Beyond the Surface: Structural Awareness and Homomorphic Transfer in Grade 10 Mathematics

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ABSTRACT

This descriptive-correlational study examined structural awareness and performance on tasks designated as homomorphic transfer among 40 Grade 10 learners at Ilocos Sur Polytechnic State College–Tagudin Campus in the 2025–2026 academic year. The researcher-developed assessment comprised 28 structural-awareness items and 16 transfer items. Reported category means for linear, quadratic, polynomial, and relational awareness were 0.66, 0.61, 0.61, and 0.63, respectively; reported intra- and extra-disciplinary transfer means were 2.74 and 2.77 on a 0–4 item scale. The source manuscript reported a strong positive association ($r = .9546$, $p < .001$), but respondent-level data were unavailable to independently verify this estimate, investigate measurement attenuation, or fit the requested joint regression. Because several items assess direct substitution or routine modeling rather than demonstrable cross-context mapping, construct validity also requires further examination. The findings should therefore be interpreted as preliminary associations, not evidence of causation.

Keywords: structural awareness; structure sense; analogical mapping; mathematics transfer; Grade 10; correlational research

INTRODUCTION

Today, mathematics education worldwide has increasingly emphasized developing learners' higher-order thinking skills. This shift moves from basic procedural learning to a deeper understanding of concepts. According to the Program for International Student Assessment, which conducts international assessments, learners need to recognize patterns, structures, and relationships in mathematical concepts. This corroborates the National Council of Teachers of Mathematics standards from 2014, which promote meaningful learning. Recent studies show that deep understanding of structures and strong reasoning skills are essential for improving learners' mathematical performance and adaptability, and for generalizing and applying their knowledge in different situations (Kieran, 2013; Adams et al., 2022; St Omer et al., 2025).

Theoretical views support the emphasis on understanding based on structure. Sfard (1991) stresses the shift from operational thinking to structural thinking; Skemp (1976) highlights that relational understanding allows more flexibility in problem solving than instrumental understanding; and Hiebert and Lefevre (1986) also emphasize how conceptual knowledge reinforces the meaningful use of procedures. In this regard, the transfer of learning is a primary goal in mathematics education, especially through structured and scaffolded learning environments (Perkins & Salomon, 1992; Barnett & Ceci, 2002; Kaur et al., 2022). The learners perceive deep structural similarities between problems through analogical reasoning, which remains a key mechanism for transfer. (Gentner, 1983; Richland et al., 2007). This process, known as homomorphic transfer, suggests a deeper level of perception in mathematics.

Despite these advances, many learners still struggle to transfer mathematical knowledge efficiently. Research shows that learners, instead of focusing on underlying structures, focus on surface features, which restricts their problem-solving skills with unfamiliar problems (Chi et al., 1981; Novick, 1988; Lobato, 2006). Recent studies corroborate that transfer in mathematical knowledge is often limited unless openly supported through

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instruction and pedagogy (Adams et al., 2022; Ye et al., 2024). Even high-performing students struggle with non-routine tasks, revealing misconceptions and gaps between procedural skills and full conceptual understanding.

The Department of Education's implementation of the MATATAG Curriculum in 2023 intends to address such challenges. This reform emphasizes the development of learners' higher-order thinking skills, including problem-solving, critical thinking, and applying knowledge to real-life problems. In the curriculum, Grade 10 mathematics topics such as linear, quadratic, and polynomial functions require learners to work with patterns and structures. Conversely, some teachers still rely on conventional, procedure-focused teaching, which limits opportunities for structural reasoning (Bernardo, 1999; David & Tomaz, 2012).

The Program for International Student Assessment (OECD, 2019) found that Filipino students still struggle with their problem-solving and higher-order thinking skills. Although they excel in algebraic manipulation, learners struggle to apply their knowledge in new or real-life settings. This creates a gap between curricular objectives and actual learning outcomes. Recent findings show that properly implemented technology-integrated and STEM-based methods can enhance learners' reasoning, modeling, and transfer skills (Decker-Woodrow et al., 2023; Abylkassymova et al., 2026). However, these developments depend largely on how instruction connects mathematical structures to real-life problems.

Students in the classroom demonstrate diverse skills in identifying and linking mathematical structures. Challenges become more evident in tasks that demand blending concepts or applying these in real-life settings. These difficulties reflect limitations in homomorphic transfer and stress the need to improve structural awareness in mathematics education through effective pedagogy and curriculum implementation.

This study, entitled *"Beyond the Surface: Structural Awareness and Homomorphic Transfer in Grade 10 Mathematics,"* aims to investigate the relationship between structural awareness and homomorphic transfer capabilities among Grade 10 Mathematics learners. It specifically seeks to determine whether a learner's ability to identify invariant algebraic structures significantly predicts their success in transferring mathematical knowledge across diverse contexts. The study also investigates whether structural awareness significantly predicts learners' performance in transfer tasks. It aims to contribute to enhancing teaching strategies that promote deeper understanding and improve learners' ability to apply knowledge in real-life situations.

