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Teacher Support Adaptivity, Metacognitive Knowledge in Mathematics, and Mathematics Performance: A Path Analysis among Grade 9 Students

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teacher support adaptivity, metacognitive knowledge, mathematics achievement, standardized mathematics performance, classroom assessment

Abstract. This study examined the relationships among Core Teacher Support Adaptivity (Core TSA), metacognitive knowledge in mathematics, and mathematics performance among Grade 9 students at Agusan National High School, Butuan City. It also investigated whether metacognitive knowledge in mathematics mediates the relationship between perceived instructional adaptivity and mathematics achievement. A quantitative cross-sectional explanatory correlational design was employed. Data were collected from 300 students selected through proportional stratified random sampling. Instruments included the Questionnaire on Teacher Support Adaptivity (QTSA), the Metacognitive Knowledge in Mathematics Questionnaire (MKMQ), final mathematics grades, and scores from the Test of Fundamental Academic Skills (TOFAS). Data were analyzed using Spearman correlation, linear regression, and path analysis within a covariance-based structural equation modeling framework with bootstrapped estimates, implemented in R statistical software. Results showed that Core TSA significantly predicted final mathematics grades but did not significantly predict the TOFAS scores. In contrast, metacognitive knowledge in mathematics significantly predicted TOFAS scores but did not significantly predict final mathematics grades. Although metacognitive knowledge in mathematics was positively associated with both measures of mathematics achievement, mediation analysis indicated that it did not significantly mediate the relationship between Core TSA and mathematics performance. These findings suggest that instructional adaptivity primarily influences classroom-based achievement through direct instructional mechanisms, while metacognitive knowledge contributes independently to performance in standardized mathematics assessments, like the TOFAS. The results highlight the complementary yet distinct roles of instructional support and cognitive regulation in mathematics learning and underscore the importance of integrating metacognitive strategy development into classroom instruction to enhance students' mathematical competence.

Introduction

Mathematics remains a core component of the Philippine basic education curriculum; however, Filipino students continue to demonstrate persistently low performance. Results from the Programme for International Student Assessment (PISA) indicate that the Philippines ranked among the lowest-performing countries in mathematics in both 2018 and 2022. In 2022, only 16% of Filipino students reached at least Level 2 proficiency, compared to the Organisation for Economic Co-operation and Development (OECD) average of 69% (Department of Education, 2023; OECD, 2023). At this level, students are expected to interpret simple situations mathematically, identify relevant information, and apply basic procedures. The low proportion of students reaching this benchmark indicates that many learners struggle with fundamental mathematical reasoning and the application of knowledge in meaningful contexts.

At the local level, similar patterns are observed. At Agusan National High School, results from the Test of Fundamental Academic Skills (TOFAS) indicate that a substantial proportion of students perform below expected proficiency levels. This underscores the need to examine both instructional and learner-related factors that may influence mathematics achievement.

Teacher support adaptivity refers to the extent to which teachers adjust instructional regulation in response to students' level of understanding. Grounded in scaffolding theory and Vygotsky's Zone of Proximal Development, adaptive instruction involves aligning the level of support with learners' needs to facilitate effective learning.

Metacognitive knowledge in mathematics is a key learner-related factor. It refers to students' awareness of their cognitive processes, including knowledge of strategies, task demands, and self-regulation. Students with higher levels of metacognitive knowledge are better able to plan, monitor, and evaluate their learning, which contributes to mathematics performance.

Despite its theoretical importance, limited empirical research has examined whether metacognitive knowledge explains how instructional support relates to mathematics performance in the Philippine secondary education context. Accordingly, this study examines the relationships among teacher support adaptivity, metacognitive knowledge in mathematics, and mathematics performance, and tests whether metacognitive knowledge explains the relationship between perceived instructional adaptivity and academic performance.

Methodology

Study Design

This study employed a quantitative, cross-sectional, non-experimental explanatory correlational design to examine the relationships among teacher support adaptivity, metacognitive knowledge in mathematics, and mathematics performance. All variables were measured at a single time point during the fourth quarter of the 2024–2025 school year. Since no experimental manipulation was introduced, findings are interpreted as statistical associations rather than causal relationships. To examine direct and indirect relationships, path analysis was conducted within a covariance-based structural equation modeling (CB-SEM) framework using the lavaan package in R. Indirect effects were estimated using bootstrapped confidence intervals with 5,000 resamples.

