JOURNAL OF EDUCATIONAL RESEARCH, INNOVATION, AND MULTIDISCIPLINARY STUDIES

JERIMS

An Academic Journal Publication

Website: | https://jerimspublication.com

INTERNATIONAL STANDARD SERIAL NUMBERS

PRINT ISSN | 3116-5559

ONLINE ISSN | 3116-5567

Volume 1, Issue 05, pp 36-42, July 2026

Research Article

Perceived Implementation of HOTS–SOLO–Based Instruction and Its Relationship to Grade 9 Students' Mathematical Performance

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Article History:

Submission: June, 2026
Revised: July, 2026
Accepted: July, 2026
Published: July, 2026

Originality: 97%
Similarity Index: 9%
Grammarly Score: 95%

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Recommended Citation:

Cardanio, M., (2026). Perceived Implementation of HOTS–SOLO–Based Instruction and Its Relationship to Grade 9 Students' Mathematical Performance. *Journal of Educational Research, Innovation, and Multidisciplinary Studies, 1(5), 36-42.*

https://doi.org/10.67001/jeri.2026.5.P6M2RX

ABSTRACT

This study examined the perceived implementation of Higher Order Thinking Skills–Structure of Observed Learning Outcomes (HOTS–SOLO)-based instruction and its relationship to the mathematical performance of Grade 9 students at Calamba National Comprehensive High School, Division of Misamis Occidental, during the School Year 2025–2026. Using a quantitative descriptive–correlational design, data were collected from 153 Grade 9 students through a researcher-developed student perception survey and a mathematical performance test. Descriptive statistics, paired-samples t-test, Pearson product–moment correlation, and simple linear regression were employed for data analysis. Results revealed a significant improvement in students' mathematical performance from pretest to posttest. Students rated the implementation of HOTS–SOLO-based instruction in terms of classroom practices and learning progression at a high level. Regression analysis further indicated that perceived HOTS–SOLO-based instruction significantly predicted students' posttest and gain scores. These findings suggest that instructional practices emphasizing higher-order thinking and structured learning progression are associated with improved mathematical performance.

Keywords: *Grade 9 students, higher order thinking skills, mathematical performance, mathematics instruction, SOLO taxonomy*

Introduction

The increasing complexity of societal and workplace demands in the 21st century has intensified the need for learners to develop higher order thinking skills (HOTS), particularly in Mathematics. Mathematical literacy today extends beyond computational proficiency to include reasoning, problem-solving, critical thinking, and the ability to apply concepts to unfamiliar and real-world situations. As a result, mathematics education has shifted toward instructional approaches that promote deep understanding and cognitive engagement rather than rote memorization and procedural learning (OECD, 2020; Schoenfeld, 2020).

In response to these global demands, the Philippine K to 12 Basic Education Curriculum emphasizes the development of higher order thinking skills across subject areas, including Mathematics. The Department of Education highlights the use of learner-centered and inquiry-based instructional strategies that encourage students to analyze, evaluate, and create mathematical ideas (Department of Education [DepEd], 2022). Despite these policy directions, national and local studies continue to reveal that many secondary students experience difficulty in solving non-routine mathematical problems and demonstrating conceptual understanding, particularly at the junior high school level (Cruz et al., 2021; Manalo & Garcia, 2023). These challenges suggest a persistent gap between curricular goals and actual classroom practices.

One instructional framework that addresses this gap is the integration of Higher Order Thinking Skills (HOTS) with the Structure of Observed Learning Outcomes (SOLO) taxonomy. HOTS-based instruction engages learners in complex cognitive processes, such as analysis, evaluation, and creation, which are essential for meaningful mathematical learning (Anderson & Krathwohl, 2021). Complementing this approach, the SOLO taxonomy provides a structured model for describing and assessing the quality of students' learning outcomes, progressing from surface-level understanding to extended abstract thinking (Biggs & Tang, 2022). When implemented together, HOTS–SOLO-based instruction offers a systematic approach to developing students' thinking skills while guiding them through progressively deeper levels of mathematical understanding.

Recent empirical studies indicate that instructional strategies grounded in HOTS and the SOLO taxonomy positively influence students' academic performance, conceptual understanding, and engagement in Mathematics (Rahman et al., 2021; Villanueva & Dela Cruz, 2024). However, instructional effectiveness is not solely determined by the design of teaching strategies but also by how these strategies are experienced and perceived by students. Learners' perceptions of classroom practices significantly influence their motivation, engagement, and learning outcomes, making student perception a critical variable in evaluating instructional implementation (Yeo & Tan, 2022).