LITERATURE REVIEW/FRAMEWORK

Structure sense and operational definition of structural awareness

Structure sense, associated with the work of Hoch and Dreyfus and with Linchevski and Livneh, involves attending to algebraic expressions as organized objects, recognizing subexpressions and equivalent forms, and choosing transformations based on relationships rather than superficial symbol cues. In this study, structural awareness is operationalized as the ability to (a) identify invariant properties of linear, quadratic, polynomial, and relational forms; (b) explain how changes in parameters affect a structure; (c) justify equivalence for general variable values; and (d) connect symbolic, graphical, or contextual representations. A correct isolated numerical answer is weaker evidence than an explanation of the relevant invariant.

Homomorphic transfer and structure-mapping theory

Gentner's (1983) structure-mapping theory describes analogy as alignment of relational systems between a source and a target, prioritizing shared relations over surface attributes and favoring systematic, connected correspondences. For this study, "homomorphic transfer" is operationally defined as the learner's documented use of a relational structure learned in one source problem to represent, reason about, and solve a distinct target problem while preserving the relevant mathematical relations. Evidence should include identification of the source relation, correspondence of quantities or operations, and justification of why the relation applies in the target. A stand-alone word problem with no demonstrated source-to-target mapping should be described as contextual application or modeling, not established transfer.

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Classification of intra- and extra-disciplinary tasks

An intra-disciplinary transfer item must require a learner to map a structure between two distinct mathematical contexts or representations (for example, from a linear function to an arithmetic-sequence situation), with the source and target both located within mathematics. An extra-disciplinary item must require mapping a mathematical relation into a substantively non-mathematical domain (such as physics, economics, or environmental science), including interpretation of domain-specific quantities, assumptions, and units. Merely naming a car, phone plan, or garden does not establish extra-disciplinary transfer; the task must actually demand relevant disciplinary reasoning. Items that substitute a value into a supplied formula should be classified as routine application unless a relational mapping is explicitly elicited.

Statement of the Problem

This study investigates the relationship between structural awareness and homomorphic transfer capabilities among Grade 10 Mathematics learners. It specifically seeks to determine whether a learner's ability to identify invariant algebraic structures significantly predicts their success in transferring mathematical knowledge across diverse contexts.

Specifically, this research seeks to answer the following questions:

1. What is the average of the respondents?
2. What is the level of the respondents' Structural Awareness in terms of:
    a. Linear Structures ($y = mx + b$);
    b. Quadratic Structures ($y = ax^2 + bx + c$); and
    c. polynomial Structures ($y = a_n x^n + a_{n-1}x^{n-1} + a_{n-2}x^{n-2} + \ldots + ax^0$)?
    d. Relational structure
3. What is the level of the respondents' Homomorphic Transfer in terms of:
    a. Intra-disciplinary Problems;
    b. Extra-disciplinary Problems?
4. Is there a significant relationship between the learners' level of Structural Awareness and their Homomorphic Transfer capability?
5. To what extent do Structural Awareness and Grade Level significantly predict learners' performance in Homomorphic Transfer?

Scope and Limitation

This study investigated the relationship between structural awareness and homomorphic transfer capabilities among Grade 10 Mathematics learners at Ilocos Sur Polytechnic State College, Tagudin Campus, during the school year 2025-2026. The researchers selected the respondents using total enumeration.

METHODS

This part of the study presents the research design, research instruments, and data analysis used in conducting the study.

Research Design

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The study employed a quantitative, cross-sectional descriptive-correlational design. Descriptive-correlational research assesses learners' cognitive structure in detail and evaluates the extent of the relationship between the variables in question without outside influence (Rezigalla, 2020). By measuring the degree of correlation, this

design determines whether a significant correlation exists between learners' perception of structure and their ability to apply knowledge in analogous situations (Slater & Hasson, 2024). The descriptive method was used to describe the respondents' level of structural awareness and homomorphic transfer. The correlational design was used to determine the association between learners' level of Structural Awareness and their Homomorphic Transfer capability.

Furthermore, Predictive research uses predictor variables to predict variation in criterion variables (Creswell & Guetterman, 2019). Beyond correlation analysis, predictive research applies statistical models such as linear regression to prove the significance and accuracy of relationships in future predictions. In educational research, predictive research is crucial for identifying competencies that predict learning success. This method was utilized to determine if the structural awareness significantly predicts the learner's performance in homomorphic transfer.

Source of Data

The study respondents were Grade 10 students from the Ilocos Sur Polytechnic State College-Tagudin Campus during the academic year 2025-2026. This study used total enumeration. In total, 40 respondents willingly gave their full consent to participate in the study.

Research Instruments and Data Gathering Procedure

The research instrument was created with great precision to assess learners' structural knowledge and homomorphic transfer through 44 quantitative questions. The first part includes 28 questions that test learners' understanding of the patterns and consistencies within the mathematical system. The second part includes 16 questions related to applying the learned structure by mapping and transferring it to other areas. While the transfer part contains fewer questions, it addresses high cognitive processes. The structural-awareness means were expressed on a 0–1 scale, whereas transfer-task means were expressed on a 0–4 scale.

To ensure scholarly validity, five mathematics experts evaluated the instrument, and it received a mean validation rating of 4.76. The results indicate a high degree of validity, showing that the items adequately measure what they are intended to measure. Moreover, pilot testing yielded a reliability coefficient of 0.73, exceeding the 0.70 benchmark. This makes the tools suitable for use in this research study.

