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IDENTIFYING CRITICAL THINKING ABILITIES TO SOLVE MATHEMATICAL LITERACY PROBLEMS INTEGRATED WITH MALAY CULTURE IN JUNIOR HIGH SCHOOL STUDENTS

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Abstrak
Penelitian ini bertujuan untuk mengidentifikasi kemampuan berpikir kritis siswa sekolah menengah pertama dalam menyelesaikan soal literasi matematis yang terintegrasi dengan budaya Melayu. Kemampuan berpikir kritis sangat penting dalam pembelajaran matematika karena memungkinkan siswa untuk menganalisis, mengevaluasi, dan memecahkan masalah kontekstual. Integrasi budaya Melayu, seperti pola simetris pada ukiran dinding luar Istana Sultan Deli dan hiasan dinding Istana Maimun yang berkaitan dengan transformasi geometri, tampak mendukung keterlibatan dan pemahaman siswa.Penelitian ini dilakukan di SMP IKAL Medan yang terletak di wilayah budaya Melayu, Sumatera Utara, Indonesia. Dengan menggunakan pendekatan deskriptif kualitatif, data dikumpulkan dari 30 siswa kelas VIII pada semester genap tahun ajaran 2024/2025. Instrumen penelitian terdiri atas tes literasi matematis berbasis budaya dan wawancara semi terstruktur. Hasil penelitian menunjukkan bahwa 10 siswa (33%) memiliki tingkat kemampuan berpikir kritis tinggi, 14 siswa (47%) berada pada tingkat sedang, dan 6 siswa (20%) berada pada tingkat rendah. Data wawancara menunjukkan bahwa siswa yang mampu mengaitkan transformasi geometri dengan motif tradisional cenderung memberikan alasan yang lebih logis, sedangkan siswa yang hanya mengandalkan pengetahuan prosedural sering mengalami kesulitan dalam menarik kesimpulan. Temuan ini menunjukkan bahwa penerapan tugas literasi matematis yang dikontekstualisasikan secara budaya dapat membantu memperkuat kemampuan berpikir kritis siswa dalam pembelajaran matematika.
Kata kunci: Berpikir Kritis; Kontekstual, Literasi Matematika; Integrasi Melayu, Siswa SMP.

Abstract
This study aims to identify the critical thinking skills of junior high school students in solving mathematical literacy problems integrated with Malay culture. Critical thinking is essential in mathematics education because it enables students to analyze, evaluate, and solve contextual problems. The integration of Malay culture, such as the symmetrical patterns on the exterior wall carvings of the Sultan Deli Palace and the wall decorations of the Maimun Palace, which are connected to geometric transformations, appears to support students' engagement and understanding. The study was conducted at SMP IKAL Medan, located in the Malay cultural region of North Sumatra,

Indonesia. Using a descriptive qualitative approach, data were collected from 30 eighth-grade students during the second semester of the 2024/2025 academic year. The instruments consisted of culturally based mathematical literacy tests and semi-structured interviews. The results showed that 10 students (33%) demonstrated a high level of critical thinking, 14 students (47%) were at a moderate level, and 6 students (20%) were at a low level. Interview data suggest that students who could relate geometric transformations to traditional motifs tended to provide more logical reasoning, while those who relied solely on procedural knowledge often struggled to draw conclusions. These findings suggest that incorporating culturally contextualized literacy tasks may help strengthen students' critical thinking abilities in mathematics learning.
Keywords: Critical Thinking; Contextual, Mathematical Literacy; Malay Integration, Middle School Student.

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INTRODUCTION

The Mills, G. E., & Huberman, A. M. (1992). *Data management and analysis methods.* California: SAGE Publications The positive impact of integrating Malay culture into mathematical literacy is evident in the improved conceptual understanding and analytical abilities of students. For example, when students were asked to explain the symmetry of wall decoration patterns at Maimun Palace after rotation, they not only performed the mathematical procedure but were also able to provide logical reasons why the patterns remained unchanged. This indicates that students can connect mathematical skills with critical thinking abilities. According to (Agusman, 2017) mathematics learning that trains analysis and evaluation can develop students' critical thinking skills.

Learning models that challenge students to analyze, evaluate, and draw conclusions from the information they obtain allow them to understand concepts more deeply and logically. This is closely related to numerical literacy, which refers to the ability to analyze and understand narratives using reasoning. This ability is demonstrated through the application of mathematical concepts, calculations, and measurements presented in various forms of representation, such as graphs, tables, and diagrams (Sehuwaky & Mastuti, 2022).

Furthermore, when these learning activities are embedded in a familiar cultural context, students become more motivated, confident, and active in discussions. This makes the learning process not only enhance their numerical reasoning but also more meaningful and relevant to their life experiences. This finding aligns with previous research (Blegur, 2022); (Sitorus & Nazaruddin, 2021);(Suciati, 2022), which shows that cultural integration enhances students' engagement and understanding. Furthermore, the representation of equations or mathematical expressions plays a vital role in enabling students to model and interpret mathematical relationships symbolically and meaningfully (Netti et al., 2021. Studies have shown that learning processes that consider students' critical thinking abilities provide deeper understanding compared to those that ignore it. Therefore, integrating critical thinking into students' engagement with mathematical representations can enhance their conceptual and analytical understanding (Setiana et al., 2022); (Estiyani et al., 2024).