Target Respondents

The study was conducted at Agusan National High School in Butuan City during the 2024–2025 school year. The target population consisted of 1,046 Grade 9 students enrolled across 26 sections and taught by six mathematics teachers. A proportional stratified random sampling design was employed, with mathematics teachers serving as strata to ensure representation across instructional contexts. A total of 514 students voluntarily completed the survey and constituted the sampling frame. From these, a final sample of 300 students was selected, with 50 students randomly drawn from each teacher stratum. Proportional allocation across sections was maintained within each stratum. The sample size was considered adequate for path analysis. Prior simulation studies indicate that samples of 200 to 300 are sufficient to detect small-to-moderate indirect effects using bootstrap estimation at $\alpha = .05$ (Fritz & MacKinnon, 2007).

Instruments

Teacher Support Adaptivity

Teacher support adaptivity was measured using the 21-item Questionnaire on Teacher Support Adaptivity (QTSA; van de Pol et al., 2022), which assesses the extent to which teachers adjust instructional regulation in response to students' level of understanding. Items were rated on a 5-point Likert scale ranging from 1 (Totally Disagree) to 5 (Totally Agree). Confirmatory factor analysis indicated that a refined three-facet structure—Adaptive High Regulation (A+), Adaptive Low Regulation (A−), and reversed Non-Adaptive High Regulation (NA+R)—provided the best representation of adaptive instructional alignment (CFI = .902, RMSEA = .072, SRMR = .054). A composite Core Teacher Support Adaptivity (Core TSA) score was computed as the mean of these facets. The Non-Adaptive Low Regulation (NA−) dimension was retained as a separate indicator of instructional under-support and was used only in descriptive and correlational analyses.

Metacognitive Knowledge in Mathematics

Metacognitive knowledge in mathematics was assessed using the Metacognitive Knowledge in Mathematics Questionnaire (MKMQ; Efklides & Vlachopoulos, 2012), which measures students' awareness of cognitive processes, including knowledge of strategies, task demands, and self-regulation in mathematics learning. Confirmatory factor analysis using robust weighted least squares estimation (WLSMV) supported a refined seven-factor model with acceptable fit (CFI = .936, TLI = .931, RMSEA = .077, SRMR = .085). Standardized factor loadings ranged from .49 to .83 ($p < .001$), and composite reliability coefficients ranged from .72 to .87. Composite mean scores were computed, with higher scores indicating greater metacognitive knowledge in mathematics.

Mathematics Performance

Mathematics performance was measured using two indicators: (a) final mathematics grade, representing classroom-based achievement, and (b) Test of Fundamental Academic Skills (TOFAS) scores, representing standardized mathematics performance. TOFAS is a standardized assessment designed to measure students' foundational academic competencies and to provide diagnostic information to support instructional decision-making.

Data Collection

The full survey instrument used in this study is provided in Appendix A. The appendix includes all items from the QTSA and the MKMQ, along with their corresponding response formats. These instruments were used to assess students' perceptions of teacher support adaptivity and their metacognitive knowledge across multiple dimensions. Permission to conduct the study was obtained from the Schools Division Office of Butuan City. Participation was voluntary, and informed consent was secured from all respondents. The data were collected during the fourth quarter of the 2024–2025 school year using structured survey administration through Google Forms. Final mathematics grades and TOFAS scores were obtained from school records and matched to survey responses using anonymized identifiers. All data were treated with strict confidentiality.

Data Analysis

All statistical analyses were conducted using the R software. Descriptive statistics were computed to summarize the levels of the study variables. Spearman's rank-order correlation coefficients were used to examine associations among Core Teacher Support Adaptivity (Core TSA), metacognitive knowledge in mathematics, and mathematics performance. Linear regression analyses were conducted to estimate the direct effects of Core TSA on mathematics performance, controlling for prior achievement (Grade 8 mathematics grade). Also, path analysis was conducted using the lavaan package within a covariance-based structural equation modeling framework to test whether metacognitive knowledge in mathematics explains the relationship between Core TSA and mathematics performance. Indirect effects were estimated using bias-corrected bootstrap procedures with 5,000 resamples. Missing data were handled using full information maximum likelihood (FIML), allowing all available cases ($N = 300$) to be included in the structural models. Statistical significance was evaluated at $\alpha = .05$.