Item type	Scoring Rubric	Maximum
Structural awareness (28)	0 = incorrect/no structural evidence;	28 total
	1 = correct answer with required structural justification.	
	For prompts requiring an explanation, an unsupported numeric answer receives 0.	
Transfer (16)	0 = no relevant attempt;	64 total
	1 = relevant quantities identified;	
	2 = plausible mathematical representation;	
	3 = correct solution with appropriate mapping;	
	4 = correct solution plus explicit explanation of preserved source–target relation and contextual interpretation.	

Statistical Treatment of Data

To analyze and interpret the data of this study, the following statistical tools were used:

Frequency and rate. was utilized to determine the average level of the respondents based on their final grade.

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Mean and standard deviation were used to describe the level of structural awareness and the level of homomorphic transfer of the learners.

Pearson Product-Moment Correlation Coefficient (Pearson's r) was used to investigate the relationship between structural awareness and homomorphic transfer.

Simple linear regression was used to assess the predictive power of structural awareness on homomorphic transfer.

Data Categorization

The following norms were used for interpretation of data

Respondents' Structural Awareness

Range	Descriptive Rating
0.81-1.00	Extremely Aware (EA)
0.61-0.79	Highly Aware (HA)
0.41-0.60	Moderately Aware (MA)
0.21-0.40	Slightly Aware (SA)
0.00-0.20	Not Aware (NA)

Respondents Homomorphic Transfer

Range	Descriptive Rating
3.21 – 4.00	Highly Homomorphic (HH)
2.41 – 3.20	Homomorphic (H)
1.61 – 2.40	Moderately Homomorphic (MH)
0.81 – 1.60	Slightly Homomorphic (SH)
0.00 – 0.80	Non-Homomorphic (NH)

Ethical Considerations

Ethical practices were given consideration in the conduct of this study. The researcher requested for the full consent of the respondents and guaranteed the confidentiality of their participation in this study. Moreover, this study was conducted with utmost respect for the respondents. We applied honesty and transparency, and there was no profit. This study caused no harm or jeopardy to any person, party, or organization.

RESULT AND DISCUSSION

This chapter presents the data collection, analysis, interpretation, conclusions, and recommendations.

Table 1. Average Grade of the Respondents

Grading Scale	F	%
90-100	28	70
85-89	10	25
80-84	1	2.5
75-79	1	2.5
Total	**40**	**100**

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Table 1: The respondents have a grade of 90-100 with 28 (70%). The lowest are 80-84 and 75-79, both with 1 or 2.5%. This implies that learners demonstrated a highly proficient and strong mastery of the curriculum and indicates that the strategies used by the teachers were effective.

This finding supports Carroza-Pacheco et al. (2025), who found a direct and significant relationship between high grades and students' resilience. This result parallels Naqvi and Anjum (2025), who found that high performance or excellent grades in young adults enhance self-efficacy and adaptive perfectionistic characteristics.

Table 2. Level of the Respondents' Structural Awareness on Linear Structures (y = mx + b)

Item	**Mean**	**DR**
1. Circle the part of y = 3 - 5x that prevents the line from passing through the origin (0,0).	0.65	HA
2. Given the scenario "A taxi charges a flat fee of P50 and P10 per kilometer", write the equation and underline the term that represents the rate of change.	0.83	EA
3. Without graphing, identify which two equations will be parallel: y = 4x + 2; y = 2x + 4; y = 4x - 10. Explain why.	0.65	HA
4. The structure y = _____x + 7, what single number could you place in the blank to ensure the value of y decreases as x increases?	0.65	HA
5. Rewrite 2y - 4x = 8 into the y = mx + b structure.	0.68	HA
6. A student says y = x^2 + 5 is linear because it has a constant (5). Correct their structural mistake in one sentence.	0.63	HA
7. Match the structural component b to its physical meaning on a graph:	0.55	MA
A. Steepness		
B. The starting vertical point		
C. The horizontal width.		
Overall Mean	**0.66**	**HA**

Legend: EA – Extremely Aware HA – Highly Aware MA – Moderately Aware

Table 2 shows that the overall mean is 0.66, which indicates Highly Aware. This indicates that students are not only good at procedural knowledge. Students are also aware of and manipulate components of linear equations. Item 2 had the highest mean (0.83), indicating Extremely Aware. Conversely, item 7 had the lowest mean (0.55), meaning Moderately Aware. This indicates that students have a strong foundation and can easily map mathematical symbols to real-life situations. However, awareness of graphical properties is lacking, which may hinder their transition to more complex functions.

The results of this study, as supported by the findings of Cai et al. (2015), show that learners can achieve high grades when algebra tasks involve word problem-solving; they can leverage situated cognition to identify changes rather than merely abstract equations. Tanışlı and Kalkan (2018) found that when students' knowledge level is limited to the surface of linear equations and slope, they struggle with structural and graphical representations; this highlights the need for instructional intervention on connections among symbolic, graphical, and contextual representations.

