and quadrilaterals; 2) Creativity in Dots (Originality & Flexibility Aspect), which challenges students to create a unique shape covering 4 square units on a grid of dots; and 3) Transformation (Elaboration Aspect), which requires students to dissect and rearrange compound shapes into new, detailed shapes (Wijaya, 2021). Instrument validation was conducted to ensure that the questions were relevant to the cognitive development of early grade students and were able to stimulate analytical abilities optimally according to modern numeracy literacy standards (Simatupang & Azis, 2022; Siswanto et al., 2024). Through this approach, it is hoped that participants will optimally develop their analytical and creative abilities.

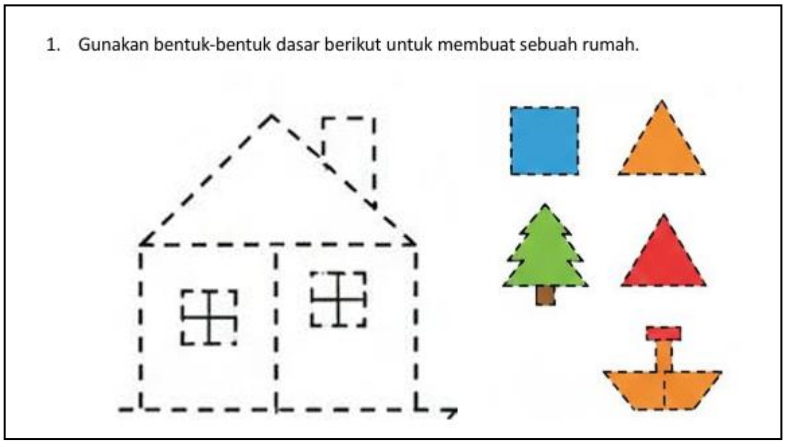

Figure 3. Question 1 of Exploring Shape Composition (Fluency Aspect)

Students are given a blank image of a "Magic House" and asked to fill it with as many combinations of plane shapes (triangles and quadrilaterals) as possible. Students are asked to draw/paste various triangles and quadrilaterals that could form the house. The fluency score is assessed based on the number of correct shape variations.

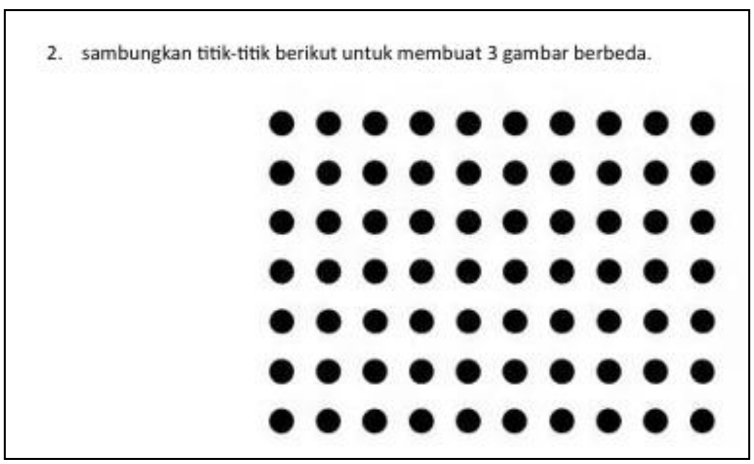

Figure 4. Question 2 of Creativity in Dots (Originality & Flexibility Aspects)

Students are given a dot grid and asked to create a flat shape with an area of 4 small square units, but with a unique shape.

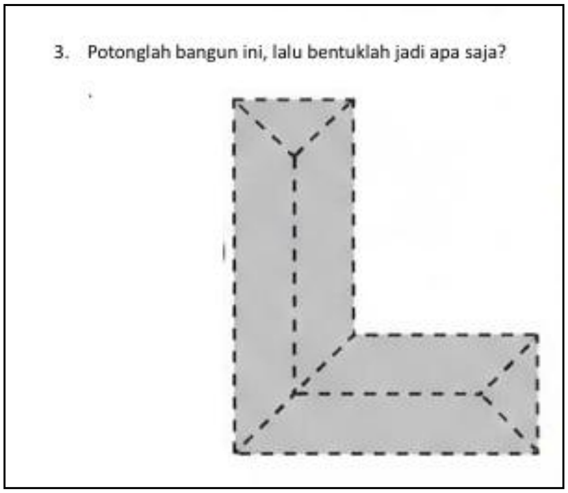

Figure 5. Question 3 of Transformation and Elaboration (Elaboration Aspect)

Students are asked to break down compound shapes and rearrange them into new shapes.

2.5 Validity and Reliability

The validity of the data in this study was ensured through method and time triangulation techniques, as well as peer debriefing to ensure objectivity of interpretation. Researchers verified the results using a think-aloud technique to ensure that what students drew or constructed truly represented their thinking processes and was not merely a coincidence (Darmayanti, 2022; Masykur et al., 2025). Furthermore, the TKBK instrument underwent content validation testing by mathematics education experts and early childhood education practitioners to ensure alignment between the problem content and the creativity indicators adapted for the concrete operational level (Kristiantari et al., 2023).

