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Integrating Metacognitive Strategies in Senior High School Science Teaching: Exploring Teacher Experiences and Student Outcomes

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Abstract

This study examined the integration of metacognitive strategies in Senior High School science teaching, its relationship with students' academic performance, and teachers' implementation experiences in public schools in the Division of Las Piñas. Using a convergent mixed-methods design, the study involved 55 science teachers selected through stratified random sampling and 10 teachers purposively selected for interviews. Quantitative data on strategy integration and students' science grades were analyzed using descriptive statistics, correlation, and regression, while interview responses underwent thematic analysis. Findings indicated consistently high integration of metacognitive strategies across instructional domains, including metacognitive knowledge, regulation, instructional planning and delivery, and classroom environment and student engagement. Students' academic performance generally ranged from satisfactory to very satisfactory. A moderate, statistically significant positive relationship was found between strategy integration and academic performance, with instructional planning and delivery emerging as the strongest predictor. Qualitative findings produced ten themes encompassing teachers' awareness, perceived value, applications, effectiveness, student engagement, challenges, support systems, observed learning behaviors, professional growth, and advice to colleagues. Overall, the findings suggest that metacognitive integration is associated with favorable science learning outcomes, although implementation challenges require institutional support. The study recommends sustained teacher development, reflective instructional practices, and structured monitoring. Its scope was limited to public Senior High School science teachers and Grade 12 performance records in Las Piñas, restricting broader generalizability. The resulting Metacognitive Strategy Integration Observation Checklist and Rollout Framework provide practical tools for strengthening instructional monitoring and professional learning, supporting Sustainable Development Goal 4 and the sustainability of quality science education.

Keywords: Academic Performance, Instructional Planning, Metacognitive Strategies, Mixed-Methods Research, Science Teaching, Student Engagement, Teacher Experiences

1. Introduction

Senior High School science subjects, including Physical Science, Earth and Life Science, Biology, Chemistry, and Physics, require students to understand scientific concepts, analyze information, and apply knowledge to complex problems. Science instruction can benefit from explicit metacognitive and self-regulated learning approaches that support scientific reasoning and conceptual understanding (Sagun & Prudente, 2023). Metacognitive strategies address these limitations by helping learners recognize their cognitive strengths, select

appropriate learning strategies, monitor comprehension, and evaluate their progress. Flavell (1979) described metacognition as awareness of one's thinking, while Schraw and Moshman (1995) emphasized the importance of metacognitive knowledge and regulation in improving learning outcomes. A Philippine study associated metacognitive instruction with improved learning outcomes among STEM learners (Antonio & Prudente, 2022). Despite these benefits, metacognitive instruction remains inconsistently implemented in Philippine public schools. Research on science-teacher professional development highlights the importance of strengthening teachers' instructional support for scientific reasoning and reflective learning (Wess et al., 2023). Although research supports positive science learning outcomes from metacognitive instruction (Antonio & Prudente, 2022), limited attention has been given to integrating and evaluating these strategies across multiple SHS science disciplines. This highlights the need for a structured observation instrument to support effective instructional planning, classroom implementation, and reflective teaching.

Research consistently associates metacognitive awareness and regulation with improved academic performance, learner autonomy, and higher-order thinking. Philippine studies identified positive relationships between metacognitive awareness and writing competence, science concept mastery, reading comprehension, and academic achievement (Discipulo & Bautista, 2022; Dolinting & Pang, 2022; Hacermida & Aboy, 2021; Medina College SHS Study, 2023). Famarin (2024) examined metacognitive strategies in General Science, while Antonio and Prudente (2022) reported evidence that metacognitive instruction can improve students' science learning achievement. Eshuis et al. (2022) examined how reflection can be supported during learning with self-generated concept maps. International findings similarly support metacognitive instruction. Stebner et al. (2022) associated strategy training with knowledge transfer, while He et al. (2024) and Stanton et al. (2021) reported improved learning outcomes. He et al. (2024) identified a positive association between metacognition and subsequent academic achievement, while Öztürk (2021) examined metacognitive instruction in mathematical reasoning. Fleur et al. (2021) further discussed the importance of metacognitive knowledge and regulation in educational contexts. In science education, Antonio and Prudente (2022) reported that metacognitive instruction can improve science learning achievement, while He et al. (2024) identified a positive association between metacognition and subsequent academic achievement. Giray (2021) also demonstrated the instructional value of prediction and self-monitoring. Studies across educational contexts have examined the role of metacognitive strategies in learning and problem-solving (Fleur et al., 2021; He et al., 2024; Knochenhauer, 2019). Antonio and Prudente (2022) emphasized the effectiveness of metacognitive instruction in science learning, while Fleur et al. (2021) and Ishak et al. (2025) discussed the importance of metacognitive strategies in supporting learning processes and educational outcomes. However, the effectiveness of metacognitive strategies depends on how consistently teachers integrate them into instruction. Traditional teaching approaches, inadequate professional development, and limited subject-specific frameworks remain barriers (Modrek & Ramirez, 2021; Perry et al., 2019; Wess et al., 2023). These findings emphasize the importance of examining both measurable student outcomes and teachers' experiences to understand the practical conditions influencing metacognitive instruction.