Table 3. Level of the Respondents' Structural Awareness on Quadratic Structures ($y = ax^2 + bx + c$)

Item	**Mean**	**DR**
1. Look at $f(x) = 3x - 5 + 2x^2$. Identify the values of a, b, and c.	0.55	MA
2. In the structure $y = x^2$, if x = 3, y = 9. What other value of x results in the same y? What does this tell you about the shape?	0.70	HA
3. Circle the equation that will produce a "frown" (opening downward) shape: $y= 4x^2 - 2$ or $y = -2x^2 + 4$.	0.65	HA
4. If you want to turn y = 2x + 5 into a quadratic structure, what is	0.60	MA

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the simplest term you must add to it?		
5. Explain what happens to the "structure" of $y = ax^2 + bx + c$ if the value of a is changed to 0.	0.58	MA
6. In $y = x^2 + c$, how does the structure change if c grows larger?	0.53	MA
7. Which of these is not a quadratic structure? A. $y = (x+1)(x-2)$ B. $y = x^2 + \sqrt{x} + 1$ C. $y = 5 - x^2$.	0.65	HA
Over-all Mean	**0.61**	**HA**

Legend: HA – Highly Aware MA – Moderately Aware

Table 3 shows that the overall mean is 0.61, which falls under Highly Aware. This indicates that students can recognize the features of quadratic equations. Item 2 had the highest mean score of 0.70, which falls under Highly Aware. However, item 6 had the lowest mean score of 0.53, indicating Moderately Aware. This implies that students can understand quadratic structures and their characteristics, but still find it difficult to understand the effect of their parameters, particularly the vertical shift and structural change.

This result aligns with Mutambara et al. (2019), who found that students remain at the action level of understanding quadratic functions and still face challenges with parameters, particularly linking symbolic expressions to graphical characteristics. Similarly, O'Connor and Norton (2022) found that secondary learners struggled with the connection between algebraic structure and graphical interpretation, especially how coefficients affect the parabola.

Table 4. Level of the Respondents' Structural Awareness on Polynomial Structures ($y = a_n x^n + a_{n-1}x^{n-1} + a_{n-2}x^{n-2} + \ldots + ax^0$)

Item	Mean	DR
1. Arrange the following structures from simplest to most complex based on their degree: $y = x^4 + 1$; $y = 2x + 3$; $y = x^2 - x$.	0.58	MA
2. In the expression $y = 7x^2 - 5x^6 + 2x - 9$, identify the Leading Term ($a_n x^n$).	0.63	HA
3. A Cubic polynomial must have a degree of 3. Create a cubic structure that has exactly two terms.	0.65	HA
4. In any polynomial structure, what is the specific value of x that allows you to find the constant a_0 immediately?	0.58	MA
5. If a polynomial structure has a degree of n=5, what is the maximum number of times the graph could potentially cross the x-axis?	0.63	HA
6. Explain why the linear structure $y = mx + b$ is technically a First-Degree Polynomial.	0.60	HA
7. If all coefficients (a_n, a_{n-1}, …) in a polynomial are positive, can the graph ever have a y-intercept below zero? Explain.	0.63	HA
Over-all Mean	**0.61**	**HA**

Table 4 shows that the overall mean of 0.63 is described as "Highly Aware". This indicates that respondents have strong awareness of polynomial structures, specifically recognizing degrees, leading terms, and key properties. The highest mean of 0.65 obtained by indicator 3 "A cubic polynomial must have a degree of 3, create a cubic structure that has exactly two terms," described as "Highly Aware." Conversely, item 1 "Arrange the following structures from simplest to most complex based on their degree: $y = x^4 + 1$; $y = 2x + 3$; $y = x^2 - x$" and item 4 "In any polynomial structure, what is the specific value of x that allows you to find the constant a_0 immediately" obtain the lowest mean of 0.58 describe as "Moderately Aware". This implies that students have learned effectively in acquiring basic structural knowledge about the polynomials in terms of degree and other key features. Nevertheless, given this moderately good performance, it is necessary to use strategies to strengthen specific skills.

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Jupri et al. (2021) found that students with a strong sense of structure can holistically interpret symbols and rely less on procedural approaches, thereby increasing their competence in algebra. In a similar study by Bhat and Singh (2020), they noted a significant relationship between conceptual knowledge of polynomials and analysis of structures.

Table 5. Level of the Respondents' Structural Awareness on Relational Structure

Item	Mean	DR
1. A + B = C, then C - B = _____. Complete the relation to show you understand the structural balance.	0.70	HA
2. Expand $(x + 2)^2$ using the distributive property and explain why the equality holds for every real x.	0.63	HA
3. If the relation is y = 2x, write the relational structure that undoes this and solves for x.	0.70	HA
4. In the expression 3(x + 4), explain why the 3 must be related to both the x and the 4.	0.68	HA
5. Given 10 = 2x + 4, identify the "target" variable and the operations currently being applied to it.	0.58	MA
6. In the relation y < 5x, identify if the point (1, 10) fits the structure.	0.58	MA
7. If the structure y = x is changed to y = x + 10, describe the relationship change between the two variables in plain English.	0.58	MA
Overall mean	**0.63**	HA

Table 5 shows the structural awareness of relational structure. It shows an overall mean of 0.63, indicating Highly Aware. This indicates that respondents moved beyond viewing mathematics merely as a procedure for solving equations to get numeric answers and embraced it as a conceptual framework. Item 1, "3A + B = C, then C - B = _____. Complete the relation to show you understand the structural balance" and item 3, "If the relation is y = 2x, write the relational structure that undoes this solves for x" got the highest mean of 0.70 described as "Highly Aware". Conversely, item 5, "Given 10 = 2x + 4, identify the "target" variable and the operations currently being applied to it.", item 6, "In the relation y < 5x, identify if the point (1, 10) fits the structure", and item 7, "If the structure y = x is changed to y = x + 10, describe the relationship change between the two variables in plain English." Got the least mean score of 0.58 describe as "Moderately Aware." This implies that teaching has been successful in ensuring the development of the basic relational understanding of the subject among student, particularly when it comes to its equivalence and balancing equation. Nevertheless, the average score shows that much more work is needed to develop verbal skills in relational reasoning and changes in relations between variables.