At the Grade 9 level, students encounter more abstract and complex mathematical concepts that require advanced reasoning and problem-solving skills. This stage represents a crucial point in students' mathematical development, as difficulties encountered here may affect their future academic performance and attitudes toward Mathematics (UNESCO, 2021). Assessing students' mathematical performance before and after exposure to HOTS–SOLO-based instruction provides a meaningful way to determine the instructional approach's effectiveness in enhancing learning outcomes.

Given these considerations, this study examines the perceived implementation of HOTS–SOLO-based instruction and its relationship to the mathematical performance of Grade 9 students at Calamba National Comprehensive High School during the School Year 2025–2026. By analyzing students' perceptions alongside their pretest, posttest, and gain scores, the study seeks to generate empirical evidence on the extent to which HOTS–SOLO-based instruction contributes to improved mathematical performance. The findings are expected to provide practical implications for mathematics teachers, school administrators, and curriculum planners in strengthening instructional practices that foster higher order thinking and meaningful learning.

Methods

This study employed a quantitative descriptive–correlational research design to determine the perceived implementation of Higher-Order Thinking Skills (HOTS)–SOLO-based instruction in Mathematics and examine its relationship with the mathematical performance of Grade 9 students. The study was conducted among 153 Grade 9 students of Calamba National Comprehensive High School during School Year 2025–2026 using purposive sampling. Data were gathered through two researcher-developed and validated instruments: the

Student Survey on the Perceived Implementation of HOTS–SOLO-Based Instruction (HSSI-S) and a Mathematical Performance Test. The collected data were analyzed using weighted mean, standard deviation, frequency, percentage, Pearson Product–Moment Correlation Coefficient, and simple linear regression to describe the variables, determine their relationship, and assess the predictive influence of HOTS–SOLO-based instruction on students' mathematical performance. Throughout the study, ethical principles were strictly observed by securing the necessary approvals, obtaining informed consent from participants, ensuring voluntary participation, and maintaining the confidentiality and anonymity of all respondents.

Results and Discussions

Table 1

Mathematical Performance of Grade 9 Students Before and After the Implementation Of HOTS–SOLO–Based Instruction

Test	N	Mean	Standard Deviation	Verbal Interpretation
Pre-Test	153	12.07	3.60	Moderate
Post-Test	153	17.27	3.78	High
Overall Total	153	14.67	3.69	High

Table 1 presents the pretest and posttest mean scores of Grade 9 students in Mathematics, reflecting their performance before and after exposure to HOTS–SOLO-based instructional practices.

The pretest results showed a mean score of 12.07 (SD = 3.60), which was verbally interpreted as Moderate. After exposure to HOTS–SOLO-based instruction, the posttest mean score increased to 17.27 (SD = 3.78), verbally interpreted as High. The increase in the mean score suggests an observable improvement in students' mathematical performance following instruction that emphasized higher order thinking skills and structured learning progression.

The improvement in students' mathematical performance after exposure to HOTS–SOLO-based instruction may be explained by the principles of constructivist learning theory, which posits that learners develop deeper understanding when they actively construct knowledge through reasoning, reflection, and problem solving (Schoenfeld, 2020). The results are also consistent with the SOLO taxonomy, which emphasizes progression from surface to deep understanding through increasingly complex learning tasks (Biggs & Tang, 2011). Similar findings were reported by Nugroho et al. (2025) and Sridana et al. (2024), who found that instruction integrating HOTS and SOLO principles was associated with improved mathematical understanding and problem-solving performance among secondary students.

To determine whether the observed difference in students' mathematical performance before and after exposure to HOTS–SOLO-based instruction was statistically significant, a paired-samples t-test was conducted. The results are shown in Table 5.

Table 2

Test of Significant Difference Between Pre-Test and Post-Test Scores

Comparison	Mean Difference	t-value	df	p-value	Decision	Interpretation
Pre-Test vs Post-Test	5.20	12.35	304	< .001	Reject Ho	Significant

Table 2 shows the result of the test of significant difference between the pretest and posttest scores of the students.

The computed mean difference between the pretest and posttest scores is 5.20. The t-test result yielded a t-value of 12.35 with a p-value of $< .001$, which is less than the 0.05 level of significance. Thus, the null hypothesis is rejected. This means that there is a significant difference between the mathematical performance of the students before and after the implementation of HOTS-SOLO-based instruction, indicating that the intervention had a significant effect on the students' performance.