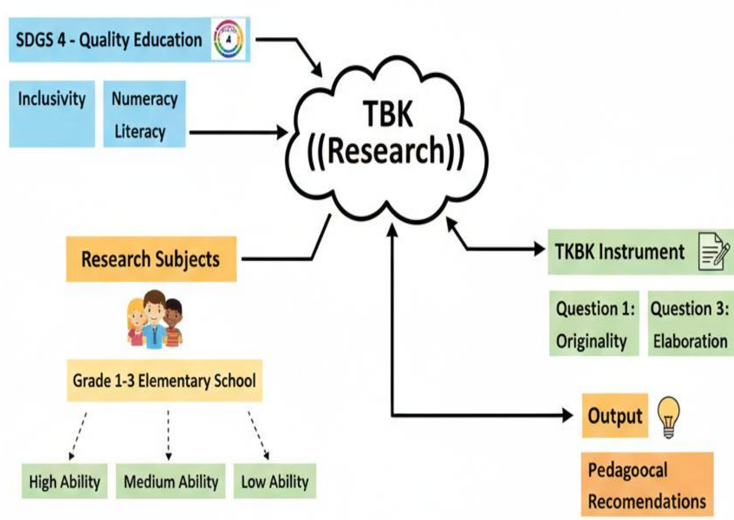

Figure 6. Research Procedures

2.6. Research Subjects

The selection of research subjects was conducted through purposive sampling technique in an elementary school in Pasuruan, East Java, involving three early grade students (Phase A/B) categorized into high ability groups (S_{KT}), medium (S_{KS}), and low (S_{KR}). The determination of subject selection criteria was based on three fundamental parameters: first, quantitative aspects including report card grades and basic geometry test scores to map cognitive disparities; second, pedagogical aspects through class teacher recommendations regarding the consistency of academic performance and daily learning behavior (Sohaeir et al., 2023); and third, communication aspects to ensure subjects have verbal skills that support the effectiveness of the think-aloud technique during clinical interviews (Afifah et al., 2024; Inganah et al., 2023). The integration of these three criteria is crucial to produce a valid and inclusive creativity profile in accordance with the mandate of SDG 4 in an effort to map students' cognitive potential transparently (Masykur et al., 2025).

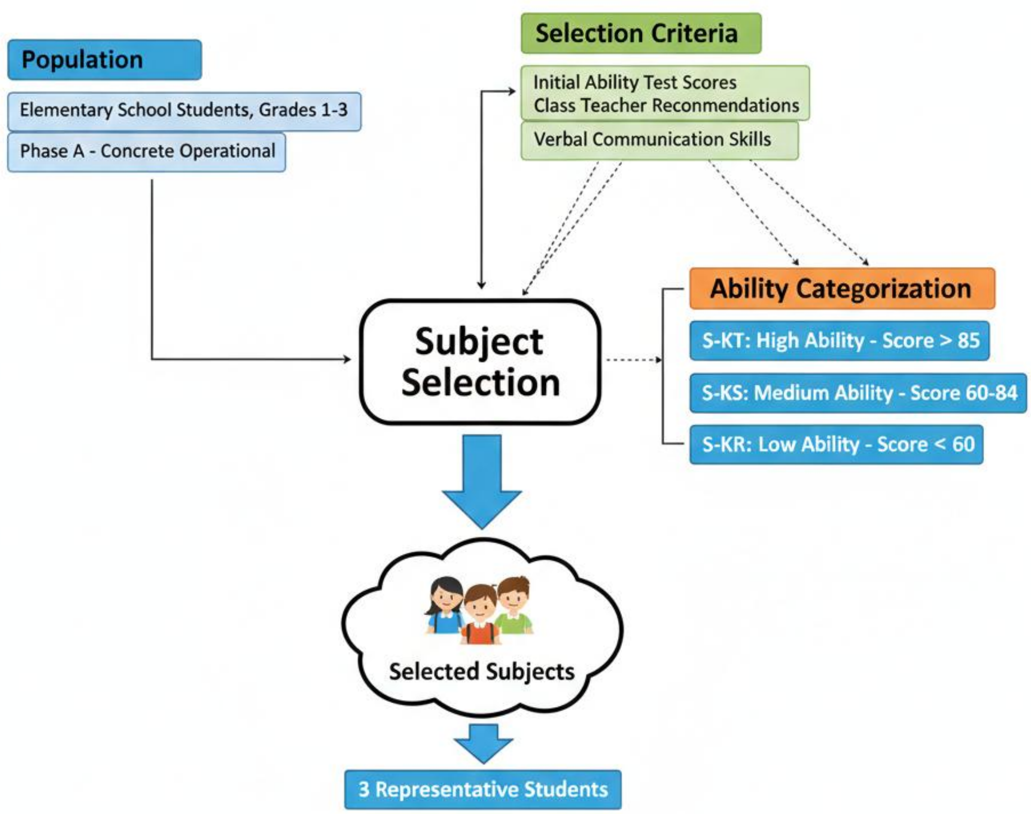

Figure 3. Research Subject Selection Flow

This study adopted a purposive sampling technique to determine the research subjects. This technique was chosen so that the researcher could intentionally select individuals deemed most suitable to provide information relevant to the research objectives. In this context, three students from grades 1-3 were selected based on their mathematical abilities, aiming to represent three different categories of mathematical ability.

a. High Ability Subjects (S-KT): Students in this category have an understanding of geometric concepts that exceeds the class average. They are able to apply geometric concepts and theories well in a variety of situations and demonstrate higher analytical skills than their classmates. They are often able to solve complex mathematical problems and demonstrate creativity in their problem-solving approaches.

b. Medium Ability Subjects (S-KS): These students have an understanding of concepts that aligns with applicable curriculum standards. They can follow lessons well and are usually able to correctly complete assignments given by the teacher. Although they understand basic concepts and can apply geometric theories in familiar situations, they may require some assistance to tackle more challenging problems.

c. Low Ability Subjects (S-KR): Students in this category require more guidance to recognize and understand the attributes of geometric figures. They may have difficulty grasping basic geometric concepts and require a more individualized and interactive teaching approach. These students often benefit from more visual and hands-on teaching methods to help them develop a deeper understanding of geometric concepts.

3. RESULTS AND FINDINGS

This section presents in-depth findings regarding the cognitive profile and Creative Thinking Level (CTL) of lower-grade elementary school students (Phase A). The analysis provides a comprehensive overview of the research data obtained through triangulation techniques, including the results of three geometry problem-solving instruments, clinical interviews, and behavioral observations. The findings are structured to address the core research questions by evaluating how students within this specific developmental phase navigate geometric challenges.