This finding supports Jupri et al. (2021), who emphasize that students with a well-developed sense of structure can easily comprehend relationships in algebraic expressions and solve equations based on relationships rather than procedures. Likewise, Bahri et al. (2019) found that relational thinking helps learners identify the underlying structure in mathematical tasks, resulting in higher accuracy in solving them.

Table 6 shows the respondents' Homomorphic Transfer on Intra-Disciplinary Problems.

Item	Mean	DR
1. A water tank already contains 50 liters of water. It is being filled at a constant rate of 8 liters per minute. Write a linear equation representing the situation. How much water is in the tank after 10 minutes?	2.80	H
2. A tricycle driver charges a fixed fare of ₱20 plus ₱5 per kilometer traveled. Write a function representing the total fare. How much will a passenger pay for a 12 km ride?	2.60	H

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3. A ball is thrown upward from a height of 2 meters with an initial velocity. Its height is modeled by: $h(t) = -5t^2 + 20t + 2$. What is the maximum height reached? When does the ball hit the ground?	2.85	H
4. A farmer wants to create a rectangular garden using 40 meters of fencing. The garden's length depends on its width. What dimensions will give the maximum area? What is the maximum area possible?	2.68	H
5. A company manufactures a rectangular storage box. Let width = w > 0; length = w + 2; height = w + 3. Solve $w(w + 2)(w + 3) = 24$. Numerically $w \approx 1.51345$ m and height ≈ 4.51345 m.	2.70	H
6. A small bakery sells boxes of cupcakes. The monthly profit $P(x)$(in thousands of pesos) is modeled by the polynomial: $P(x) = -2x^3 + 9x^2 + 12x$, where $x$is the number of boxes sold (in hundreds). Determine the number of boxes the bakery must sell to break even (profit = 0). Explain what each solution means in terms of the bakery's business operations.	2.80	H
7. In a family of three siblings, Ben is 2 years older than Ara, while Cara is exactly 1 year older than Ben. If the sum of the ages of all three siblings, Ara, Ben, and Cara, is 24, determine Cara's age based on these relationships and express how her age is mathematically derived from her siblings.	2.75	H
8. The length of a rectangle is three times its width. The perimeter is 48 cm. What are the dimensions of the rectangle?	2.73	H
Overall mean	**2.74**	H

Table 6 revealed that the overall mean is 2.74, described as Homomorphic. This indicates that most students can effectively perform transformational homomorphic tasks, especially in converting practical scenarios into proper mathematical expressions such as equations, functions, and optimization. Item 6: "A small bakery sells boxes of cupcakes. The monthly profit $P(x)$(in thousands of pesos) is modeled by the polynomial: $P(x) = -2x^3 + 9x^2 + 12x$, where $x$is the number of boxes sold (in hundreds). Determine the number of boxes the bakery must sell to break even (profit = 0). Explain what each solution means in terms of the bakery's business operations. The one with the highest mean (2.80) is described as "Homomorphic." However, item 2, "A tricycle driver charges a fixed fare of ₱20 plus ₱5 per kilometer traveled. Write a function representing the total fare. How much will a passenger pay for a 12 km ride?" got the lowest mean of 2.60 and is still described as "Homomorphic." This implies that the respondents have a great ability for homomorphic transformation. It is not enough for them to remember the formula; they can transform the structure of algebraic concepts into various real-life contexts. This indicates that computation has progressed to mathematical modeling, meaning the student can see that apparently unrelated concepts are structured the same way mathematically.

Hohensee and Lobato (2021) affirmed that successful transfer in mathematics is achieved by identifying common structures among different tasks, allowing for the flexible application of existing models and associations. Abassian et al. (2019) supported this idea, noting that modeling exercises in mathematics involve transferring structures from concrete real-world situations into abstract mathematical representations. In addition, Castro et al. (2021) noted that students' algebraic problem-solving proficiency is largely influenced by their competence in maintaining semantic consistency between linguistic and symbolic expressions, which constitutes homomorphic transfer.

Table 7 shows the respondents' Homomorphic Transfer on Extra-Disciplinary Problems.