Results and Discussion

Levels of Teacher Support Adaptivity, Metacognitive Knowledge, and Mathematics Performance

Students reported moderate levels of Core TSA ($M = 3.24$, $SD = 0.37$), instructional under-regulation ($M = 2.96$, $SD = 0.74$), and metacognitive knowledge in mathematics ($M = 2.93$, $SD = 0.47$), with slightly greater variability observed in instructional under-regulation. Classroom-based performance was relatively high ($M = 87.00$, $SD = 4.74$), whereas standardized mathematics performance was considerably lower ($M = 15.70$, $SD = 5.10$). This pattern suggests a divergence between classroom-based achievement and standardized performance, indicating that students may perform better under guided instructional conditions than in independent assessment contexts. Table 1 shows the descriptive statistics of the core study variables. It is to note that the psychosocial variables are composite mean scores derived from multi-item Likert-type scales

Variable	**Mean**	**SD**
Core TSA	3.24	0.37
Instructional Under-regulation (NA−)	2.96	0.74
Metacognitive Knowledge in Mathematics	2.93	0.47
Final Mathematics Grade	87.00	4.74
TOFAS Score	15.70	5.10

Table 1. Descriptive Statistics of Core Study Variables (N = 300)

Associations Among Teacher Support Adaptivity, Metacognitive Knowledge, and Mathematics Performance

Core TSA was moderately positively associated with final mathematics grade (ρ = .366, p < .001) but was not significantly associated with TOFAS performance. This indicates that adaptive instructional support is primarily related to classroom-based outcomes. In contrast, metacognitive knowledge in mathematics was significantly associated with both final mathematics grade (ρ = .198, p < .01) and TOFAS score (ρ = .232, p < .001), with a stronger relationship observed for standardized performance.

These findings suggest that while instructional support is more closely linked to classroom achievement, metacognitive knowledge in mathematics contributes to performance across both assessment contexts. These relationships are presented in Table 2. It is to note that various p-values denotes statistical significance at various level of significance, say, **p < .01 and ***p < .001.

Variable	1	2	3	4	5
1. Core TSA	—				
2. Instructional Under-regulation	-.013	—			
3. Metacognitive Knowledge in Mathematics	.149	-.065	—		
4. Final Mathematics Grade	.366***	-.172**	.198**	—	
5. TOFAS Score	.001	-.015	.232***	.191**	—

Table 2. Spearman Correlations (ρ) Among Core Study Variables (N = 300)

Direct Effects of Teacher Support Adaptivity on Mathematics Performance

Core TSA significantly predicted final mathematics grade (B = 2.051, p = .001) but did not significantly predict TOFAS performance (B = −1.243, p = .125). This finding indicates that adaptive instructional practices exert a direct influence on classroom-based achievement but not on standardized assessment performance. The regression results are presented in Table 3. The **B** values denotes the unstandardized regression coefficient estimate with Grade 8 included as a covariate.

Outcome Variable	Predictor	B	SE	t	p
Final Mathematics Grade	Core TSA	2.051	0.612	3.35	.001
	Grade 8	0.562	0.048	11.66	< .001
TOFAS Score	Core TSA	-1.243	0.808	-1.54	.125
	Grade 8	0.377	0.064	5.92	< .001

Table 3. Direct Effects of Teacher Support Adaptivity on Mathematics Performance

Mediation Analysis of Mathematics Performance

Metacognitive knowledge in mathematics did not mediate the relationship between Core TSA and either final mathematics grade or TOFAS performance. Core TSA was not a significant predictor of metacognitive knowledge in mathematics, resulting in non-significant indirect effects across both outcome variables. Although metacognitive knowledge in mathematics significantly predicted TOFAS performance, it did not function as an explanatory mechanism linking instructional support to either classroom-based or standardized mathematics outcomes.

These findings indicate that metacognitive knowledge in mathematics operates as an independent predictor of mathematics performance rather than as a pathway through which instructional support exerts its effects. The mediation results are presented in Tables 4 and 5. Note that the analysis was conducted using a sample size of N=300. Indirect effects were estimated using bootstrapping with 5,000 resamples, while the Grade 8 variable was included as a control variable.