3.1 Research Subject Profile

The subjects in this study were selected using a purposive sampling technique to obtain a contrasting picture across cognitive levels. Subjects were selected based on a combination of initial math ability test scores, classroom teacher recommendations, and students' verbal communication skills for in-depth interviews. The following is a detailed profile of the research subjects:

3.1.1 High Ability Subject (S-KT)

AZ is a third-grade elementary school student who achieved a score of 92 on the basic mathematics ability test, positioning him in the high-performance tier. He consistently demonstrates above-average academic performance, particularly excelling in visual logic and spatial reasoning tasks. Cognitively, AZ is in a significant transition stage, moving from concrete operational thinking toward more abstract conceptualization. This developmental progression allows him to manipulate geometric ideas mentally without relying solely on physical manipulatives.

His cognitive profile is further characterized by a remarkably strong working memory, which enables him to recall and synthesize multiple geometric attributes simultaneously during problem-solving. AZ exhibits a high degree of curiosity and intellectual persistence when confronted with non-routine problems. Unlike his peers, he demonstrates high self-efficacy; he views complex geometric tasks not as academic hurdles, but as engaging creative challenges or "puzzles" to be solved. This psychological orientation allows him to apply his advanced cognitive strengths—such as systematic analysis and intuitive synthesis—to achieve innovative results in non-routine geometric problem-solving effectively.

3.1.2 Medium Ability Subject (S-KS)

RN is a second-grade elementary school student who achieved a score of 75 on the basic mathematics ability test, placing him within the "average" or medium-performance category. He is characterized as a highly disciplined student who demonstrates a strong ability to follow structured teacher instructions and classroom protocols. While RN possesses a solid foundational understanding of basic geometric concepts such as triangles and quadrilaterals, his problem-solving approach is predominantly linear and conventional.

In terms of cognitive characteristics, RN exhibits a strong tendency toward "reproductive thinking," where he prioritizes the replication of known patterns and formulas over the exploration of novel methods. This behavior suggests that his cognitive flexibility is still restricted by a psychological need for academic certainty; he often hesitates to attempt non-routine procedures for fear of deviating from the "correct" answer established in textbooks or by the teacher. Consequently, while he is capable of completing tasks accurately within a familiar framework, he rarely engages in autonomous exploration or heuristic strategies, indicating that his creative potential is currently dormant under the influence of procedural rigidity.

3.1.3 Low Ability Subject (S-KR)

DI is a first-grade elementary school student who scored 40 on a basic math proficiency test, placing him in the low-achieving category. DI frequently exhibits significant difficulty identifying differences between similar geometric shapes, such as squares and rectangles, or triangles of various orientations. From a cognitive perspective, DI is still in the pre-conceptualization stage of geometric development. He tends to view geometric shapes as whole objects without understanding or recognizing their constituent attributes, such as sides, vertices, and angle measures.

These cognitive characteristics cause DI to experience spatial disorientation when faced with shape manipulation tasks. He frequently fails to connect lines to form closed polygons, indicating that his understanding of the boundaries of geometric space is not yet fully developed. Difficulty recognizing these attributes is a major obstacle to his spatial reasoning development, requiring more intensive concrete media support and highly structured instruction to begin building basic geometric literacy. This situation reflects the need for numeracy interventions that focus on the fundamentals of visual perception before moving on to more complex problem-solving. Table 1 is a Summary of Basic Sociodemographic and Cognitive Data; it provides a summary of the participants' data to compare their cognitive levels.

Table 1. Sociodemographic and Cognitive Baseline Summary

Subject Code	Pseudonym	Grade	IMA Score	Primary Cognitive Marker
S-KT	AZ	3rd	92	Transitioning to Abstract; Strong Working Memory.
S-KS	RN	2nd	75	Pattern-Dependent; Reproductive Thinking.
S-KR	DI	1st	40	Pre-Conceptual; Attribute Identification Deficit.

The research followed a structured hierarchical flow to ensure data validity through triangulation, as illustrated in the following diagram:

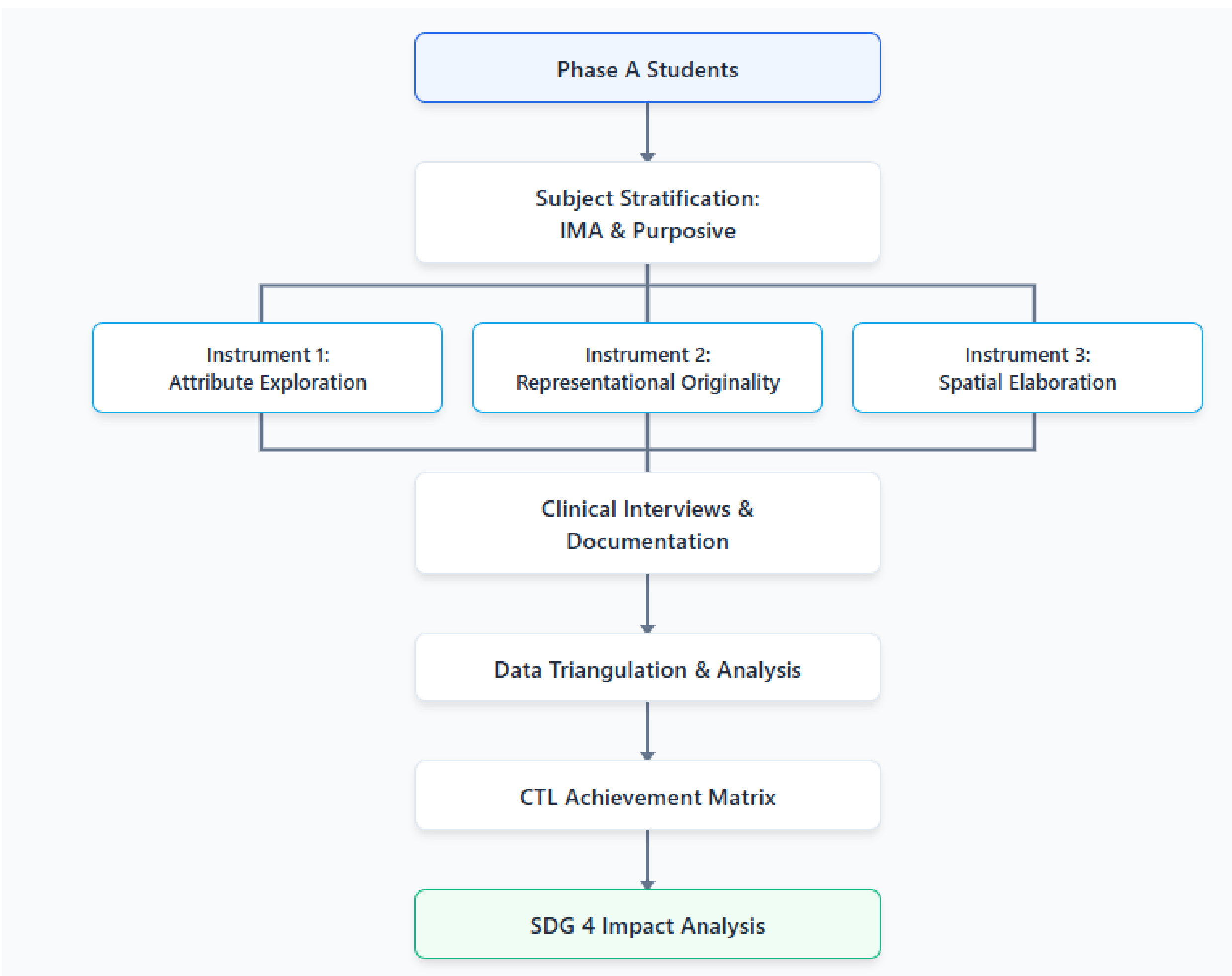

Figure 4. Research Flowchart

3.2 Analysis of Instrument 1: Geometric House Composition (Attribute Exploration)

This instrument was designed to evaluate students' ability to manipulate basic shapes (triangles and quadrilaterals) to build functional structures. The primary focus of the analysis was on Fluency and Flexibility indicators, exploring how students perceive and utilize geometric attributes within a constructive context.

3.2.1 Cognitive Analysis of S-KT (AZ) in Building Composition

Figure 5. S-KT (AZ) Geometric House Decomposition Results.

AZ demonstrated highly mature Cognitive Decomposition skills. Instead of viewing the roof of the house as a single, large triangle, AZ divided the area into three geometric zones: two right triangles on the edges and one trapezoid in the center.

1) Fluency Aspect: AZ was able to provide more than five different combinations of plane shapes within a single house frame.
2) Flexibility Aspect: AZ's strategy shifted from using a single shape to combining several smaller shapes to form a single function (the roof).

Subject AZ demonstrated a highly mature cognitive profile through his mastery of Cognitive Decomposition skills. Rather than viewing the roof of the house as one large, static triangle, he mentally deconstructed the area into several modular components. From the aspect of fluency, AZ was able to produce more than five different combinations of plane shapes within a single house frame, where his ability to rapidly produce alternative sketches indicates a high flow of ideas (ideational flow) in geometric space. Meanwhile, in the aspect of intersection (flexibility), AZ's strategy shifted dynamically from using a single shape to combining several smaller shapes—such as dividing the roof area into two right-angled triangles and one central trapezoid—to fulfill one complete structural function.

3.2.2 Cognitive Analysis of S-KS (RN) in Building Composition

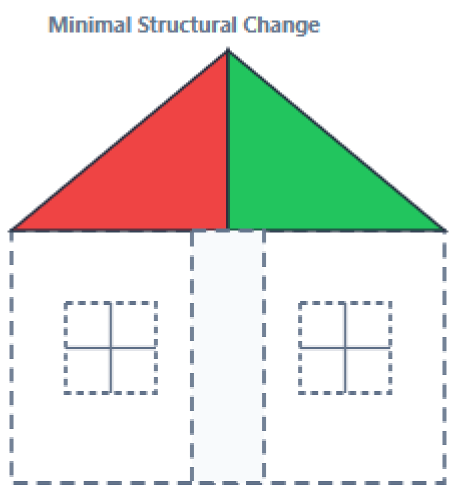

Figure 6. S-KS (RN) Visual Elaboration with Minimal Structural Change

Based on the visual work evidence (a house with a blue and orange roof), RN demonstrates a Visual Elaboration profile, but remains structurally conventional.

1) Fluency Aspect: RN generated two distinct compositional ideas. Her strategy was to place two triangles side by side to form a wide roof.

2) Flexibility Aspect: RN's flexibility is evident in her ability to use two contrasting colors to differentiate the sides of the roof.