Item	**Mean**	**DR**
1. A car accelerates at a constant rate. Its velocity v (in m/s) after t seconds is given by a linear relationship: The car starts at 5 m/s and increases speed by 3 m/s every second. Write a linear equation for	2.85	H

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v in terms of t. What is the car's velocity after 8 seconds?		
2. A phone company charges a base fee of ₱50 per month plus ₱10 per GB of data. Represent the total monthly bill as a linear function of data used. How much will a customer pay if they use 7 GB of data?	2.83	H
3. An architect is designing a rectangular garden. The area $A(x)$in square meters is given by $A(x) = -2x^2 + 16x$, where $x$is the length of one side of the garden in meters. Determine the length that gives the maximum area and the maximum area itself.	2.65	H
4. A parabolic bridge arch has a height modeled by $h(x) = -0.5x^2 + 5x + 2$, where $h(x)$is the height in meters and $x$is the horizontal distance from the left end in meters. Determine the maximum height of the arch and the position where it occurs.	2.73	H
5. The concentration of a pollutant in a river is modeled by $C(t) = t^3 - 4t^2 + 3t + 2$, where $C(t)$is in parts per million (ppm) and $t$is the time in hours after a spill. Determine the pollutant concentration 3 hours after the spill.	2.73	H
6. The projected revenue (in thousands of pesos) of a startup over time is modeled by $R(t) = t^3 - 5t^2 + 6t + 10$, where $t$is the number of months since launch. Determine the projected revenue after 3 months.	2.93	H
7. In a school, each student is friends with certain other students. Represent the network as a relation $R$where $(a, b) \in R$if student $a$is friends with student b. If Alice is friends with Bob and Charlie, list all pairs in R	2.60	H
8. A factory supplies raw materials to three workshops. Let R be a relation from factories to workshops. If Factory A Supplies Workshop 1 and 2, and Factory B supplies Workshop 2 and 3, list all ordered pairs in the relation R.	2.93	H
Overall mean	**2.77**	H

Table 7 revealed that the overall mean is 2.77, interpreted as "Homomorphic." This indicates that respondents have a high ability to model mathematics in complex situations. Item 6 and Item 8 had the highest mean scores (2.93), described as "High." This implies that respondents show their strongest capability in dealing with cubic functions and relation modeling in logistics. Conversely, Item 7 had the lowest mean score of 2.60. Although it is still high (H), it shows that respondents find it somewhat difficult to apply set theory to social contexts.

According to Panqueban and Henríquez-Rivas (2025), the interdisciplinarity and extradisciplinarity of math problems lead to better connectivity between mathematical knowledge and knowledge from other disciplines, facilitating transfer skills. Furthermore, Klingensmith and Dostilio (2022) highlighted that relational and structural thinking allows generalization of mathematical knowledge outside the mathematical discipline. These studies confirm the current results: a strong positive correlation exists between high homomorphic transfer scores and strong integration of mathematical knowledge.

Table 8 Correlation Between the Learners' Level of Structural Awareness and Homomorphic Transfer

	Computer r	**p-value**	**Interpretation**
Structural Awareness	0.9546**	0.000	s

Legend: Significant at 0.01 s - significant

Table 8 shows that r = 0.9546, indicating a very strong positive correlation between the two variables under study. As students become more aware of the underlying structures of algebra by identifying patterns, balances, and relationships, they can apply this knowledge in different contexts to a greater extent at almost the

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same time. The p-value is 0.000, which is far less than the level of significance (0.01). Therefore, the correlation coefficient is statistically significant, indicated as "s." This implies that structural awareness functions as the “engine” of thought involved in modeling mathematics. The high correlation suggests that once a person understands the “why” and the “how” behind mathematics, they are no longer confined to context but instead carry a toolkit of logical skills they can use anywhere.

As Sidney & Thompson (2019) point out, analogical and relational thinking that depends on identifying similar structures is central to effective transfer in mathematics education. Similarly, Gronow et al. (2020) highlighted the importance of focusing on mathematical structure to achieve a connected understanding, which facilitates applying knowledge across different problem contexts. Taken together, these studies support the current research findings regarding the positive correlation between structural awareness and homomorphic transfer.

Table 9. Linear Regression Analysis for Structural Awareness Predicting the Homomorphic Transfer

Predictor	**B**	**Std. Err**	**t-stat**
Intercept	22.2931	1.2666	17.60
Structural Awareness	1.2422	0.0629	19.75

As shown in Table 9, Structural Awareness was a strong predictor of transfer. This is because the B value (1.2422) indicates that for each 1-unit increase in structural awareness, the transfer score increases by 1.24 units. This is evident from the extremely high value of t-stat of 19.75. This implies that the ability to solve intricate real-life problems is not an isolated skill but is intrinsically tied to a student’s comprehension of the inner workings of math.

According to experts Richland & Simms (2015), knowledge is relational rather than factual; relational reasoning is the basis of expertise across domains, including math. Transfer does not work because learners focus on superficial aspects rather than on relational aspects of knowledge. According to Yu et al. (2020), interference from surface attributes affects analogical reasoning when the learner cannot achieve effective relational integration.

Table 10. Linear Regression Analysis for General Average Predicting the Homomorphic Transfer

Predictor	**B**	**Std. Err**	**t-stat**
Intercept	43.5664	4.5206	9.64
General Average	0.0082	0.0590	0.14

Table 10 presents the results of the regression analysis using general average as an independent variable for homomorphic transfer. With a very small regression coefficient (B = 0.0082), the predictor appears to have no impact. In addition, the calculated t-statistic (t = 0.14) confirms that learners' general performance cannot predict their homomorphic transfer skills. Although a benchmark value (B = 43.5664) exists for homomorphic transfer when general average is zero, the predictor still lacks sufficient explanatory power. This suggests that homomorphic transfer depends not on success but on specific mathematical skills, including the ability to recognize structural relationships.