Critical thinking skills are a crucial foundation for solving mathematical problems, especially those requiring higher-order reasoning (Hidayat & Noer, 2021). In the school context, these skills can be developed through various approaches, one of which is integrating local cultural contexts combined with technology. This integration helps students connect mathematical concepts with real-life situations, thereby fostering deeper understanding and engagement (Ye et al., 2023); (Arisoy & Aybek, 2021); (Viberg et al., 2023); (Delina, 2021) promising approach is culturally integrated mathematical literacy, which involves presenting contextual problems derived from the surrounding community (Padmakrisya & Meiliasari, 2023); (Irianti et al., 2021).

Preliminary observations conducted at SMP Swasta Ikal indicate that students tend to demonstrate stronger reasoning and reflective thinking when familiar cultural elements such as Malay ornaments and traditions are incorporated into mathematical problems. This demonstrates the potential of culturally integrated learning to strengthen students' critical thinking processes at this school.

However, empirical research directly examining the relationship between cultural literacy and critical thinking skills is still very limited, especially in the context of mathematics learning. Most previous studies have focused on one aspect either cultural integration or critical thinking separately. Therefore, more in-depth empirical studies are needed to explore how cultural literacy can support the enhancement of students' critical thinking skills in mathematics learning. Based on this gap, this study aims to identify and describe the critical thinking abilities of SMP Swasta Ikal students in solving mathematical literacy problems integrated with the Malay cultural context.

METHOD

This study employed a qualitative descriptive approach aimed at describing students' critical thinking abilities in solving mathematical literacy problems integrated with Malay culture. This approach was chosen because the researchers sought to gain an in-depth understanding of students' thinking processes, including how they analyze, evaluate, and draw conclusions, rather than focusing solely on the final learning outcomes (Fadya & Ardiyanti, 2024); (Prafianti & Ambarwati, 2022). The study was conducted at SMP Swasta Ikal, a junior high school that consistently integrates Islamic values and local Malay culture into learning activities and other school programs. The strong sociocultural characteristics of this school provide a relevant context for investigating the relationship between culture and mathematics learning (Mulbasari et al., 2023); (Sembiring & Asmin, 2025).

The participants consisted of 30 eighth-grade students who had received culture-based mathematical literacy instruction and lived in an environment rich in Malay culture. Participants were selected using purposive sampling, which involves deliberately choosing participants based on criteria aligned with the research objectives (Sugiyono, 2020). The criteria included students who had participated in mathematics learning with a culture-based context and were located in areas dominated by Malay social and cultural environments.

Student Grouping Based on Ability

Students' academic abilities varied, so they were grouped according to the school's Minimum Mastery Criteria (KKM) as follows: high for students with scores ≥75, medium for students with scores between 55–74, and low for students with scores ≤54. This classification was used to reflect variations in mastery levels relative to the school's KKM. Based on this criterion, 10 students were categorized as high, 14 as medium, and 6 as low. This grouping allows for comparison of critical thinking abilities across different proficiency levels, enabling a more focused and objective analysis of the research findings.

Research Instruments

The primary instrument in this study was the researcher as a human instrument, responsible for collecting, interpreting, and verifying data. Additional instruments included Malay culture-based mathematical literacy questions (reflecting local contexts such as traditions, dances, and cultural ornaments), interview guides, observation sheets, and documentation of student work. Data were collected through: Culture-based mathematical literacy tests to assess indicators of critical thinking, such as analyzing, evaluating, and drawing conclusions. In-depth interviews with selected students to further explore their thinking processes. Observations and documentation, including notes on the learning process and students' work.

Data Analysis Procedures

Data were analyzed using Miles and Huberman's interactive analysis cycle (Miles & Huberman, 1994, *Qualitative Data Analysis: An Expanded Sourcebook*)), which comprises three main stages. First, data reduction, involving selecting, focusing, and simplifying raw data from tests, interviews, and observations. Second, data display, organizing data into descriptive narratives, tables, or direct interview quotations. Third, drawing and verifying conclusions, interpreting the meaning of the data to answer the research focus regarding students' critical thinking abilities.

Trustworthiness Procedures

To ensure data validity and credibility, several trustworthiness procedures were applied. First, data triangulation, comparing information from tests, interviews, observations, and documentation to confirm consistency. Second, member checking, asking selected students to verify the interpretations of their interview responses. Third, peer debriefing, discussions with other researchers to ensure consistent data interpretation and minimize bias. Fourth, audit trail, documenting the entire data collection and analysis process to enhance dependability and confirmability.

RESULT AND DISCUSSION

The Analysis of student answer sheets revealed variations in critical thinking abilities when solving mathematical literacy problems integrated with Malay culture. Students were classified into three categories: low, medium, and high, based on their analytical, evaluative, and inferential performance indicators (Yuliatin et al., 2024). This study aims to describe students' critical thinking abilities in solving mathematical literacy problems integrated with Malay culture. Data were obtained through analysis of student answer sheets, which were grouped based on critical thinking ability categories: low, medium, and high. The critical thinking ability indicators used refer to the aspects of analyzing, evaluating, and drawing conclusions from information logically and systematically(Yuliatin et al., 2024). Before assessing students' critical thinking abilities, they were given an understanding of the role of mathematics in their environment, one of which is applied to carvings, dance, and traditional clothing, as reflected in the Malay cultural context (Yusuf et al., 2022) (Arisoy & Aybek, 2021). Integration of Malay Culture through Geometric Transformation Literacy Tasks. The integration of Malay culture in mathematical literacy can be implemented through local artifacts found at Maimun Palace. These artifacts, in the form of carved ornaments, serve as contextual representations of geometric transformations. The literacy question below illustrates the connection between cultural preservation and mathematical reasoning.