In the Philippine educational context, integrating metacognitive strategies supports the K to 12 curriculum's emphasis on critical thinking, independent learning, and student-centered instruction. Research has examined the role of metacognitive strategies in supporting science learning and academic achievement (Antonio & Prudente, 2022; Famarin, 2024; He et al., 2024). Nevertheless, variations in instructional practices and limited access to structured teaching resources remain significant concerns. National education policies provide institutional support for strengthening reflective teaching and classroom assessment. DepEd Order No. 42, s. 2017 established the Philippine Professional Standards for Teachers (PPST), while DepEd Memorandum No. 089, s. 2025 emphasized performance management and evaluation. DepEd Order No. 35, s. 2016 institutionalized Learning Action Cells as mechanisms for collaborative teacher development. These policies establish a basis for improving instructional practices through professional learning, classroom observation, and continuous assessment. Internationally, metacognitive instruction has gained recognition for promoting learning autonomy, scientific reasoning, and educational effectiveness. The Organisation for Economic Co-operation and Development (OECD, 2023) documented challenges in student learning outcomes through the PISA 2022 assessment, highlighting the importance of strengthening educational quality. Research across educational contexts further demonstrated the importance of metacognitive training, assessment, and instructional support (Stebner et al., 2022; Sukarelawan et al., 2024). Despite these developments, contextual differences in teacher preparation, available resources, and classroom conditions influence implementation. The Philippine public-school setting therefore requires locally appropriate strategies and observation instruments aligned with national teaching standards and international educational priorities.

This study is anchored on four complementary educational theories explaining metacognitive awareness, instructional organization, classroom interaction, and self-regulated learning. Metacognitive Theory by Schraw and Moshman (1995) distinguishes metacognitive knowledge from metacognitive regulation. Metacognitive knowledge concerns learners' understanding of their cognitive processes, tasks, and available strategies, whereas regulation involves planning, monitoring, and evaluating learning. These concepts establish the theoretical basis for examining how science teachers develop students' awareness and control of learning processes. Constructive Alignment by Biggs (1996) emphasizes consistency among intended learning outcomes, instructional activities, and assessment. Within science teaching, this perspective supports integrating reflection, goal setting, self-questioning, and self-assessment into instructional planning and delivery. Sociocultural Theory by Vygotsky

(1978) explains the importance of social interaction, instructional scaffolding, and collaborative learning in cognitive development. This theory supports examining how classroom environments encourage discussion, reflection, problem-solving, and student engagement. Self-Regulated Learning Theory by Pintrich (2000) integrates cognitive, motivational, and metacognitive processes. It emphasizes learners' capacity to establish goals, monitor progress, regulate strategies, and evaluate outcomes, providing a complementary foundation for understanding metacognitive instruction. Collectively, these theories establish four interconnected domains of metacognitive integration: metacognitive knowledge, metacognitive regulation, instructional planning and delivery, and classroom environment and student engagement (Biggs, 1996; Schraw & Moshman, 1995; Vygotsky, 1978; Zohar & Barzilai, 2013). The study applies a convergent mixed-methods framework to examine these domains among public SHS science teachers in the Division of Las Piñas. Quantitative data determine the level of metacognitive strategy integration and its relationship with Grade 12 students' science performance, while qualitative interviews explore teachers' experiences, challenges, and instructional practices. Integrating both strands provides the basis for the development of the Metacognitive Strategies Integration Observation Checklist (MSIOC) and its Rollout Framework.

Although metacognitive strategies have demonstrated benefits for learning and academic achievement, several research and implementation gaps remain. Existing studies frequently focus on students' metacognitive awareness or performance in individual subjects rather than examining how teachers systematically integrate these strategies across SHS science disciplines (Antonio & Prudente, 2022; Discipulo & Bautista, 2022; Famarin, 2024). Another concern involves the limited availability of context-sensitive observation instruments for assessing metacognitive teaching. Wess et al. (2023) reviewed professional development programs aimed at improving science teachers' facilitation of scientific argumentation. Medina College SHS Study (2023) and Dolinting and Pang (2022) likewise highlighted the importance of systematic frameworks. Sukarelawan et al. (2024) examined metacognitive awareness using Rasch modeling, providing relevant evidence for its assessment. Furthermore, research suggests that metacognitive awareness does not automatically translate into improved academic performance. Miller and Geraci (2011) identified difficulties in students' evaluation of their learning, while Agrawal et al. (2025) reported weak relationships between awareness and achievement in particular educational contexts. These findings emphasize the need to consider instructional implementation, learner characteristics, and contextual conditions. Teacher experiences also remain important because challenges involving instructional time, classroom management, student readiness, and professional support may influence the effectiveness of metacognitive strategies (Modrek & Ramirez, 2021; Wess et al., 2023). Understanding these experiences alongside quantitative performance data can provide a more comprehensive explanation of metacognitive integration. Accordingly, this study investigates the level of metacognitive strategy integration among public SHS science teachers in the Division of Las Piñas, its relationship with Grade 12 students' academic performance during school year 2025–2026, and teachers' experiences in implementation. It further provides a research-based foundation for the MSIOC and Rollout Framework to guide classroom observation, professional development, and sustained instructional improvement.