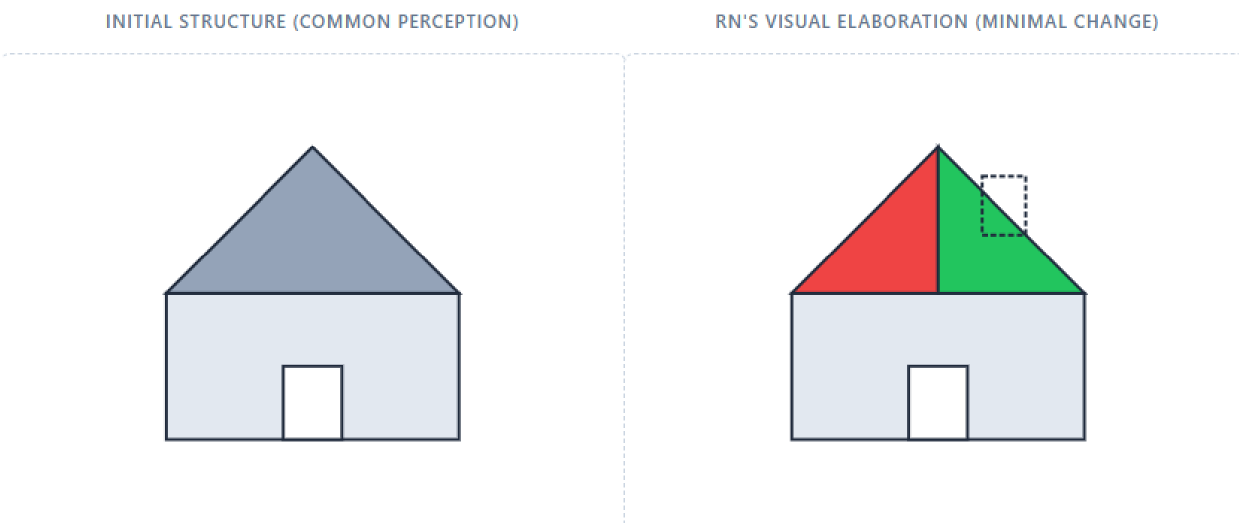

Figure 7. S-KS (RN) Visual Elaboration with Minimal Structural Change

Based on visual evidence in the form of a picture of a house with a blue and orange roof, subject RN shows a Visual Elaboration profile but still maintains a conventional structure. RN prioritizes visual distinction over geometric innovation, which is evident in his ability to produce two different composition ideas but still uses the basic strategy of placing two triangles side by side to form a wide horizontal roof. From the aspect of fluency, he is able to provide a variety of ideas although limited to traditional alignment. Meanwhile, in the aspect of flexibility, RN's ability is limited only to changes in the surface level (the use of contrasting colors), while the underlying geometric structure remains rigid and does not show any attempt at form decomposition.

3.2.3 Cognitive Analysis of S-KR (DI) in Building Composition

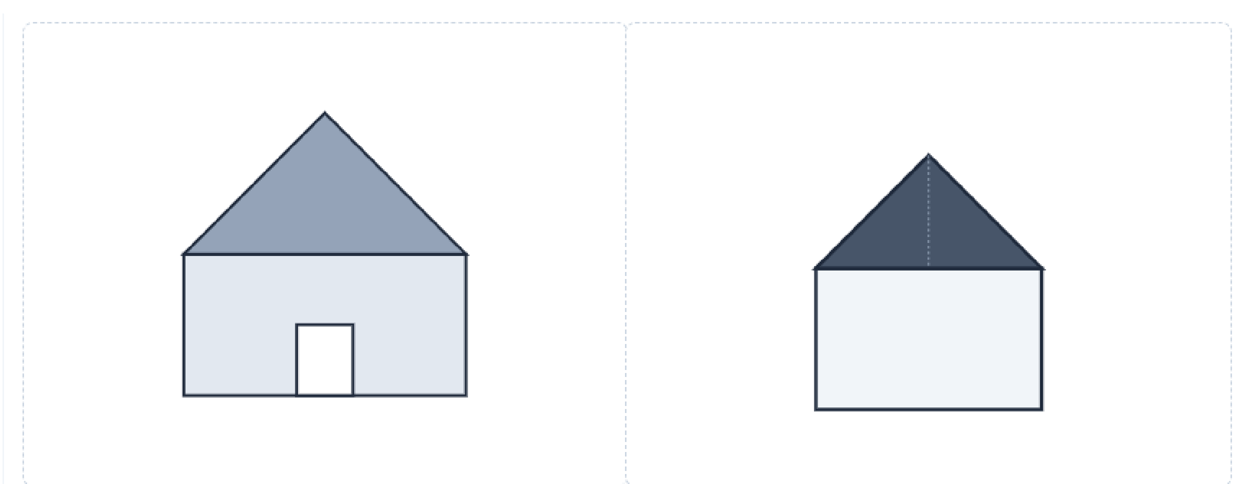

Figure 8. S-KR (DI) Holistic Spatial Perception Deficit

Subject DI showed significant cognitive challenges at the spatial perception stage, where he did not yet have the fundamental ability to manipulate the orientation and scale of shapes. In the aspect of spatial constraints, DI was only able to place one rigid triangle directly above a square without any attempt to vary the position, size, or relationship between the shapes. This was caused by an attribute identification deficit, where DI viewed plane shapes as whole holistic objects rather than as a collection of sides and angles, so that indicators of fluency and flexibility did not appear in his work results.

3.3 Instrument Analysis 2: Dot-Grid Exploration (Originality & Representation)

This instrument challenges students to connect dots to create three different images, aiming to measure Originality and Flexibility.

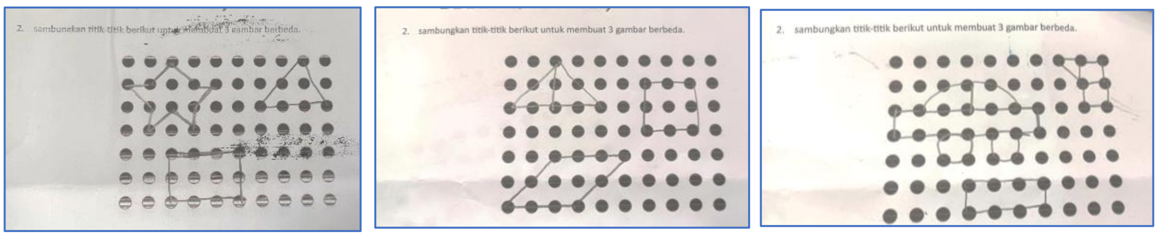

Figure 9. student's answer to question no. 2

3.3.1 S-KT Cognitive Analysis (AZ): Representational Object Transformation

AZ demonstrated cognitive abilities that transcended the boundaries of abstract geometry. Using the dot grid, he not only drew plane figures but also created representational objects in the form of cars/trucks.

1) Originality: AZ demonstrated the courage to deviate from rigid instructions. He utilized dots as the structural framework of the vehicle, adding asymmetrical details to the wheels (loops) and the truck body. This demonstrated his cognitive level of ability to perform a visual synthesis between mathematical concepts and reality.
2) Flexibility: AZ was able to dynamically change the direction of the lines (diagonal and horizontal) to form the angles of the car's cabin, a feat rarely performed by other students his age.