Context:

Princess Aisyah, a young architect, was assigned by the local government to assist in the restoration of Maimun Palace, a symbol of the Deli Malay Sultanate's grandeur from the 19th to early 20th century. During the restoration, she observed that many curved ornaments and symmetrical motifs on the palace's fences and walls were damaged due to aging.

Purpose:

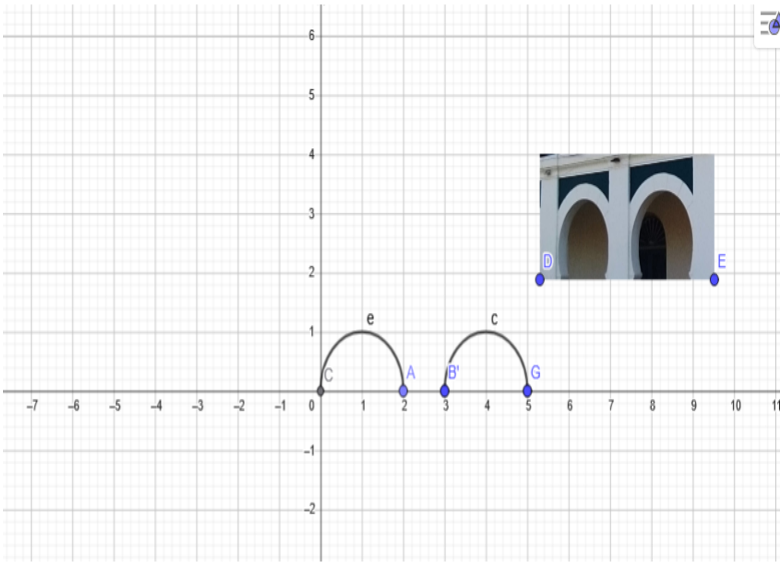
To preserve the authenticity of the ornament designs, Aisyah applied geometric transformations to reconstruct each motif according to its original position and size. Task Description (structured into sub-items):

a. **Analyzing Indicator:** Identify the coordinates of the first and second curved ornaments located at points $(0,0);(2,0)$ and $(3,0);\ (4,0)$ Determine the pattern of coordinate repetition when the motif is duplicated six times horizontally, with a distance of one unit between each.

b. **Evaluating Indicator:** Examine the type of transformation used to repeat the curved ornaments. Does the repetition represent translation, reflection, or rotation? Provide reasoning based on geometric properties.

c. **Drawing Conclusion Indicator:**
Based on your analysis, explain how geometric transformations such as translation and reflection can support the restoration and preservation of Malay cultural ornaments at Maimun Palace.

Table 1. Geometry Transformation Literacy Questions

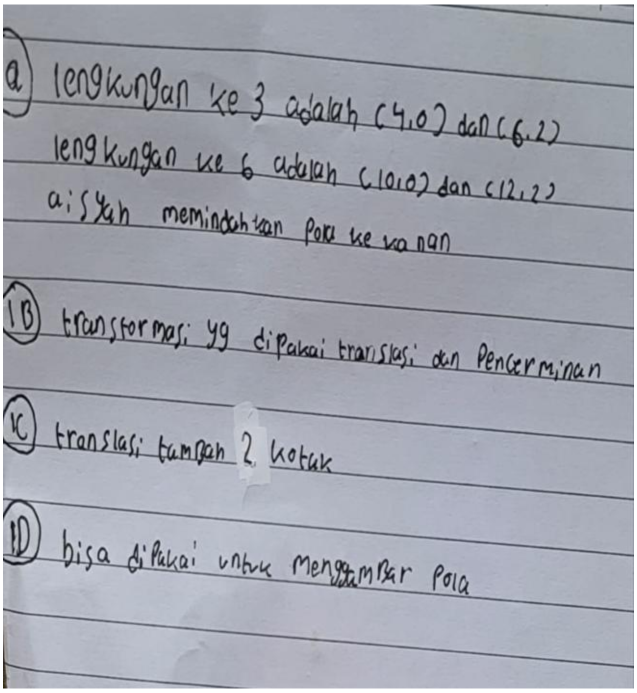
 	(a) Identify and write down the coordinates of the 3rd and 6th curves if the pattern is repeated parallel to the right. *(Analyzing)* (b) Explain how the combination of translation and reflection across the x-axis affects the coordinate positions of each curve from the 1st to the 6th. *(Evaluating)* (c) Aisyah found that the 4th curve was shifted vertically by 2 units. Identify the type of geometric transformation that occurred. *(Evaluating)* (d) Based on the final arrangement, explain the role of geometric transformations in preserving the authenticity of Malay cultural ornaments at Maimun Palace. *(Drawing conclusions)*.

1. Students with Low Critical Thinking Skills

Table 1 presents a series of geometric transformation literacy questions designed to integrate mathematical reasoning with the Malay cultural context, specifically through the symmetrical and repeating patterns of traditional ornamental curves found in Maimun Palace. These questions require students to identify the type of transformation, such as translation and reflection, determine coordinate relationships, and justify their reasoning based on geometric principles and cultural preservation concepts. To assess students' critical thinking processes, these tasks aim to reveal how they apply analytical, synthetic, and evaluative skills when solving contextual mathematical problems.