The study primarily aligns with Sustainable Development Goal 4 (Quality Education), particularly its emphasis on improving educational quality, relevant learning outcomes, and teacher competencies. By examining metacognitive strategy integration in SHS science teaching, the research addresses instructional approaches intended to strengthen critical thinking, scientific understanding, problem-solving, and independent learning. Its emphasis on teacher professional development, classroom observation, and reflective instructional practice supports efforts to improve teaching quality. The proposed MSIOC and Rollout Framework provide structured mechanisms for monitoring instructional practices and identifying areas requiring professional support. The study also has relevance to SDG 9 (Industry, Innovation and Infrastructure) through its focus on evidence-based instructional innovation. The development of a localized observation instrument and implementation framework represents an approach to strengthening educational processes and supporting systematic improvements in science teaching. These connections are educational and institutional rather than direct measurements of SDG achievement. The research contributes to the objectives of these goals by examining practices and developing tools that may support improved science education.

The study contributes primarily to educational and institutional sustainability by examining how metacognitive strategies can be systematically incorporated into SHS science instruction. Its emphasis on reflective thinking, self-regulation, and learner autonomy supports the development of learning competencies relevant to continuing education and lifelong learning. For science teachers, the MSIOC and Rollout Framework provide a structured basis for evaluating instructional practices, identifying professional development needs, and improving classroom implementation. These outputs support the continuity of reflective teaching and the integration of metacognitive approaches across science disciplines. At the institutional level, the study supports school administrators and education policymakers in strengthening classroom observation, professional learning, and instructional evaluation. Alignment with DepEd teaching standards and professional development mechanisms may facilitate consistent implementation and monitoring of metacognitive practices. The research also has potential socio-economic relevance through its focus on strengthening students' analytical thinking, problem-solving abilities, and independent learning. These competencies are valuable for further education and future participation in knowledge-based activities, although the study does not directly measure employment or economic outcomes. Overall, the study provides an evidence-based foundation for improving the quality and continuity of science

instruction through metacognitive strategy integration, teacher professional development, and systematic classroom assessment.

2. Material and methods

2.1 Research Design

The study utilized a convergent mixed-methods research design, combining quantitative and qualitative approaches to examine metacognitive strategy integration in SHS science instruction. This design enabled the collection of measurable evidence and contextual insights, consistent with Creswell and Plano Clark (2018), Johnson and Onwuegbuzie (2004), and Tashakkori and Teddlie (2003). The quantitative strand assessed teachers' integration of metacognitive knowledge, regulation, instructional planning and delivery, and classroom environment and student engagement. It also examined the relationship between strategy integration and students' academic performance, consistent with Creswell and Creswell's (2018) discussion of quantitative research. The qualitative strand explored teachers' experiences, perceptions, challenges, and reflective practices through semi-structured interviews, following Greene et al.'s (1989) emphasis on contextual understanding. Both datasets were analyzed separately and subsequently integrated through triangulation to identify convergent and divergent findings, strengthening the interpretation of results (Fetters et al., 2013).

2.2 Locale of the Study

The study was conducted in eight public Senior High Schools within the Division of Las Piñas City, Philippines, during school year 2025–2026. These schools provided the setting for examining metacognitive strategy integration across science subjects, including Physical Science, Earth and Life Science, Biology, Chemistry, and Physics. The research focused on public SHS science instruction, where teachers' classroom practices and students' consolidated academic performance served as the primary sources of quantitative evidence. The selected schools also provided the context for exploring teachers' experiences and instructional challenges associated with implementing metacognitive strategies.

2.3 Respondents of the Study

The study involved 65 public Senior High School science teachers from eight schools in the Division of Las Piñas City, comprising 55 quantitative respondents and 10 qualitative co-participants. The quantitative respondents provided information on metacognitive strategy integration through classroom observations and teacher-reported academic performance records. The qualitative strand involved 10 science teachers who shared their experiences, challenges, reflective practices, and observations regarding the integration of metacognitive strategies. These co-participants were independent of the quantitative sample and participated in semi-structured interviews. Eligible teachers were required to be currently handling at least one SHS science subject, possess at least one year of teaching experience at the SHS level, and voluntarily participate in the research. Qualitative co-participants were additionally required to have actual experience implementing metacognitive strategies and the ability to provide detailed accounts of their instructional practices. Students were not direct respondents. Their consolidated science academic performance, obtained from teachers' class records, served as the quantitative indicator of student learning outcomes.