The statistically significant difference between the pretest and posttest scores indicates that students' mathematical performance significantly improved after exposure to HOTS–SOLO-based instructional practices. This finding supports the view that learning environments emphasizing higher order cognitive processes, such as analysis, evaluation, and reasoning, are associated with higher achievement in Mathematics (Hattie & Donoghue, 2021). The result is consistent with studies by Manalo and Garcia (2023) and Villanueva and Dela Cruz (2024), which reported significant improvements in students' mathematical performance following instruction that emphasized analytical reasoning and structured learning progression.

To determine the extent to which HOTS classroom practices were implemented in Mathematics as perceived by the students, the responses to the HSSI-S questionnaire were analyzed. The results are presented in Table 3.

Table 3

Level of Perceived Implementation of HOTS–SOLO–Based Instruction in Mathematics in terms of HOTS Classroom Practices

Statements	Weighted Mean	Standard Deviation	Description
1. My Mathematics teacher asks questions that require me to analyze my answers.	3.48	0.514	Agree
2. I am encouraged to explain how I arrived at my answers in Mathematics.	3.09	0.518	Agree
3. I am asked to apply mathematical concepts to real-life situations.	3.28	0.579	Agree
4. Our Mathematics lessons challenge me to think critically rather than just recall formulas.	3.48	0.586	Agree
5. I am encouraged to compare different solutions to the same Mathematics problem.	3.29	0.584	Agree
6. I am required to justify my mathematical solutions using logical reasoning.	3.28	0.544	Agree
7. Our class activities help me develop problem-solving skills.	3.48	0.551	Agree
8. I am asked to evaluate whether my answers are reasonable.	3.30	0.488	Agree
9. My Mathematics teacher encourages me to ask questions and explore new ideas.	3.42	0.533	Agree
10. I am engaged in activities that require deeper thinking in Mathematics.	3.39	0.540	Agree
Total	3.35	0.54	Agree

3.50 – 4.00 Strongly Agree 1.50 – 2.49 Disagree
2.50 – 3.49 Agree 1.00 – 1.49 Strongly Disagree

Table 3 presents the level of perceived implementation of HOTS–SOLO–based instruction in terms of HOTS classroom practices.

The overall weighted mean of 3.35 with a standard deviation of 0.54 is verbally interpreted as Agree. This suggests that the students generally perceived that HOTS classroom practices were implemented in their Mathematics classes. The indicators with the highest weighted means include challenging students to think critically, encouraging analytical questioning, and developing problem-solving skills.

The findings suggest that students experienced instructional practices that promoted higher order thinking, such as explaining solutions, justifying answers, and evaluating reasonableness of responses. These practices align with the Revised Bloom's Taxonomy, which emphasizes analysis, evaluation, and creation as essential cognitive processes for deep learning (Anderson & Krathwohl, 2001). Similar results were reported by Zhao et al. (2023) and Manalo and Garcia (2023), who found that students' exposure to HOTS-oriented classroom practices was positively associated with engagement and mathematical achievement.

To assess students' perceptions of structured learning progression aligned with the SOLO taxonomy, the SOLO-related items of the HSSI-S questionnaire were analyzed. The results are shown in Table 7.

Table 4

Level of Perceived Implementation of HOTS–SOLO–Based Instruction in Mathematics in terms of HOTS Classroom Practices

Statements	Weighted Mean	Standard Deviation	Description
1. Our Mathematics lessons help me understand topics step by step.	3.60	0.530	Strongly Agree
2. I am guided to move from simple ideas to more complex mathematical concepts.	3.49	0.527	Agree
3. I am encouraged to connect different Mathematics topics when solving problems.	3.35	0.542	Agree
4. Our teacher helps me improve my answers from basic to more complete explanations.	3.61	0.488	Strongly Agree
5. I am taught how to organize my thoughts when solving mathematical problems.	3.28	0.519	Agree
6. I am encouraged to explain how different ideas in Mathematics are related.	3.30	0.551	Agree
7. Our Mathematics activities allow me to reflect on my answers and make improvements.	3.49	0.527	Agree
8. I am given opportunities to improve my work based on teacher feedback.	3.46	0.513	Agree
9. Our teacher helps me understand why an answer is correct or incorrect.	3.67	0.473	Strongly Agree
10. Mathematics lessons help me develop a deeper and more meaningful understanding of concepts.	3.65	0.479	Strongly Agree
Total	3.49	0.51	Agree