However, students with low critical thinking skills showed difficulty in solving these problems. They struggled to identify important information and to break down the relationships between coordinates and the types of transformations presented in the question. In particular, they experienced difficulty in interpreting the geometric nature of Malay ornamental patterns, which led to a tendency to focus solely on the visual aspects. As a result, their reasoning appeared fragmented, and they failed to connect cultural representations with the underlying principles of geometric transformations. Furthermore, the students' explanations for their answers were often incomplete and lacked logical consistency, thereby resulting in inaccurate conclusions. To illustrate this pattern of reasoning more clearly, a snippet of a student's answer process representing this category is presented below.

Additionally, Figure 1 presents an example of a low-ability student's response. In this case, the student recognized the ornamental curve only as a visual pattern without identifying the geometric transformation involved. The response revealed that the student relied merely on perception, stating, *"I thought it looked like a mirror, so I chose reflection."* This shows that the reasoning was based on visual similarity rather than an analytical understanding of geometric reflection. The answer lacked mathematical justification, and the coordinate relationships were not logically explained. Overall, such responses demonstrate that low-ability students tend to interpret the problem intuitively instead of applying systematic reasoning based on geometric concepts.



a."The 3rd curve is (4,0) and (6,2)"
"The 6th curve is and (10,0) and (12,2) "
Aisyah shifts the pattern to the right"
b. The transformations used are translation and reflection"
c. "Translation plus 2 boxes (units)"
d. "Can be used to draw patterns"

Figure 1. Example of a low-ability student's response showing limited conceptual understanding in identifying reflection and translation within Malay ornamental patterns.

The performance of low-achieving students (Low Mathematical Ability LMA) in the Analysis stage of critical thinking skills exhibits a distinctive pattern. The Analysis stage requires students to break down problems and examine relationships between data; however, in this group, such abilities often manifest in an informal manner. Conceptually, students generally succeed in identifying the types of transformations involved. In the context of Malay cultural geometric transformation patterns, students are able to recognize that the pattern involves translation (shift) and reflection (mirror). They can observe translational relationships, for example, noticing the shift from the 3rd curve to the 6th curve, and identifying that the pattern moves from one position to another indicating partial success in identifying relational connections.

However, the fundamental weakness of LMA students emerges when they are required to move from qualitative observation to quantitative or procedural analysis. The most evident example appears when students attempt to calculate the magnitude of the translation. Although they notice that the pattern shifts from coordinate $x = 4$ and $x = 10$ (which should result in a 6-unit translation), the student instead concludes that the shift is only "plus 2 boxes." This error indicates a failure in procedural analysis they rely on simple, visual estimation rather than applying the formal coordinate difference formula $(x_2 - x_1)$. Furthermore, their analysis remains bound to concrete representations. Students tend to fail in identifying the underlying assumptions or general rules that govern the transformation. Instead of formulating a general translation vector $T(a, b)$ or expressing the algebraic rule $P(x, y) \rightarrow P'(x + a, y + b)$, they merely provide specific examples of shifts. This finding reinforces that their analytical process has not yet reached the level of formal mathematical understanding, but remains at the stage of visual description. A clinical interview was conducted to verify the thinking process of the student (LMA) and to examine the cognitive deficits identified in the answer sheet related to Geometric Transformation. The main focus of the interview was on the Analysis and Evaluation stages.

1. Stage of Identification and Conceptual Analysis

At the initial stage, the student was able to provide elementary clarification regarding the concepts used. When asked, *"What kind of transformation did you actually use to create the repetitive pattern of the Malay motif?"*, the student replied: "There is a shift, miss. And there's also something like a mirror, like it's flipped."

This response shows that the student succeeded at the identification stage in recognizing the types of transformations involved translation and reflectionalthough expressed in informal terminology.

2. Cognitive Deficit in Procedural Analysis

A significant cognitive deficit was detected when examining the Procedural Analysis stage, particularly in quantifying the translation vector. The student incorrectly calculated a horizontal shift of 6 units as "2 boxes" on the answer sheet.

Interview Excerpt (Analysis Stage):

"Try to explain how you calculated the shift from point (4, 0) to point (10, 0) until you wrote the shift as 2 boxes?"

Student's Response:

"I counted the empty spaces between those curves, Ma'am. From the middle, there are two big empty boxes there."

This response indicates that the student failed to perform a cognitive translation from a discrete visual representation (counting boxes) to a continuous algebraic representation (calculating coordinate differences). The student did not apply the rule $\{T = (x_2 - x_1)\}$ instead relied on visual estimation, leading to numerical error.

3. Weakness in Executive Function (Evaluation Stage)

This weakness was further confirmed during the Evaluation and Self-Regulation stages. When asked to recheck the calculation:

Interview Excerpt (Evaluation Stage):

"Now let's calculate, 10 minus 4, what's the result? Is it equal to 2?"

Student's Response:

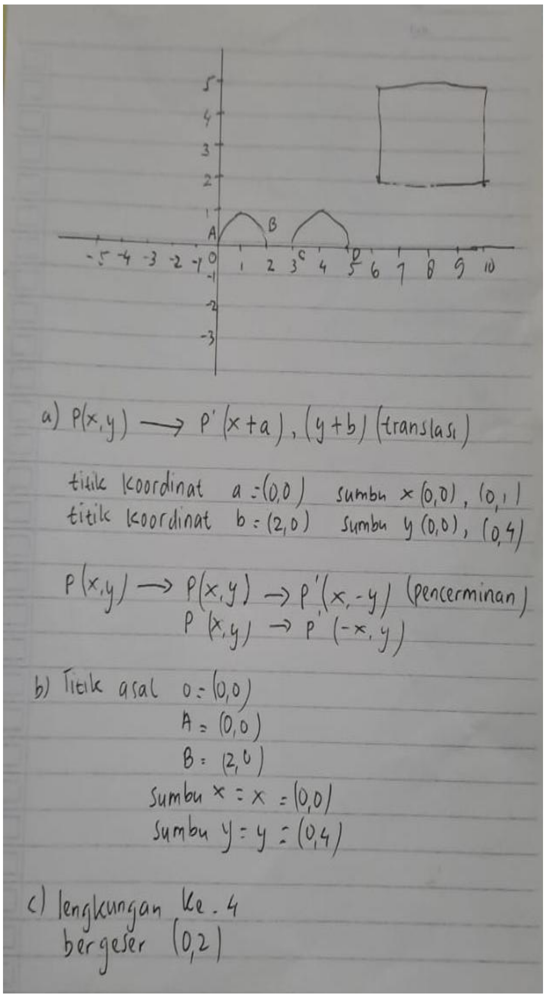
"Oh yes, it's 6. Not the same. But I didn't know that was how to calculate it before."

This response reveals that the student possesses basic computational ability, but the executive function that is, the ability to select the correct strategy and verify results was not activated during problem solving. The student did not evaluate the quality of their initial answer, assuming that their visual counting method was valid. As a result, the data presented on the answer sheet ("2 boxes") became mathematically invalid and unreliable. This serves as strong evidence that the Analysis and Evaluation stages constitute the main obstacles for students with low mathematical ability.

4. Students with Moderate Critical Thinking Skills

Students in the intermediate group are able to connect cultural contexts with mathematical ideas and identify simple patterns, such as symmetry and repetition. However, their explanations are often lacking in precision in mathematical terminology. For example, several students described the transformation as "flipped" or "turned," instead of using formal expressions such as *reflection across the y-axis* or *90° rotation*. As illustrated in Figure 2, their responses demonstrate partial understanding across several critical thinking indicators. Specifically, they show the ability to analyze by recognizing relationships between cultural ornament patterns and geometric transformations, but they struggle to evaluate their reasoning or draw logical conclusions about why a particular transformation applies.

One student, for instance, wrote, *"the shape just flips down,"* without identifying the reflection axis or justifying the rule mathematically. This indicates that while they recognize visual symmetry (Analyzing), they have not yet engaged in deeper reasoning to assess or verify their conclusions (Evaluating and Drawing Conclusion). To illustrate this thought pattern, a snippet of one student's answer process representing this category is presented below.



a) $P(x, y) \rightarrow P'(x + a), (y + b)$ (translation)

coordinate point $a = (0,0)$

x-axis $(0,0), (0,1)$

coordinate point b = $(2,0)$

y-axis $(0,0)$, $(0,4)$

$P(x, y) \rightarrow P'(x, -y)$

(reflection across the X-axis)

$P(x, y) \rightarrow P'(-x, y)$

(reflection across the Y-axis)

b) Coordinate Points, Origin point

O = (0,0)

A = (0,0)

B = (2,0)

x-axis = (0,0)

y-axis = (0,4)

c) Transformation Application

The 4th arc shift $(0,2)$

Figure 2. Example of a moderate-ability student's response showing partial reasoning in identifying translation and reflection within Malay ornamental patterns.

Students with Average Mathematical Ability (AMA) demonstrate analytical thinking characterized by procedural accuracy and quantitative success, yet their reasoning remains limited in formalization and generalization. In solving geometric transformation problems, AMA students are able to deconstruct tasks and examine relationships among data through systematic computation. For instance, when identifying the translation of a pattern shifting from $x = 4$ to $x = 10$, they correctly calculate the coordinate difference $(10 - 4 = 6)$ and determine the translation vector as $T(6,0)$. They also apply the formula $P(x, y) \rightarrow P'(x + a, y + b)$

accurately to specific coordinates, such as translating the vertex point $(6,2)$into $(12,2)$. These actions indicate mastery of procedural and quantitative reasoning, aligning with Ennis's (1991) concept of analytical competence in critical thinking. However, their analytical process tends to remain example-based; they often fail to generalize or formalize their findings as symbolic rules, such as expressing the transformation generally as $P(x, y) \rightarrow P'(x + 6, y)$. This reliance on manual or point-by-point procedures shows that while AMA students can analyze correctly, their reasoning has not yet developed into a formal or abstract framework. Consistent with Facione (2015), this suggests that AMA students are in a transitional phaseable to perform logical and systematic analysis but still requiring guidance to synthesize and generalize their reasoning within higher-order critical thinking. The main focus of the interview was on the **Analysis** stage (how students arrived at a solution) and the **Evaluation** stage (how they validated their solution).

1. Conceptual Identification and Analysis Stage

At the initial stage, students were able to provide basic clarification and use more precise terminology than LMA students.

When asked, *"What types of transformations did you actually use to create this repeated Malay motif pattern?"*, the student responded:

Student Response: "I used translation, Miss, to shift the pattern. And there's also reflection, to flip the curved parts so they face each other."

Analysis:

This response shows success at the identification stage, where the student recognizes and applies formal mathematical terms (translation and reflection), even though the explanation remains relatively simple (dictionary-like). This indicates better conceptual understanding compared to LMA students.

2. Procedural Analysis Success and Limitations in Formalization

The strength of AMA students lies in procedural analysis. They can perform quantitative calculations correctly. During the interview, the researcher asked:

Interview Excerpt (Analysis Stage):

"Can you explain how you calculated the shift from the peak point of the first curve at $(6,2)$ to the second peak point at $(12,2)$?"