3.3.2 Cognitive Analysis S-KS (RN): Repetition of Conventional Patterns

RN demonstrated a high level of Fluency but was trapped in reproductive thinking. He produced three different shapes: a Triangle, a Square, and a Parallelogram.

1) Characteristics: The shapes RN produced were basic shapes that followed the rules of points very precisely. However, his ideas were conventional and very similar to examples in textbooks.
2) Barrier to Originality: RN was afraid of making mistakes, so he preferred to draw shapes that were "definitely correct" rather than trying unique shapes. When questioned, RN replied, "I just drew what the teacher taught me."

3.3.3 Cognitive Analysis S-KR (DI): Failure to Form Polygons

Subjects with DI demonstrate fundamental barriers to understanding the concept of closed shapes. Based on observational data, DI only produces random or broken lines connecting two to three points without successfully creating a complete area or polygon. This barrier stems from DI's inability to process the relationships between points as spatial boundaries. This failure to form polygons automatically closes the opportunity for creativity indicators to emerge, as the necessary foundation for spatial numeracy has not been firmly established.

3.3.4 Clinical Interview Insights: Metacognitive Awareness

AZ displayed high metacognition. When asked about his diagonal division strategy, he stated: "If I just drew a straight line, it would look like a regular house. I wanted to see if I could make it look like it was moving, like a vehicle." This demonstrates a conscious effort towards Originality.

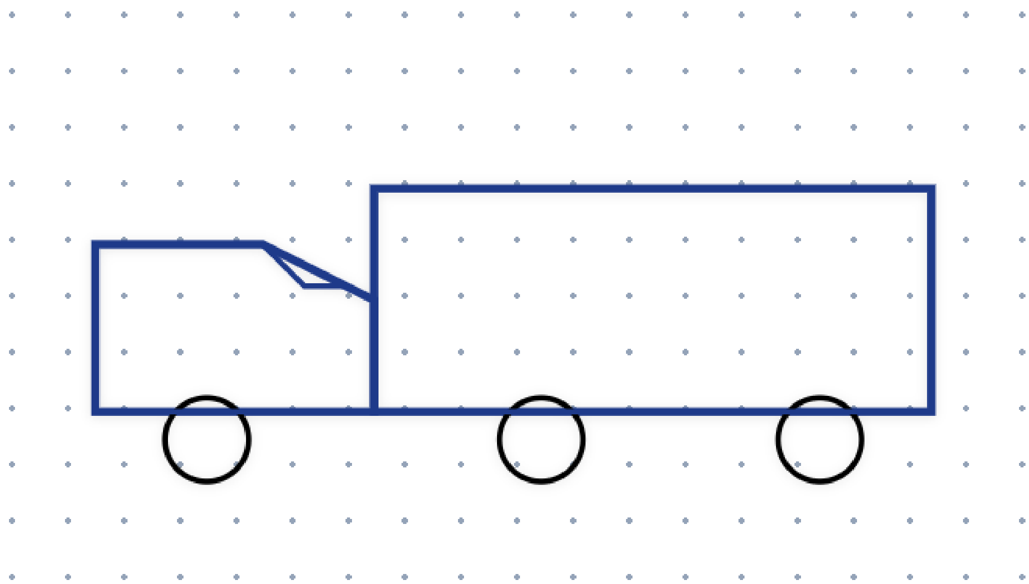

Figure 10. S-KT (AZ) Originality: Representational Truck from Geometric Dots.

3.4 Instrument Analysis 3: Shape Transformation (Elaboration & Spatiality)

This instrument requires students to cut a composite shape and rearrange it into a new shape, measuring Elaboration.

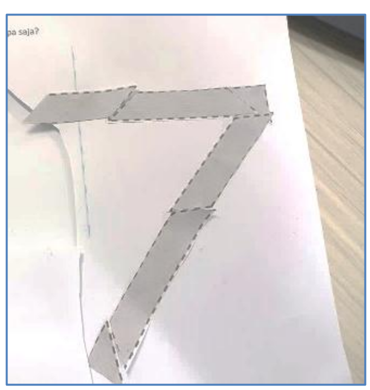

Figure 11. student's answer to question no. 3

3.4.1 Cognitive Analysis of S-KT (AZ): Meaningful Reconstruction

AZ demonstrates highly detailed elaboration skills through the creation of a Chevron/Arrow Shape.

1) Detail Aspect: AZ is meticulous in joining the diagonals of the pieces to form a sharp, symmetrical arrowhead. The precision of each piece demonstrates superior visual-spatial understanding.
2) Functional Narrative: AZ is able to give new meaning to the arrangement, "This arrow lets people know which way to go." This demonstrates the ability to cognitively integrate physical form and symbolic function.

3.4.2 Cognitive Analysis of S-KS (RN): Simple Horizontal Alignment

RN arranges the pieces of the shape in a row without forming a new, unified object.

Characteristics: He is able to name each type of geometric figure he has (e.g., "this is a triangle, this is a square"), but he fails to synthesize the pieces to form a shape that has a different meaning from the original. The elaboration that emerges is limited to attribute identification, not idea transformation.

3.4.3 S-KR Cognitive Analysis (DI): Spatial Disorientation

DI experiences complete confusion when asked to rearrange the pieces of a figure. He tends to leave the pieces scattered or simply pile them up randomly.

Obstacle: DI loses the concept of part-to-whole relationships. He fails to see that the small pieces come from the same larger figure, indicating a low level of cognitive and spatial elaboration.