Path / Effect	B	SE	p	β
Core TSA → Metacognitive Knowledge in Mathematics	0.097	0.073	.179	.078
Metacognitive Knowledge in Mathematics → Final Mathematics Grade	0.815	0.524	.120	.080
Core TSA → Final Mathematics Grade (Direct)	2.210	0.558	< .001	.173
Indirect Effect	0.079	0.083	.340	.006

Table 4. Mediation Model Predicting Final Mathematics Grade

Path / Effect	B	SE	p	β
Core TSA → Metacognitive Knowledge in Mathematics	0.099	0.072	.171	.079
Metacognitive Knowledge in Mathematics → TOFAS Score	2.269	0.629	< .001	.207
Core TSA → TOFAS Score (Direct)	-1.168	0.760	.124	-.085
Indirect Effect	0.224	0.180	.214	.016

Table 5. Mediation Model Predicting TOFAS Score

Conclusion and Recommendations

This study examined the relationships among Core TSA, metacognitive knowledge in mathematics, and mathematics performance among Grade 9 students. The findings indicate that Core TSA significantly predicts classroom-based mathematics performance but does not predict standardized mathematics performance, suggesting that adaptive instructional practices are more strongly aligned with outcomes in guided learning environments.

Metacognitive knowledge in mathematics demonstrated significant positive associations with both classroom-based and standardized mathematics performance and emerged as a significant predictor of standardized performance. However, it did not significantly predict classroom-based performance within the structural model.

Furthermore, metacognitive knowledge in mathematics did not mediate the relationship between Core TSA and either classroom-based or standardized mathematics performance. The absence of significant indirect effects indicates that metacognitive knowledge in mathematics functions as an independent cognitive factor rather than as a pathway through which instructional support influences achievement.

Overall, the findings demonstrate that Core TSA and metacognitive knowledge in mathematics contribute to mathematics performance through distinct but complementary mechanisms, with instructional adaptivity supporting classroom-based outcomes and metacognitive knowledge strengthening performance in independent assessment contexts.

Implications

The findings of this study carry several important implications for classroom practice, school-level support, curriculum implementation, and future research in mathematics education.

At the classroom level, the results highlight the importance of adaptive instructional practices in supporting student learning. The need for teachers to align instruction with students' varying levels of understanding implies that differentiated instruction, guided practice, and responsive feedback are essential components of effective mathematics teaching. This suggests that continuous, evidence-based refinement of instructional strategies is necessary to optimize student outcomes.

The relatively low performance in the Test of Fundamental Academic Skills (TOFAS) further implies a need to strengthen students' metacognitive skills within mathematics instruction. Integrating strategies that promote planning, monitoring, and evaluation, such as think-aloud problem-solving, reflective questioning, and self-checking, appears critical for developing students' independent problem-solving abilities. This emphasizes the role of metacognitive strategy instruction as a key mechanism for improving both conceptual understanding and performance.

At the institutional level, the findings imply that school support systems play a crucial role in enhancing instructional quality. The promotion of a culture of reflective practice through professional development, lesson study, peer observation, and collaborative dialogue can support teachers in implementing adaptive and metacognitively oriented instruction. Moreover, given constraints in instructional time and the limited feasibility of interventions conducted outside regular class hours, embedding these strategies within regular class periods is essential to ensure equitable access for all students.

In terms of curriculum implementation, the results imply that structured opportunities for metacognitive engagement should be intentionally integrated into daily instruction. Activities such as problem-solving reflections, strategy discussions, and formative assessments that emphasize reasoning processes can enhance students' ability to regulate their own learning. These practices highlight the importance of shifting from purely procedural instruction toward approaches that value thinking processes.

Finally, the study implies the need for further research in similar public secondary school contexts. There is a need to examine how metacognitive knowledge develops over time and how targeted instructional interventions influence both classroom-based and standardized mathematics performance. Generating context-specific evidence through systematic inquiry can provide valuable insights for improving instructional practices and student learning outcomes

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Competing Interests Statement

The author declares that there are no competing interests regarding the publication of this research.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Appendices

No appendices are attached to this study.