Student Response: "I calculated the difference in x, Miss, because the y values are both 2. So 12 minus 6 equals 6. That means the translation is T(6,0)."

Analysis:

This response shows that the student successfully performed a cognitive translation from a visual representation (a point on the graph) to an algebraic one (using the formula $\{\Delta x = (x_2 - x_1)\}$. The student overcame the conceptual deficit previously found in LMA students. However, AMA students often stop at this stage they correctly identify the vector $T(6,0)$ but rarely proceed to express the general rule, such as $P(x, y) \rightarrow P'(x + 6, y)$.

3. Weakness in Executive Function (Advanced Evaluation Stage)

Although AMA students perform calculations accurately, their weaknesses appear when asked to justify (evaluate) their solutions within a broader mathematical framework. During the evaluation interview, the following question was asked:

Interview Excerpt (Evaluation Stage):

"Why do we need to use the translation $T(6,0)$ instead of simply shifting the pattern six boxes to the right? What is the importance of the formula $P(x, y) \rightarrow P'(x + a, y + b)$?"

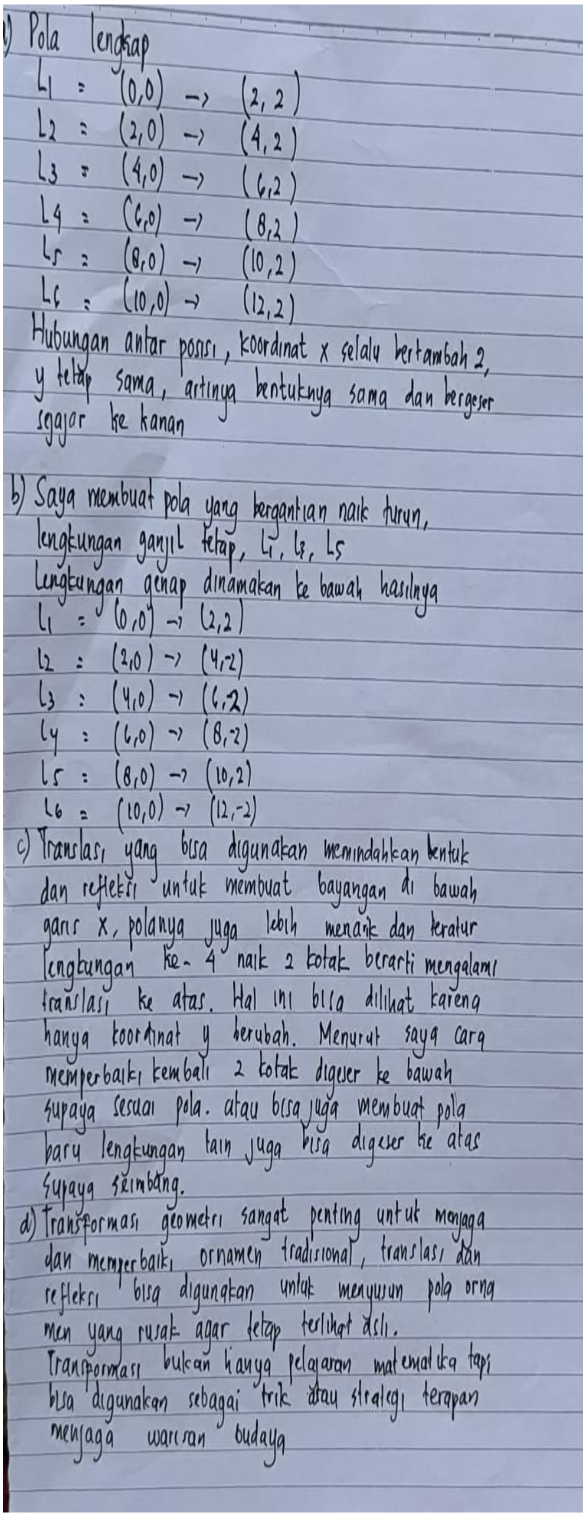
Student Response: "Because using the formula is more certain. If we just count boxes, we might make a mistake. But it's basically the samejust shifting six units to the right."

Analysis:

This response reveals that AMA students possess correct computational reasoning but demonstrate a pragmatic evaluative function. They evaluate the correctness of the procedure ("more certain") but cannot justify *why* the algebraic formula represents a more general and abstract mathematical relationship than simple physical displacement. Students perceive the formal formula merely as a tool for "accuracy" rather than as a symbolic generalization of a geometric transformation. This indicates a lack of self-regulation in distinguishing between a procedurally correct solution and a formally valid one. In line with Ennis (1991) and Facione (2015), this pattern reflects that AMA students' evaluation process remains at a practical level, not yet achieving reflective or theoretical reasoning required in higher-order critical thinking.