3.5 Creative Thinking Level Achievement Matrix (CBT)

Based on the results of the cognitive analysis of all instruments, the following is a matrix of creativity indicator achievements that determine the student's final cognitive profile:

Table 2. Recapitulation of Creative Thinking Level (TKBK)

Indicator	S-KT (AZ)	S-KS (RN)	S-KR (DI)
Fluency	Very Good: Provides >5 solutions on instrument 1 and object representation on instrument 2.	Good: Produce 3 types of basic flat shapes independently.	Deficient: Unable to produce valid plane shapes.
Flexibility	Very Strong: Capable of performing roof decomposition and changing the direction of diagonal lines on the dot-grid.	Limited: Only able to draw shapes in standard orientation (horizontal-vertical).	No Appearance: Fixed to a single line without any variation in shape.
Originality	Emergence: Creating real objects (cars/trucks) on top of an abstract geometric framework.	Not Appearing: All answers are repetitions of textbook material.	No Emergence: No idea formed.
Elaboration	Detail: Arranges arrows/chevrons with precision and provides a functional narrative.	Enough: Do visual elaboration through the use of contrasting colors in the house.	No Appearance: The building pieces are left scattered without structure.
The Final Result	Level 4 (Very Creative)	Level 2 (Quite Creative)	Level 0 (Not Creative)

3.6 Impact on SDG Target 4 (Quality Education)

The findings of this study have strategic implications for achieving the global target of Sustainable Development Goals (SDGs) point 4, particularly in the context of inclusive and transformative basic education. The details are as follows:

a. Achieving Inclusive Basic Numeracy Literacy (Target 4.1): This study provides empirical evidence that the failure of creativity in the S-KR (DI) subject is rooted in an incomplete understanding of the basic concept of polygons. The implications for SDG 4 policy are the need to strengthen numeracy literacy in the early stages (Grade 1) to prevent cognitive disparities in subsequent levels of education. Quality education must ensure that every child has a solid cognitive foundation before being directed to complex thinking skills.

b. Developing 21st-Century Skills (Target 4.4): Achieving Level 4 of the AZ (S-KT) demonstrates that geometry can be an effective medium for developing High-Order Thinking Skills (HOTS) from an early age. AZ's ability to create "Cars" and "Arrows" (aspects of originality and elaboration) is an indicator of the achievement of relevant technical and creative skills for future innovation, in line with the SDGs mandate to increase the number of individuals with competitive skills.

c. Implementation of Differentiated Learning (Target 4.5): The matrix in point 5 emphasizes the importance of eliminating gender and ability disparities in education. Quality education does not mean providing uniform treatment, but rather differentiated treatment. For Level 0 students, education should focus on remediation and concrete media, while for Level 4 students, the curriculum should provide exploratory enrichment so that their innovative potential is not hampered by conventional learning patterns.

d. Early Diagnosis to Mitigate Learning Loss: By using visual-based geometry problem-solving tools, teachers can detect students' cognitive barriers early. This early diagnosis is crucial in the context of SDG 4 to prevent permanent learning lag and ensure that students' cognitive transition from the concrete operational stage to the formal operational stage is optimal and equitable for all levels of students.

4. DISCUSSION

An exploration of the cognitive profiles of early grade students through geometry problem solving reveals a sharp dichotomy between procedural abilities and original ideas in children's reasoning structures. Findings from the first instrument, the Geometric House Composition, clearly highlight the difference between reproductive and productive thinking. Subject RN (S-KS) engaged in visual elaboration through contrasting roof colors (blue and orange) but remained stuck in episodic memory of the standard house shape, while subject AZ (S-KT) demonstrated spatial maturity through cognitive decomposition skills by breaking the roof area into several smaller geometric zones. This phenomenon confirms that for early grade students, the ability to see large objects as a combination of smaller parts is a strong early indicator of thinking flexibility. This aligns with

Wang's (2022) view that area decomposition in geometry is a manifestation of executive function maturity in managing complex visual information beyond standard school procedures.

Further elaboration through the second instrument, the Dot-Grid Exploration, revealed the most significant finding, in which subject AZ transcended the boundaries of formal mathematics by transforming coordinate points into representations of real-world objects such as cars and trucks. Theoretically, this boldness in moving beyond rigid instructions—from simply drawing plane figures to representational objects—demonstrates high-level visual synthesis and divergent thinking, where AZ was able to visually synthesize point coordinates with real-life objects. This analysis suggests that at a mature cognitive level, mathematics is considered a medium for creative expression, not simply the manipulation of numbers. This finding is supported by Yang's (2020) research, which highlights the importance of balancing cognitive complexity with exploratory challenges to stimulate innovative and original learning performance.

Examining the barriers in low-ability (DI) subjects, it was found that the failure to form closed polygons and instead producing random lines indicates a "cognitive wall" at the spatial perception stage. Without an understanding that lines are connecting spatial boundaries, creativity is impossible because incomplete basic numeracy literacy is a major barrier. This provides a crucial lesson: mathematical creativity is rooted in mastery of basic attributes such as sides and angles. This analysis is reinforced by Patston et al. (2021), who stated that without a solid foundation of numeracy literacy, efforts to develop creativity will only result in cognitive confusion; therefore, criticism of the Phase A curriculum should be directed at mastering pragmatic concepts before demanding higher-level creativity.

Analysis of the third instrument, Shape Transformation (Cut and Arrange), further strengthens the study of the elaboration aspect, where AZ's ability to arrange diagonal pieces into precise arrow or chevron shapes demonstrates visual-motor coordination that aligns with logical reasoning. AZ is able to imagine new orientations of a shape, which in Piaget's theory is referred to as advanced concrete operations, while DI's failure to rearrange the pieces reflects significant spatial disorientation. Reflecting on these findings, we demonstrate that geometry problem-solving based on physical manipulation is a highly effective diagnostic tool for detecting students' cognitive readiness. This is in line with Essel (2024) who emphasized that manipulative activities are an essential bridge to mitigate learning barriers in early childhood before entering the abstract symbolic stage.

This study aims to analyze the impact of geometry problem solving on the cognitive and creative thinking skills of lower-grade elementary school students. The findings indicate that presenting non-routine geometry problems through concrete visual media successfully mapped students' cognitive profiles, with each subject demonstrating significantly different responses to the instruments.