2.4 Sample and Sampling Procedure

The study employed stratified random sampling for the quantitative strand and purposive sampling for the qualitative strand. The total population comprised 74 public SHS science teachers in the Division of Las Piñas City. After reserving 10 teachers for qualitative participation, the quantitative sampling population consisted of 64 teachers. The quantitative sample size was determined using the Raosoft Sample Size Calculator with a 95% confidence level, 5% margin of error, and 50% response distribution, resulting in 55 respondents. School affiliation served as the basis for stratification, and eligible teachers were randomly selected within each school to ensure proportional representation. For the qualitative strand, 10 teachers were purposively selected based on their experience in integrating metacognitive strategies, willingness to participate in interviews and observations, and ability to provide meaningful insights into instructional practices and challenges. The separate sampling procedures supported both quantitative representation and qualitative depth.

2.5 Research Instrument

The study utilized the researcher-developed Metacognitive Strategies Integration Observation Checklist (MSIOC), teacher-reported academic performance records, and a semi-structured interview guide. The MSIOC was designed to measure the extent of metacognitive strategy integration in science instruction. Anchored in Flavell (1979) and Schraw and Moshman (1995), it assessed four domains: metacognitive knowledge, metacognitive regulation, instructional planning and delivery, and classroom environment and student engagement. The instructional planning domain incorporated subject-specific metacognitive practices emphasized by Perry et al. (2019), while the classroom environment domain reflected the importance of supportive learning conditions discussed by Stanton et al. (2021). The instrument used a four-point Likert scale: 4 for Always Integrated, 3 for Often Integrated, 2 for Sometimes Integrated, and 1 for Not Integrated. Content validity was

established through expert evaluation by specialists in science education, curriculum development, and research methodology, guided by foundational metacognitive frameworks (Flavell, 1979; Schraw & Moshman, 1995; Zimmerman, 2002). The checklist underwent pilot testing in a comparable public SHS, and reliability analysis yielded a Cronbach's alpha coefficient of 0.87, indicating high internal consistency. Expert feedback and pilot results informed revisions to item clarity, sequencing, theoretical alignment, and usability. Teacher-reported academic performance data consisted of consolidated sectional averages obtained from existing science class records. These records served as the dependent variable in examining the relationship between metacognitive integration and academic achievement. The semi-structured interview guide gathered teachers' experiences, implementation challenges, perceived benefits, observations of student engagement, and recommendations for instructional improvement. It underwent expert evaluation to ensure that questions were open-ended, non-leading, and aligned with the research objectives. Interviews were audio-recorded with permission and transcribed verbatim for thematic analysis.

2.6 Data Gathering Procedure

Data collection began with obtaining approval from the Division Office of Las Piñas and permission from participating school principals. Informed consent was secured from teachers, followed by an orientation explaining the study's objectives, participation requirements, confidentiality measures, and data collection procedures. Before implementation, the MSIOC underwent expert validation and pilot testing in a comparable public SHS. Feedback was incorporated to improve the instrument's clarity, consistency, and applicability to classroom instruction. The researcher conducted non-participant classroom observations using the MSIOC. Each participating teacher was observed during two to three regular science instructional sessions to assess the integration of metacognitive knowledge, regulation, instructional practices, and classroom engagement. Observation scores were recorded and consolidated by domain. Following the observations, teachers submitted anonymized sectional weighted averages of students' science academic performance from existing class records. These data were used to examine the relationship between metacognitive strategy integration and academic achievement. Qualitative data were gathered through semi-structured interviews with purposively selected teachers. Interviews were conducted face-to-face or virtually according to participants' availability, lasting approximately 30–45 minutes. With permission, interviews were recorded and transcribed verbatim. Observation scores, interview transcripts, and qualitative notes were subsequently organized, encoded, and anonymized using participant codes to maintain confidentiality.

2.7 Data Analysis Techniques

Quantitative and qualitative data were analyzed separately and subsequently integrated in accordance with the convergent mixed-methods design. Descriptive statistics, including frequency, percentage, mean, and standard deviation, were used to determine the level of metacognitive strategy integration across the four domains measured by the MSIOC. These measures summarized teachers' instructional practices and the extent of strategy implementation. Pearson Product-Moment Correlation Coefficient (r) was employed to determine the relationship between metacognitive strategy integration and students' consolidated academic performance in science. Regression analysis was also conducted to assess the predictive contribution of metacognitive integration domains to academic performance. Qualitative interview transcripts, field notes, and reflection journals were analyzed through thematic coding following Creswell and Creswell's (2018) procedures. The process involved transcription and familiarization, initial coding, clustering related codes, identifying overarching themes, and interpreting findings in relation to the research questions. Emerging themes were examined to identify teachers' experiences, implementation challenges, instructional practices, and perceived effects on student learning. Following the separate analyses, quantitative and qualitative findings were integrated through triangulation and convergent analysis. Areas of agreement and difference between statistical results and teachers' narratives were identified to provide a comprehensive interpretation of metacognitive strategy integration and its relationship with academic performance.