3. Students with High Critical Thinking Skills

High-ability students demonstrated strong analytical and metacognitive control in solving transformation problems. They not only identified the correct transformation type but also justified their reasoning using accurate geometric terminology, such as rotational symmetry of order four. As presented in Figure 3, they often evaluated multiple alternative solutions (e.g., comparing the effect of two reflections versus one rotation) before drawing conclusions. During interviews, these students described checking coordinate relationships and confirming the invariance of size and shape, indicating reflective and evaluative thinking processes. Overall, students in this category integrated conceptual knowledge and cultural context effectively, demonstrating both cognitive accuracy and cultural awareness.


a) Pola lengkap
L1 : (0,0) -> (2,2)
L2 : (2,0) -> (4,2)
L3 : (4,0) -> (6,2)
L4 : (6,0) -> (8,2)
L5 : (8,0) -> (10,2)
L6 : (10,0) -> (12,2)
Hubungan antar posisi, koordinat x selalu bertambah 2, y tetap sama, artinya bentuknya sama dan bergeser sejajar ke kanan
b) Saya membuat pola yang bergantian naik turun, lengkungan ganjil tetap, L1, L3, L5
Lengkungan genap dinamakan ke bawah hasilnya
L1 : (0,0) -> (2,2)
L2 : (2,0) -> (4,-2)
L3 : (4,0) -> (6,2)
L4 : (6,0) -> (8,-2)
L5 : (8,0) -> (10,2)
L6 : (10,0) -> (12,-2)
c) Translasi yang bisa digunakan memindahkan bentuk dan refleksi untuk membuat bayangan di bawah garis x, polanya juga lebih menarik dan teratur lengkungan ke-4 naik 2 kotak berarti mengalami translasi ke atas. Hal ini bisa dilihat karena hanya koordinat y berubah. Menurut saya cara memperbaiki kembali 2 kotak digeser ke bawah supaya sesuai pola. atau bisa juga membuat pola baru lengkungan lain juga bisa digeser ke atas supaya simbang.
d) Transformasi geometri sangat penting untuk menjaga dan memperbaiki ornamen tradisional, translasi dan refleksi bisa digunakan untuk menyusun pola ornamen yang rusak agar tetap terlihat asli.
Transformasi bukan hanya pelajaran matematika tapi bisa digunakan sebagai trik atau strategi terapan menjaga warisan budaya

a)**Complete Pattern**

$L_1 = (0,0) \to (2,2), L_2 = (2,0) \to (4,2),$
$L_3 = (4,0) \to (6,2), L_4 = (6,0) \to (8,2),$
$L_5 = (8,0) \to (10,2), L_6 = (10,0) \to (12,2)$

Relationship between positions: coordinate always increases by , remains the same, meaning the shape is identical and shifts parallel to the right.

b)**I created an alternating up-and-down pattern,** the odd curves stay.

The even curves are reflected downwards, resulting in

$L_1 = (0,0) \to (2,2), \quad L_2 = (2,0) \to (4,-2),$
$L_3 = (4,0) \to (6,-2), L_4 = (6,0) \to (8,-2),$
$L_5 = (8,0) \to (10,2), \quad L_6 = (10,0) \to (12,-2).$

c) **Translation** can be used to shift the shape and reflection to create a mirror image below the -axis. The pattern also becomes more interesting and regular. The 4th curve shifting up 2 boxes means it undergoes an upward translation. This can be seen because only the coordinate changes. I think the way to correct it is to shift it back down 2 boxes to match the pattern. Or we could also create a new pattern by shifting other curves up to be symmetrical. d) **Geometric transformation** is very important for maintaining and repairing traditional ornaments. Translation and reflection can be used to reconstruct damaged ornament patterns so they look authentic. Transformation is not just a math lesson but can be used as an applied trick or strategy to preserve cultural heritage.

Figure 3. Example of a high-ability student's response demonstrating complete reasoning and conceptual understanding of geometric transformations based on Malay ornamental patterns

The main focus of the interview was directed toward examining students' abilities in Generalization (Formalization), Justification (Why), and Higher-Level Evaluation of the solutions they provided.

1. Advanced Conceptual Identification and Analysis Stage

At the initial stage, High Mathematical Ability (HMA) students not only identified concepts but immediately generalized the relationships among data. When asked, *"What is the most important relationship between patterns L_1 to L_6 that you identified in Point (a)?"*, the student responded:

Student Response:

"The relationship is Translation, Miss. The x-coordinates always increase by 2 for each curved unit ($L_n \to L_{n+1}$), while y remains constant, y ∈ $\{0,2\}$. This means the entire pattern is a periodic function translated repeatedly by the vector T $(2,0)$ to produce the motif. The form remains $y = f(x)$, but the domain shifts."

Analysis:

The student successfully went beyond simple identification. Rather than merely stating "translation," they analyzed the relationship between data (x increases by 2, y remains constant), generalized the transformation rule ($T(2,0)$), and linked it to a broader mathematical concept (periodic function). This demonstrates strong mastery of the Conceptual Identification and Analysis stage, marked by high-level abstraction and reasoning.

2. Procedural Analysis Success and Formal Generalization

The strength of HMA students lies in their ability to formalize quantitative findings into generalized algebraic rules.

When asked, *"If the basic motif L_1 is defined by the boundaries $(0,0)$ and $(2,2)$, how would you express the boundaries of the curve L_n in general using a formula?"*, the student responded.

Student Response:

"Sure, Miss. Since each L_n shifts by $T(2(n-1),0)$ from L_1, the initial x-boundary for every L_n is $x = 2(n-1)$, while the final boundary is $x = 2(n-1) + 2$.

Therefore, the nth curve boundary is: L_n : $[2(n-1), 0] \rightarrow [2n, 2]$.This is the general rule that applies to all n."

Analysis:

Unlike AMA students who mainly focus on coordinate differences, the HMA student used their analytical results to construct a generalized algebraic model. Their ability to formulate the curve boundary L_n as a function of n reflects complete mastery of the **Formalization Analysis** stage. This indicates both symbolic generalization and conceptual abstraction hallmarks of higher-level mathematical reasoning (Ennis, 2011; Facione, 2015).