The impact on the first instrument, Geometry House Composition, highlighted the difference between reproductive and productive thinking. Findings from subject S-KS (RN), who used contrasting colors (blue and orange) for the roof, indicated an attempt at visual elaboration. However, cognitively, RN remained trapped in episodic memory of standard house shapes. In contrast, subject S-KT (AZ) demonstrated cognitive decomposition skills by breaking the roof area into several smaller sections. This demonstrates that for lower-grade students, the ability to see a large object as a combination of smaller parts is an early indicator of spatial maturity, supporting flexibility (Wang, 2022).

The most significant findings emerged from the second instrument, Dot-Grid Exploration. Subject S-KT (AZ) demonstrated a cognitive profile that transcended the boundaries of formal mathematics by transforming points into images of cars/trucks. Theoretically, this demonstrates strong divergent thinking, as AZ was able to visually synthesize point coordinates with real-world objects. AZ's courage to move beyond rigid instructions (drawing plane figures) to create representational objects suggests that mathematics is considered a medium for creative expression at a higher cognitive level. Furthermore, the finding that subject S-KR (DI) only produced random lines provides a crucial lesson: creativity cannot emerge without basic numeracy literacy (Patston et al., 2021). DI's failure to form closed polygons indicates a barrier at the spatial perception stage, where he does not yet understand the basic attributes of a figure.

The impact on the third instrument, Transformation of Figures (Cutting and Stacking), strengthens the analysis of the elaboration aspect. S-KT (AZ)'s ability to arrange diagonal pieces into precise chevrons or arrows demonstrates synchronous visual-motor coordination with logical reasoning. AZ was able to imagine new orientations of a figure, which in Piaget's theory is referred to as advanced concrete operations. Meanwhile, S-KR (DI)'s failure to rearrange the geometric pieces indicates spatial disorientation. This confirms that physical manipulation-based geometry problem solving is highly effective as an early diagnostic tool for detecting students' cognitive readiness to accept more complex material (Essel, 2024).

Overall, these findings indicate that students' creativity levels are positively correlated with their mastery of basic geometric concepts. However, the aspect of originality, as demonstrated by AZ (the car image), demonstrates that children's imagination often transcends formal logic. This has important implications for the mathematics curriculum: geometry in early grades should not be taught rigidly, but rather should be directed toward the exploration of new ideas that are inclusive of students' artistic and design talents.

Viewed from the perspective of SDG 4 (Quality Education), this study emphasizes that inclusive education must begin with understanding each child's creative profile. The impact of geometry problem-solving for Level 4 students is the strengthening of High-Order Thinking Skills (HOTS), which provide the foundation for future innovation (Rati, 2023; Sánchez-Gómez, 2023). For Level 0 students, the impact is a tool to mitigate learning gaps so they receive appropriate numeracy literacy interventions. By identifying these unique findings early on, schools can achieve equitable and differentiated quality education, ensuring each student develops according to their maximum cognitive potential.

5. CONCLUSION AND SUGGESTIONS

CONCLUSION

Based on the research results and discussion regarding the cognitive profiles of lower-grade elementary school students (phase A) through geometry problem solving, it can be concluded that mathematical ability levels significantly correlate with achievement of the Creative Thinking Level (CTL). A tangible impact is seen at three different profile levels:

1. High Ability Students (S-KT) reach CTL Level 4 (Very Creative). The impact of geometry problem solving at this level is the emergence of high levels of originality and flexibility, where students are able to transform abstract concepts into representational objects (such as a picture of a car) and perform precise elaboration (arrow/chevron shapes). This demonstrates cognitive maturity at the concrete operational stage, which is inclusive of creative imagination.
2. Medium Ability Students (S-KS) reach CTL Level 2 (Quite Creative). The visible impact is the ability to think fluently (fluency) in producing standard plane figures, but still in a reproductive manner. Students at this level tend to be cautious in exploring new ideas and rely more on procedural memorization than visual experimentation.
3. Low Ability Students (S-KR) are at TBK Level 0 (Not Creative). Cognitive barriers in the form of misconceptions about basic geometric attributes (such as the concept of closed shapes) are the main barrier to the emergence of creativity indicators. Without basic numeracy literacy, the problem-solving process cannot stimulate divergent thinking.

Overall, this research proves that visual geometry is an effective diagnostic and stimulation instrument for mapping children's cognitive levels from an early age. Achieving creativity at an early age is a key indicator of the success of quality education, as mandated by SDG 4.

RECOMMENDATIONS

Based on the research findings, several suggestions can be put forward:

1. For Educators (Teachers): Teachers should implement Differentiated Learning. Students at lower levels require scaffolding in the form of physical manipulatives to reinforce basic concepts, while students at higher levels need to be given open-ended problems that stimulate artistic and design imagination to accelerate their HOTS potential.
2. For Curriculum Developers: Geometry material in lower elementary grades should not only focus on name recognition and formulas, but should also be integrated with exploratory activities such as dot grids and tangrams to foster spatial flexibility from the foundational stage.
3. For Future Researchers: Further research with a broader range of subjects is needed to examine how environmental and gender factors influence children's cognitive transition

from Level 2 to Level 4. Furthermore, the use of digital technology (such as simple dynamic geometry software) can be explored for its influence on improving authenticity in early grade students.

4. Link to SDG 4: Educational institutions are advised to incorporate GCV mapping as part of their learning quality evaluations. This is crucial to ensuring educational inclusivity, where every child has the right to develop according to their unique creative profile, creating a future generation of innovators.

Ethical & Author Statements

CRediT Statement: Ani Afifah: Conceptualization, Methodology, and Analysis. Samuel Karim: Writing, Supervision and data curation.

Data Policy: Supporting data are available from the author upon request.

AI Policy: AI tools were used solely for linguistic consistency. Final analysis is original human output.

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