2.8 Ethical Considerations

The study observed ethical research principles in accordance with the Data Privacy Act of 2012 (Republic Act No. 10173). Institutional permission and informed consent were obtained before data collection. Participation was voluntary, and respondents were informed of their right to withdraw at any stage without penalty. Confidentiality was maintained through anonymized participant codes and the use of consolidated academic performance records rather than individually identifiable student information. Research data were stored in password-protected files accessible only to the researcher. Audio recordings were transcribed verbatim and subsequently deleted to prevent unauthorized access. All collected information was used exclusively for academic research purposes to protect participants' privacy, dignity, and rights.

3. Results and Discussion

3.1 Level of Metacognitive Strategy Integration in Senior High School Science Teaching

3.1.1 Metacognitive Knowledge Integration

The findings revealed a high level of metacognitive knowledge integration (M = 3.53, SD = 0.60). Helping students recall prior knowledge received the highest rating (M = 3.76), followed by encouraging students to articulate existing knowledge and learning needs (M = 3.70) and incorporating reflection questions (M = 3.66). Comparatively lower ratings were recorded for allowing learners to select and evaluate learning strategies (M = 3.28), journaling (M = 3.32), and comparing learning strategies (M = 3.40). These results indicate strong foundational practices but less consistent opportunities for independent reflection and strategy selection. The findings suggest that teachers emphasized guided metacognitive awareness more consistently than learner-directed regulation. These results are consistent with the need for explicit metacognitive instruction in science learning discussed by Sagun and Prudente (2023), while Giray (2021) emphasized self-monitoring strategies. Modrek and Ramirez (2021) and Perry et al. (2019) similarly highlighted the need for structured and subject-specific approaches. Consistent with Flavell's (1979) and Zimmerman's (2002) theoretical models, the findings emphasize strengthening independent reflection, journaling, and strategic learning choices through systematic instructional support.

3.1.2 Metacognitive Regulation Integration

Metacognitive regulation integration obtained a high overall mean of 3.52 (SD = 0.64). Teachers frequently established clear learning objectives (M = 3.65), modeled think-aloud and reflective questioning strategies (M = 3.57), and used checklists or rubrics to support learning monitoring (M = 3.55). Lower ratings were observed for monitoring prompts (M = 3.44), pre-task planning (M = 3.46), and self-assessment checkpoints (M = 3.48). These findings demonstrate consistent implementation of goal-setting and reflective modeling, with comparatively less emphasis on continuous monitoring and independent planning. The results indicate that metacognitive regulation was more established in teacher-guided activities than in sustained student monitoring. Eshuis et al. (2022) examined structured reflection in concept-mapping activities, while Sagun and Prudente (2023) investigated metacognitive and self-regulated approaches in a Philippine science classroom. Fleur et al. (2021) discussed metacognitive monitoring and regulation as important components of learning, while Perry et al. (2019) highlighted challenges in subject-specific metacognitive instruction. Consistent with Zimmerman's (2002) self-regulated learning model, the findings support reinforcing structured monitoring, planning, and self-evaluation activities.

3.1.3 Instructional Planning and Delivery Integration

Instructional planning and delivery demonstrated a high level of integration (M = 3.54, SD = 0.63). Teachers frequently required students to plan before completing tasks (M = 3.61), incorporated real-world and inquiry-based problem-solving activities (M = 3.60), encouraged strategy-sharing (M = 3.58), and embedded formative assessments (M = 3.57). Relatively lower ratings were recorded for incorporating metacognitive prompts into worksheets or digital tools (M = 3.46) and adapting instructional delivery based on student feedback (M = 3.48). These findings identify purposeful lesson design and inquiry-based instruction as instructional strengths. The results demonstrate the importance of intentionally embedding metacognitive processes into lesson preparation and delivery. Antonio and Prudente (2022) reported evidence supporting metacognitive instruction in science learning, while Fleur et al. (2021) discussed metacognitive monitoring and regulation as important components of learning. Related research underscores the value of reflective concept mapping and metacognitive science instruction (Eshuis et al., 2022; Sagun & Prudente, 2023). Consistent with Fleur et al.'s (2021) discussion of metacognitive regulation, the findings support strengthening adaptive teaching and incorporating explicit metacognitive prompts into instructional materials.

3.1.4 Classroom Environment and Student Engagement Integration

Classroom environment and student engagement recorded the highest overall mean among the four domains (M = 3.56, SD = 0.61), indicating high integration. Teachers consistently promoted open classroom discussions (M = 3.63), recognized effort and reflection (M = 3.62), and provided feedback encouraging deeper thinking (M = 3.61). Comparatively lower ratings were recorded for enabling students to initiate learning strategies independently (M = 3.48) and using questioning techniques to encourage metacognitive dialogue (M = 3.52). These findings indicate supportive classroom environments with opportunities to strengthen independent student participation. The results suggest that teachers effectively encouraged reflective interaction and positive learning behaviors, although student-initiated metacognitive activities remained less developed. Sagun and Prudente (2023) examined metacognitive approaches to science learning, while Giray (2021) emphasized reflective questioning. Modrek and Ramirez (2021) and Perry et al. (2019) highlighted the need for structured classroom practices that sustain metacognitive engagement. Consistent with Flavell's (1979) and Zimmerman's (2002) models, the findings emphasize strengthening student agency, collaborative reflection, and deeper questioning.