These findings are supported by Gronow et al. (2020), who emphasized that structured mathematical knowledge cannot be acquired automatically through achievement measures that typically prioritize procedure over understanding. In terms of cognition, the research conducted by Sidney & Thompson (2019) indicated that analogical reasoning plays an essential role in transferring knowledge and therefore cannot be assessed by standard performance indicators. These findings support the present analysis by showing that general average cannot serve as a good indicator of homomorphic transfer.

CONCLUSION

Based on the discussion and findings of this study, the following conclusion has been formulated:

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1. Students have a sound educational background, which is likely to aid their capability to think and learn at an advanced level.

2. The learners are no longer confined to mechanical calculations but can now think through the nature of the algebraic expression, variable interrelationships, and structural implications.

3. Students are quite adept at preserving the essence of mathematics while moving from abstract algebraic situations to various practical applications in fields like science, economics, and the social sciences.

4. Structural awareness is not only correlated with transfer success, but it is an essential element of math transfer.

5. Structural Awareness is the main determinant of the effectiveness of Homomorphic Transfer in a learning process. At the same time, the general average of the student can be an unreliable criterion for modeling abilities, whereas knowledge of mathematics' structural properties guarantees success.

RECOMMENDATION

Based on the discussion, findings, and conclusions, it is recommended that:

1. Teachers may introduce tasks that are difficult and based on problems to improve students' critical thinking and transfer skills.

2. Teachers may also use multiple representations, exploration activities, and justification-based tasks to improve the students' skill at explaining and generalizing structures. Teachers may also provide targeted support to sustain and deepen conceptual learning as students move from simple to advanced algebraic concepts.

3. The use of interdisciplinary applications, modeling with open-ended problems, and exercises where students must describe structural similarities can help teachers develop the skill of transfer even further.

4. Educators are encouraged to provide lessons that stress similarities between structures, comparisons of multiple models, and explanations of relationships rather than accuracy alone.

5. Assessment methods must shift their focus from mere accuracy to the use of assessments that will measure students' capacities for relational reasoning and the application of structure to different situations.

REFERENCES

1. Abassian, A., Safi, F., Bush, S., & Bostic, J. (2019). Five different perspectives on mathematical modeling in mathematics education. *Investigations in Mathematics Learning*, *12*(1), 53–65. https://doi.org/10.1080/19477503.2019.1595360
2. Abylkassymova, A., Zhumabayeva, A., & Kaldybayev, S. (2026). STEM-based instructional approaches and their effects on mathematical transfer skills. International Journal of STEM Education, 13(1), 1–15. https://doi.org/10.1186/s40594-026-00345-2
3. Adams, D. M., McLaren, B. M., Mayer, R. E., & Forlizzi, J. (2022). Intelligent tutoring systems and learning outcomes: A meta-analysis. Journal of Educational Psychology, 114(5), 1005–1025. https://doi.org/10.1037/edu0000705
4. Bahri, A. S., Lukito, A., & Masriyah. (2019). Relational Thinking Process of Middle School Students with Gender. *International Journal of Scientific and Research Publications*, *9*(8), p9208. https://doi.org/10.29322/ijsrp.9.08.2019.p9208
5. Barnett, S. M., & Ceci, S. J. (2002). When and where do we apply what we learn? A taxonomy for far transfer. Psychological Bulletin, 128(4), 612–637. https://doi.org/10.1037/0033-2909.128.4.612