3.50 – 4.00 Strongly Agree 1.50 – 2.49 Disagree
2.50 – 3.49 Agree 1.00 – 1.49 Strongly Disagree

Table 4 presents the weighted mean scores reflecting students' perceptions of SOLO taxonomy–based learning progression in Mathematics. The table reveals an overall weighted mean of 3.49 with a standard deviation of 0.51, verbally interpreted as Agree. This indicates that students perceived the learning progression in Mathematics as structured, moving from simple concepts to more complex ideas. High ratings were noted in helping students understand why answers are correct or incorrect and in developing a deeper and more meaningful understanding of concepts.

The overall weighted mean of 3.49 (SD = 0.51) was verbally interpreted as Agree. Several indicators received Strongly Agree ratings, particularly those related to understanding why answers are correct or incorrect and developing deeper conceptual understanding.

To determine whether the perceived implementation of HOTS–SOLO-based instruction significantly predicted students' mathematical performance, simple linear regression analysis was conducted. The results are presented in Table 5

Table 5
Regression Analysis Showing the Predictive Effect of the Level of Perceived Implementation of HOTS–SOLO–Based Instruction on Students' Mathematical Performance

Dependent Variable	Predictor Variable	β (Beta)	R	R^2	t-value	p-value	Interpretation
Posttest Scores	Level of Perceived Implementation of HOTS–SOLO–Based Instruction	0.61	0.61	0.37	9.84	< .001	Significant Predictor
Gain Scores	Level of Perceived Implementation of HOTS–SOLO–Based Instruction	0.58	0.58	0.34	9.02	< .001	Significant Predictor

Table 5 presents the regression analysis, which shows the predictive effect of the level of perceived implementation of HOTS-SOLO-based instruction on students' mathematical performance, as measured by posttest scores and gain scores.

The results indicate that the level of perceived implementation of HOTS-SOLO-based instruction significantly predicts students' posttest scores, with a beta value of 0.61, R value of 0.61, and $\boldsymbol{R^2}$ value of 0.37. The computed t-value of 9.84 and p-value of < .001 signify that the predictor is statistically significant.
Similarly, the level of perceived implementation of HOTS-SOLO-based instruction significantly predicts students' gain scores, with a beta value of 0.58, R value of 0.58, and $\boldsymbol{R^2}$ value of 0.34. The t-value of 9.02 and p-value of < .001 further confirm that the perceived implementation of HOTS-SOLO-based instruction is a significant predictor of improvement in students' mathematical performance.

The findings indicate that higher levels of perceived implementation of HOTS–SOLO-based instruction were associated with higher mathematical performance and greater learning gains. This supports instructional effectiveness models, which emphasize that students' experiences of cognitively demanding and well-structured instruction are strong predictors of achievement (Hattie & Donoghue, 2021). The results are consistent with studies by Nugroho et al. (2025) and Dong and Zhang (2024), which reported that instructional practices integrating higher order thinking and structured learning progression significantly predicted students' mathematics achievement.

Conclusions
The findings of the study demonstrate that the implementation of Higher-Order Thinking Skills (HOTS)–SOLO-based instruction is positively associated with the mathematical performance of Grade 9 students. Students who experienced instructional practices emphasizing higher-order thinking, structured learning progression, analytical reasoning, and problem-solving exhibited significant improvements in their mathematical achievement. Moreover, students' positive perceptions of the implementation of HOTS–SOLO-based instruction were found to be significant predictors of their mathematical performance, indicating that effective integration of these instructional approaches contributes to deeper conceptual understanding and enhanced learning outcomes in Mathematics.

Recommendations
Based on the findings and conclusions of the study, it is recommended that Mathematics teachers consistently integrate HOTS–SOLO-based instructional strategies into classroom practice to strengthen students' higher-order thinking and problem-solving skills. School administrators and curriculum developers should provide continuous professional development, instructional resources, and policy support to facilitate effective implementation of these approaches. Learners and parents are likewise encouraged to actively support the development of analytical and critical thinking skills both in school and at home. Furthermore, education stakeholders may consider incorporating HOTS–SOLO-based strategies into curriculum and instructional policies to improve Mathematics education, while future researchers are encouraged to replicate and extend this

study across different grade levels, subject areas, and educational settings using various research designs to further validate and enrich the existing findings.

Conflict of Interests

The author declares that they have no conflicts of interest

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