3.2 Academic Performance of Grade 12 Students in Science

The academic performance distribution for the first semester of school year 2025–2026 showed that 49.1% of the 55 reported performance records fell within the Satisfactory category (80–84), while 45.5% were classified as Very Satisfactory (85–89). Only 3.6% reached Outstanding performance (90–100), and 1.8% were classified as Fairly Satisfactory (75–79). Overall, 94.6% were within the Satisfactory to Very Satisfactory categories, indicating generally favorable academic outcomes but relatively limited representation in the highest achievement category. These findings indicate that satisfactory achievement was common within the study context, although high levels of metacognitive integration did not necessarily correspond to outstanding academic performance. He et al. (2024) identified a positive association between metacognition and subsequent academic achievement, while Antonio and Prudente (2022) reported evidence supporting metacognitive instruction in science learning. Sagun and Prudente (2023) examined metacognitive and self-regulated learning approaches in a Philippine science classroom. Similarly, Perry et al. (2019) and Fleur et al. (2021) discussed the importance of metacognitive reflection, monitoring, and regulation. These findings support continued attention to learner independence, deeper questioning, and strategic self-assessment without assuming that metacognitive integration alone determines academic achievement.

3.3 Relationship Between Metacognitive Strategy Integration and Academic Performance

3.3.1 Correlation Between Metacognitive Integration Domains and Academic Performance

Pearson correlation analysis revealed statistically significant positive relationships between all four metacognitive integration domains and academic performance. Instructional planning and delivery demonstrated the strongest correlation ($r = 0.436$, $p = 0.001$), followed by metacognitive knowledge ($r = 0.421$, $p = 0.002$), classroom environment and student engagement ($r = 0.412$, $p = 0.003$), and metacognitive regulation ($r = 0.398$, $p = 0.004$). Overall metacognitive integration was also significantly associated with academic performance ($r = 0.417$, $p = 0.002$). These findings establish positive associations across all measured instructional domains. The results suggest that higher levels of metacognitive strategy integration were associated with better science achievement, particularly when strategies were systematically incorporated into instructional planning and delivery. This aligns with Zimmerman's (2002) self-regulated learning model and evidence from He et al. (2024) concerning metacognition and academic achievement. However, the moderate associations indicate that metacognitive integration does not fully account for differences in achievement. Wess et al. (2023) examined science-teacher professional development, while Modrek and Ramirez (2021) discussed cognitive regulation, supporting attention to instructional conditions.

3.3.2 Predictive Contribution of Metacognitive Integration to Academic Performance

Regression analysis demonstrated that all four metacognitive integration domains were statistically significant predictors of academic performance. Instructional planning and delivery had the strongest reported standardized coefficient ($\beta = 0.334$, $p = 0.001$), followed by metacognitive knowledge ($\beta = 0.312$, $p = 0.003$), classroom environment and student engagement ($\beta = 0.298$, $p = 0.003$), and metacognitive regulation ($\beta = 0.287$, $p = 0.004$). The overall model was statistically significant, $F(4, 50) = 12.36$, $p < 0.001$, with $R^2 = 0.42$, indicating that the model accounted for 42% of the reported variance in academic performance. These findings identify instructional planning and delivery as the strongest statistical predictor among the examined domains, emphasizing the importance of integrating reflection, goal-setting, and monitoring into lesson design. This supports Zimmerman's (2002) model of self-regulated learning and findings by Antonio and Prudente (2022) concerning metacognitive instruction and science learning achievement. Sagun and Prudente (2023) investigated structured metacognitive approaches in science teaching, while Modrek and Ramirez (2021) examined cognitive regulation. Although the regression findings indicate meaningful predictive relationships, they do not establish that metacognitive integration independently caused improvements in academic performance.

3.4 Teachers' Experiences in Integrating Metacognitive Strategies in Science Teaching

3.4.1 Awareness and Personal Value of Metacognition

The qualitative findings revealed that teachers developed their initial awareness of metacognitive strategies during college education, practicum teaching, and lesson planning. Participants described metacognition as valuable for encouraging students to recognize their learning processes, evaluate their progress, and develop thinking skills beyond memorization. Teachers also emphasized the importance of understanding students' cognitive abilities and adapting instruction to their learning needs. These experiences highlight the relevance of teacher preparation in establishing metacognitive awareness and instructional competence. The findings are consistent with Flavell (1979), whose theoretical framework emphasizes awareness of cognitive processes. They also complement the high ratings for metacognitive knowledge and instructional planning, suggesting that early professional exposure provides a foundation for reflective classroom practices.