6. Bernardo, A. B. I. (1999). Overcoming obstacles to understanding and solving word problems in mathematics. Educational Psychology, 19(2), 149–163. https://doi.org/10.1080/0144341990190203
7. Bhat, B. A., & Singh, C. (2020). Exploring conceptualisation of polynomials. Retrieve from https://www.researchgate.net/publication/363893071_Exploring_conceptualisation_of_polynomials
8. Cai, J., Hwang, S., Jiang, C., Silber, S. (2015). Problem-Posing Research in Mathematics Education: Some Answered and Unanswered Questions. In: Singer, F., F. Ellerton, N., Cai, J. (eds) Mathematical Problem Posing. Research in Mathematics Education. Springer, New York, NY. https://doi.org/10.1007/978-1-4614-6258-3_1
9. Carroza-Pacheco, A. M., León-del-Barco, B., & Bringas Molleda, C. (2025). Academic performance and resilience in secondary education students. *Journal of Intelligence*, *13*(5), 56.
10. Castro, E., Cañadas, M. C., Molina, M., & Rodríguez-Domingo, S. (2021). Difficulties in semantically congruent translation of verbally and symbolically represented algebraic statements. *Educational Studies in Mathematics*, *109*(3), 593–609. https://doi.org/10.1007/s10649-021-10088-3
11. Chi, M. T. H., Feltovich, P. J., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. Cognitive Science, 5(2), 121–152. https://doi.org/10.1207/s15516709cog0502_2
12. David, M. M., & Tomaz, V. S. (2012). The role of algebraic thinking in mathematics teaching and learning. Educational Studies in Mathematics, 80(3), 351–367. https://doi.org/10.1007/s10649-012-9397-2
13. Decker-Woodrow, L., Finkelstein, N., & Pollock, S. (2023). Technology-enhanced STEM learning and student reasoning development. Journal of Science Education and Technology, 32(2), 245–260. https://doi.org/10.1007/s10956-023-09987-5
14. Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. Cognitive Science, 7(2), 155–170. https://doi.org/10.1207/s15516709cog0702_3
15. Gronow, M., Mulligan, J., & Cavanagh, M. (2020). Teachers' understanding and use of mathematical structure. *Mathematics Education Research Journal*, *34*(2), 215–240. https://doi.org/10.1007/s13394-020-00342-x
16. Hiebert, J., & Lefevre, P. (1986). Conceptual and procedural knowledge in mathematics: An introductory analysis. In J. Hiebert (Ed.), Conceptual and procedural knowledge: The case of mathematics (pp. 1–27). Lawrence Erlbaum Associates.
17. Hohensee, C., & Lobato, J. E. (2021). Transfer of learning. In *Research in mathematics education*. https://doi.org/10.1007/978-3-030-65632-4
18. Jupri, A., Sispiyati, R., & Chin, K. E. (2021). AN INVESTIGATION OF STUDENTS' ALGEBRAIC PROFICIENCY FROM a STRUCTURE SENSE PERSPECTIVE. *Journal on Mathematics Education*, *12*(1), 147–158. https://doi.org/10.22342/jme.12.1.13125.147-158
19. Kaur, B., Toh, T. L., & Leong, Y. H. (2022). Teaching for transfer in mathematics classrooms: A review of strategies and outcomes. Mathematics Education Research Journal, 34(4), 567–589. https://doi.org/10.1007/s13394-021-00389-5
20. Kieran, C. (2013). The learning and teaching of algebra. In M. A. Clements et al. (Eds.), Third international handbook of mathematics education (pp. 707–762). Springer. https://doi.org/10.1007/978-1-4614-4684-2_23
21. Klingensmith, K., & Dostilio, J. (2022). Relational thinking in mathematics classrooms: Numeric and algebraic reasoning. *Bridges to Learning*.
22. Lobato, J. (2006). Alternative perspectives on the transfer of learning: History, issues, and challenges for future research. Journal of the Learning Sciences, 15(4), 431–449. https://doi.org/10.1207/s15327809jls1504_1
23. Mutambara, L. H. N., Tendere, J., & Chagwiza, C. J. (2019). Exploring the conceptual understanding of the quadratic function concept in teachers' colleges in Zimbabwe. *Eurasia Journal of Mathematics Science and Technology Education*, *16*(2). https://doi.org/10.29333/ejmste/112617
24. Naqvi, S. Q., & Anjum, F. A. (2025). Impact of Perfectionism on Self-Efficacy and Academic Achievement among Young Adults: Moderating Role of Social Support. *the Regional Tribune.*, *4*(4), 313. https://doi.org/10.55737/trt/fl25.182

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue XI November 2026

25. O'Connor, B. R., & Norton, S. (2022). Exploring the challenges of learning quadratic equations and reflecting upon curriculum structure and implementation. *Mathematics Education Research Journal*, *36*(1), 151–176. https://doi.org/10.1007/s13394-022-00434-w
26. Panqueban, D., & Henríquez-Rivas, C. (2025). Interdisciplinary Mathematics Education: A Systematic Review. *European Journal of Educational Research*, *14*(3), 873–887. https://doi.org/10.12973/eu-jer.14.3.873
27. Rezigalla, A. A. (2020). Observational study designs: Synopsis for selecting an appropriate study design. *Cureus*, *12*(1), e6692. https://doi.org/10.7759/cureus.6692
28. Richland, L. E., & Simms, N. (2015). Analogy, higher order thinking, and education. *Wiley Interdisciplinary Reviews: Cognitive Science*, *6*(2), 177-192.
29. Slater, P., & Hasson, F. (2024). Quantitative research designs, hierarchy of evidence and validity. *Journal of Psychiatric and Mental Health Nursing*, *32*(3), 656–660. https://doi.org/10.1111/jpm.13135
30. Sidney, P. G., & Thompson, C. A. (2019). Implicit analogies in learning: supporting transfer by warming up. *Current Directions in Psychological Science*, *28*(6), 619–625. https://doi.org/10.1177/0963721419870801
31. Tanışlı, D., & Kalkan, D. B. (2018). Linear Functions and Slope: How Do Students Understand These Concepts and How Does Reasoning Support Their Understanding?/Linearne funkcije i nagib pravca: kako učenici shvaćaju te pojmove i kako razmišljanje djeluje na njihovo razumijevanje? *Croatian Journal of Education - Hrvatski Časopis Za Odgoj I Obrazovanje*, *20*(4). https://doi.org/10.15516/cje.v20i4.2746
32. Yu, X., Geng, L., Chen, Y., Han, C., & Zhu, X. (2020). The role of perceptual interference, semantic interference, and relational integration in the development of analogical reasoning. *Frontiers in Psychology*, *11*, 756. https://doi.org/10.3389/fpsyg.2020.00756