3. Strength in Executive Function (Evaluation and Justification Stage)

The main distinguishing factor lies in the evaluation stage. HMA students were able to justify *why* formal solutions are superior, as seen in their responses to Point (d). When asked, *"You mentioned that transformation is important for preserving traditional ornaments. Mathematically, why is using algebraic formulas better than simply observing and redrawing the pattern manually?"*, the student responded:

Student Response:

"Using the translation formula $P'(x+a, y+b)$represents the highest form of pattern evaluation. If we only redraw it, the result is prone to cumulative errors. With algebraic formulas, we ensure perfect congruence between the original and its image. Moreover, formulas allow us to predict the position of L_{100} without drawing the previous 99 patterns. So, algebraic representation is both a validation and predictive tool."

Analysis:

This response demonstrates strong executive reasoning. The student not only stated that the formula is "more precise" but justified the superiority of the formal method using advanced concepts such as *cumulative error*, *congruence*, and *predictive capability*. This is clear evidence of Higher Level

Evaluation within critical thinking ability, as the student integrates logical reasoning, abstraction, and mathematical justification a pattern consistent with Facione's (2015) and Ennis's (2011) frameworks of advanced critical thinking competence.

Cross-Case Analysis

A comparative analysis across ability levels was conducted to identify patterns in students' critical thinking indicators. Quantitatively, of the twelve students analyzed, 4 (33.3%) were categorized as high, 5 (41.7%) as medium, and 3 (25%) as low in critical thinking ability.

Tabel 4. Summary of Students' Critical Thinking Indicators Across Ability Levels

Indicator of Critical Thinking	Low Ability	Moderate Ability	High Ability
Analyzing	Focused only on visual appearance; unable to identify relationships between data	Recognized simple patterns but lacked precision	Identified and explained transformation types accurately
Evaluating	Failed to verify or compare reasoning	Attempted to evaluate but inconsistently	Compared alternative solutions using logical justification
Drawing Conclusions	Incorrect or missing conclusions	Simple but incomplete	Logical and systematic conclusions based on data

The table shows that analytical and evaluative processes were dominant among high-ability students, while low-ability students exhibited surface-level responses. These differences confirm that students' cognitive engagement levels correspond with their conceptual mastery and metacognitive awareness. Numerical triangulation supports these findings: approximately 75% of high-ability students could correctly identify geometric transformations and justify their reasoning, compared to only 20% of low-ability students. This highlights the significant gap between perceptual and analytical understanding in culturally contextualized mathematical tasks.

Discussion

The findings above align with (Facione, 2018) critical thinking framework, which emphasizes *analysis, evaluation,* and *inference* as core skills in logical reasoning. High-ability students fulfilled all three dimensions, demonstrating systematic thought processes and reflective control, whereas low-ability students primarily engaged in recall-based reasoning.These results also correspond with (Ennis, 2000) argument that critical thinking development requires both cognitive and dispositional readiness. Students with limited motivation and linguistic mastery struggled to express reasoning formally, which constrained their analytical depth. From a pedagogical perspective, the integration of Malay culture supports Gay's (2018) theory of *culturally responsive teaching*, which connects students' lived experiences with abstract mathematical ideas. The use of local ornament patterns such as the symmetrical carvings of Maimun Palace helped contextualize transformations, making mathematics more meaningful and relatable. However, its success depends on teachers' ability to scaffold discussions and prompt students' reflective thinking through guiding questions (e.g., "Why does this transformation make sense?" or "Could another method yield the same result?"). Overall, the study demonstrates that culturally contextual mathematical literacy tasks can enhance students' motivation and deepen understanding, provided that scaffolding strategies are applied systematically. For low and medium ability students, structured interventions such as repeated exposure to mathematical vocabulary and guided visualization of geometric transformations are essential to strengthen both conceptual and linguistic aspects of critical thinking. These findings reinforce the importance of designing mathematics learning that not only develops critical thinking skills but also maintains cultural relevance, thereby cultivating students who are both intellectually analytical and culturally grounded.

CONCLUSION

This study aimed to describe students' critical thinking abilities in solving geometry transformation problems integrated with Malay cultural motifs. The findings clearly demonstrate differences across ability levels. Students with low critical thinking ability tended to rely on visual perception without applying logical reasoning or evaluating alternative answers. Those with moderate ability began to analyze and interpret information but still showed hesitation and inconsistency in justification. In contrast, high-ability students were able to explain their reasoning systematically, use relevant evidence, evaluate alternatives, and draw logical conclusions. These findings indicate that students' critical thinking levels are closely related to their capacity to analyze, evaluate, and reason logically in culturally contextualized mathematics learning. Integrating Malay cultural motifs into geometry instruction not only enhances students' conceptual understanding but also promotes the preservation of local cultural identity. This aligns with the goals of culturally responsive education that connects students' cultural backgrounds with abstract mathematical reasoning. From an educational perspective, the results suggest that teachers should design learning activities that integrate local cultural contexts and explicitly foster analytical and evaluative thinking skills. Curriculum designers may also consider embedding cultural elements as part of contextual mathematics learning materials to make the learning process more meaningful and inclusive. Future research could extend this study by conducting quantitative validation of the findings with larger samples, developing intervention models that integrate culture-based learning with technology (e.g., GeoGebra), or implementing longitudinal studies to observe the development of students' critical thinking skills over time. Such studies would provide deeper insights into how culturally embedded mathematics education contributes to both cognitive growth and cultural awareness among students.

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