3.4.2 Application and Effectiveness of Metacognitive Strategies

Teachers reported incorporating concept mapping, think-aloud activities, reflection journals, self-questioning, and post-activity reflection into science instruction. Participants described using concept maps in Disaster Risk Reduction lessons and reflective writing following Chemistry laboratory activities. They identified think-aloud strategies as useful for explaining problem-solving processes, while concept mapping and self-questioning helped

students organize information and evaluate their understanding. The findings demonstrate how metacognitive strategies were incorporated into actual classroom activities rather than remaining theoretical concepts. These experiences support the importance of instructional planning, reflective modeling, and student self-evaluation. They also complement the quantitative findings showing high integration in metacognitive regulation and instructional delivery. The reported practices are consistent with Zimmerman's (2002) emphasis on planning, monitoring, and reflection in self-regulated learning.

3.4.3 Student Engagement and Changes in Learning Behaviors

Participants observed increased classroom participation, questioning, reflective thinking, and responsibility among students exposed to metacognitive activities. Teachers reported that learners became more willing to participate in discussions, explain their understanding, review their notes, and evaluate their progress. Reflection activities were also perceived as helpful in remembering lessons, while concept mapping supported students' comprehension of scientific concepts. These experiences complement the high-rating for-classroom environment and student engagement ($M = 3.56$). They suggest that metacognitive practices were perceived by teachers as supportive of student participation and independent learning. The findings also provide qualitative context for the positive relationships between metacognitive integration and academic performance. However, these observations represent teachers' reported experiences rather than independently established causal effects.

3.4.4 Teacher Growth and Professional Development

Teachers reported becoming more attentive to how students learn and more reflective about their instructional decisions. Participants recognized that metacognitive strategies encouraged them to consider students' thinking processes, identify learning difficulties, and adjust teaching approaches. They also recommended beginning with familiar strategies, such as concept mapping and reflection papers, before introducing more complex activities involving self-questioning and peer feedback. The findings emphasize the importance of gradual implementation and continuing professional development in sustaining metacognitive instruction. Teachers' experiences complement the quantitative results identifying instructional planning as the strongest predictor of academic performance. Consistent with Fleur et al.'s (2021) discussion of metacognitive monitoring and regulation, the findings support strengthening teachers' instructional competence through structured reflection, collaborative learning, and progressive strategy integration.

3.5 Challenges and Support Systems in Metacognitive Strategy Integration

3.5.1 Challenges in Classroom Implementation

Teachers identified several challenges affecting the implementation of metacognitive strategies, including differences in students' learning abilities, limited confidence, language difficulties, and problems expressing ideas through writing or discussion. Participants also described instructional time constraints, curriculum demands, and varying levels of student readiness. These challenges affected the consistency with which teachers incorporated independent reflection, monitoring, and student-directed learning activities. The findings help explain why some metacognitive indicators received comparatively lower ratings despite high overall integration. Wess et al. (2023) reviewed challenges in supporting science teachers' facilitation of scientific argumentation, while Modrek and Ramirez (2021) examined cognitive regulation. Perry et al. (2019) similarly highlighted challenges associated with applying metacognitive approaches in specific subject contexts. These findings support the need for instructional flexibility and targeted assistance.

3.5.2 Institutional Support and Teacher Collaboration

Participants identified instructional coaching, supervisory feedback, science coordinators, peer collaboration, and Learning Action Cell sessions as important sources of professional support. Teachers reported receiving guidance from instructional supervisors and sharing metacognitive teaching practices with colleagues. These collaborative activities provided opportunities to discuss instructional difficulties, exchange strategies, and strengthen classroom implementation. The findings indicate that professional support systems play an important role in maintaining reflective instructional practices. Collaboration and coaching provide opportunities for teachers to address implementation challenges and refine their approaches. These experiences reinforce the importance of sustained professional learning and institutional assistance in strengthening metacognitive instruction across science classrooms.

3.6 Integration of Quantitative and Qualitative Findings

The integration of both datasets revealed convergence between teachers' high ratings of metacognitive strategy integration and their reported classroom experiences. The four instructional domains consistently demonstrated high integration, while qualitative accounts described practical applications of reflection, goal-setting, concept mapping, monitoring, and collaborative learning. Instructional planning and delivery emerged as both the strongest correlate ($r = 0.436$) and strongest predictor ($\beta = 0.334$) of academic performance. Teachers' accounts of purposeful lesson preparation, inquiry-based instruction, and reflective assessment complemented these statistical findings. The convergence suggests that structured instructional planning is central to the observed relationship between metacognitive integration and science achievement. Qualitative findings also expanded the

quantitative results by identifying implementation challenges involving instructional time, student readiness, learner diversity, and professional support. These challenges help contextualize the relatively lower ratings for independent strategy selection, journaling, monitoring prompts, and adaptive instruction. Overall, the combined findings support the development of structured monitoring and professional development mechanisms while recognizing that the statistical associations do not establish causation.

3.7 Proposed Metacognitive Strategy Integration Observation Checklist and Rollout Framework

3.7.1 Development of the Metacognitive Strategy Integration Observation Checklist

The study developed the Metacognitive Strategies Integration Observation Checklist (MSIOC) as a proposed instrument for systematically observing and assessing metacognitive practices in Senior High School science teaching. The checklist addresses four domains: metacognitive knowledge, metacognitive regulation, instructional planning and delivery, and classroom environment and student engagement. Its development was informed by the consistently high integration ratings, significant relationships with academic performance, and identified weaknesses in journaling, monitoring, learner autonomy, and instructional adaptation. The MSIOC provides a structured basis for classroom observation, teacher reflection, instructional feedback, and professional development. Its proposed application is consistent with the Philippine Professional Standards for Teachers (PPST; DepEd Order No. 42, s. 2017) and classroom observation and coaching provisions under the Performance Management and Evaluation System (DepEd Memorandum No. 089, s. 2025). The study also identified its relevance to scientific literacy and critical thinking concerns reflected in the PISA 2022 results (OECD, 2023). These connections support the instrument's potential contribution to systematic instructional monitoring, subject to further implementation and evaluation.

3.7.2 Development of the MSIOC Rollout Framework

The proposed Rollout Framework was organized into four interconnected phases: Preparation, Capacity Building, Implementation and Monitoring, and Evaluation and Sustainability. Preparation focuses on institutional coordination, orientation, and instrument finalization. Capacity Building involves teacher training, demonstrations, coaching, and mentoring. Implementation and Monitoring emphasize classroom application, observation, and instructional feedback, while Evaluation and Sustainability address continuing assessment and improvement. The framework also incorporates feedback mechanisms to support sustained implementation. The framework responds directly to the study's findings that, despite high levels of metacognitive integration, teachers experienced difficulties involving student readiness, instructional demands, confidence, and professional support. By connecting teacher development, classroom observation, collaborative reflection, and continuous evaluation, the proposed framework provides an organized approach to strengthening metacognitive instruction. Its intended contribution is to support the consistent implementation and monitoring of metacognitive strategies across public Senior High School science classrooms.

4. Conclusion & Recommendations

The study concluded that metacognitive strategies were highly integrated into Senior High School science teaching among public school teachers in the Division of Las Piñas. Teachers consistently incorporated metacognitive knowledge, regulation, instructional planning, and student engagement practices into classroom instruction. Grade 12 students generally demonstrated satisfactory to very satisfactory academic performance, although relatively few achieved outstanding results. Correlation and regression analyses established a significant positive relationship between metacognitive strategy integration and academic performance, with instructional planning and delivery emerging as the strongest predictor. Teachers' experiences further revealed improvements in student participation, questioning, independence, and responsibility, alongside challenges involving confidence, language barriers, and instructional support. The convergence of quantitative and qualitative findings emphasized the importance of sustained metacognitive practices and institutional assistance. Overall, the study provided empirical and contextual support for developing the Metacognitive Strategy Integration Observation Checklist (MSIOC) and Rollout Framework to strengthen systematic implementation, monitoring, and continuous instructional improvement.

Science teachers are encouraged to consistently incorporate concept mapping, think-aloud activities, self-questioning, and reflection journals into instructional planning and classroom activities. They should use the proposed MSIOC for self-assessment, reflective teaching, and identifying areas requiring improvement, subject to further validation and evaluation. School administrators and instructional supervisors should strengthen classroom observation, coaching, and professional development programs that support metacognitive integration. Learning Action Cells, peer mentoring, and collaborative seminars should address teachers' implementation challenges, particularly confidence and language barriers. Schools should encourage students to participate in reflective learning, self-evaluation, and inquiry-based activities to strengthen independence and responsibility. The Department of Education may consider integrating the MSIOC and Rollout Framework into professional development initiatives, school improvement plans, and relevant PPST-aligned instructional supervision practices. Future researchers should evaluate these proposed tools across different educational settings and

examine the relationship between metacognitive integration and student achievement over successive school years.

The study was limited to public Senior High School science teachers and Grade 12 students in the Division of Las Piñas during the school year 2025–2026. Its quantitative component involved 55 teachers, while the qualitative component included 10 purposively selected participants, restricting the transferability of findings to other educational contexts. Private schools, other grade levels, and non-science subjects were excluded. The correlational design established statistical associations but could not demonstrate causation between metacognitive integration and academic performance. Furthermore, the proposed MSIOC and Rollout Framework require further evaluation across different settings. Future studies may employ broader samples, additional educational contexts, and longitudinal approaches.

5. Compliance with ethical standards

The study complied with the Data Privacy Act of 2012 (Republic Act No. 10173) by obtaining institutional permission and informed consent, ensuring voluntary participation and the right to withdraw without penalty, protecting participants' anonymity and confidentiality, securely managing research data, and using all collected information exclusively for academic purposes.

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