IJGGSD
ISSN: 3155-7716
International Journal of Global Goals and Sustainable Development
RESEARCH | INNOVATION | INCLUSION | SUSTAINABLE FUTURES
DOI: https://doi.org/10.65339/ijggsd.V1.I1.77

Metacognition, Learning Strategies, and Motivation in Science Education: Associations with Academic Performance and Implications for Physics Curriculum Development

Veronica S. Roque[1], Marlon B. Marvilla[2], Jannea Lyn C. Estardo[3], Roel S. Ang[4]

[1]Unit Registrar/Faculty Member, Our Lady of Fatima University, Nueva Ecija, Inc., Nueva Ecija, Philippines

[2]School Principal, Kalantiyaw Elementary School, Malvar St., Bagumbuhay, Proj. 4, Quezon City, Philippines

[3]Registrar's Staff, Our Lady of Fatima University, Nueva Ecija, Inc., Nueva Ecija, Philippines

[4]Associate Professor V, Nueva Ecija University of Science and Technology, Graduate School, Nueva Ecija, Philippines

Email: ronaroque1@gmail.com

ABSTRACT

This study examined the relationships among metacognitive skills, learning strategies, learning motivation, and previous Science academic performance as a basis for developing a needs-responsive Physics instructional framework. Anchored in metacognitive theory, self-regulated learning, situated expectancy-value theory, and curriculum development models, the study employed a quantitative descriptive-correlational design involving 89 undergraduate BS Psychology and BS Nursing students in Cabanatuan City, Philippines, selected through purposive sampling. Data were collected using the Metacognitive Skills Scale, Learning Strategy Questionnaire, Science Motivation Questionnaire II, and Problem-Solving Skills Scale and analyzed using descriptive statistics, Cronbach's alpha, and Spearman's rank-order correlation. Results revealed an overall metacognitive mean of 3.85, while metacognitive learning strategies obtained the highest mean (M = 4.04), followed by resource-management (M = 3.99) and cognitive strategies (M = 3.80). Learning motivation averaged 3.97. Significant positive correlations were found among metacognitive skills, motivation, and learning strategies (ρ = .335–.707, $p < .05$). All three constructs were also significantly associated with previous Science academic performance among 84 respondents with usable grade data (ρ = −.264 to −.339, $p < .05$), indicating that higher self-reported learning scores generally corresponded to better grades. Identified instructional needs included conceptual confidence, visual representation, study scheduling, and metacognitive monitoring. The findings support the development of a proposed Physics instructional framework incorporating scaffolded instruction, strategic learning, and systematic problem solving. The study primarily aligns with Sustainable Development Goal 4 (Quality Education) and has a complementary connection to SDG 9 (Industry, Innovation and Infrastructure) through evidence-informed educational innovation. Its potential contribution to educational and institutional sustainability lies in supporting responsive instructional planning and continuous curriculum improvement. However, the proposed framework requires validation and empirical evaluation, as the correlational findings do not establish causality or actual Physics competence.

Keywords: *Academic Performance, Curriculum Development, Learning Motivation, Learning Strategies, Metacognitive Skills, Physics Education, Self-Regulated Learning, Sustainable Development*

1. INTRODUCTION

Science education develops scientific literacy, critical thinking, problem-solving, and evidence-based decision-making. Physics learning particularly requires students to integrate conceptual understanding, mathematical reasoning, visual representations, and systematic problem-solving processes. Effective learning therefore depends not only on disciplinary knowledge but also on students' metacognitive skills, learning strategies, and motivation. Metacognition, described as awareness and regulation of one's thinking (Flavell, 1979), enables learners to plan, monitor, and evaluate their learning. Cognitive, metacognitive, and resource-management strategies support knowledge acquisition and self-regulated learning, while motivation influences students' engagement, effort, and persistence (Eccles & Wigfield, 2020). These interconnected factors are particularly relevant to students in science-related programs who must apply scientific knowledge to complex academic and professional situations. Effective science curriculum development integrates disciplinary knowledge, scientific practices, and real-world applications (National Research Council, 2012). International and Philippine educational frameworks similarly emphasize scientific literacy, inquiry, and evidence-based reasoning (Organization for Economic Co-operation and Development [OECD], 2023a; Department of Education [DepEd], 2016). Recent Physics education research further highlights the instructional relevance of metacognitive monitoring, self-regulated learning, and multiple representations (Leblond et al., 2026; Osman et al., 2025; Tuveri et al., 2026). Within this context, the present study examines the relationships among metacognitive skills, learning strategies, learning motivation, and previous Science academic performance among undergraduate BS Psychology and BS Nursing students. Its findings provide a descriptive basis for proposing a needs-responsive Physics instructional framework emphasizing conceptual understanding, strategic learning, and systematic problem solving (Ulu & Yerdelen-Damar, 2024; He et al., 2024).

Research Problem

Despite the recognized importance of metacognition, motivation, and learning strategies, students may experience difficulties understanding complex scientific concepts, organizing study activities, and applying appropriate strategies to academic tasks. These difficulties are particularly relevant to Physics, where effective learning requires conceptual reasoning, mathematical interpretation, and coordination of verbal, visual, and symbolic representations. Research indicates that metacognitive and self-regulated learning approaches can support science achievement, although their effectiveness varies across strategies and instructional contexts (He et al., 2024). Studies in Physics education also identify potential benefits of metacognitive instruction while recognizing challenges in implementation and assessment (Osman et al., 2025). Furthermore, Physics problem solving requires students to move effectively among different representations of scientific phenomena (Tuveri et al., 2026). However, the relationships among students reported metacognitive skills, learning motivation, learning strategies, and previous Science grades require examination within the local undergraduate context. Specifically, the study addresses the need to determine students' learning characteristics, identify significant associations among these constructs, and establish an empirical basis for proposing responsive Physics instructional strategies. The investigation focuses on undergraduate students enrolled in BS Psychology and BS Nursing programs. Because academic performance is represented by previous Science grades rather than Physics-specific achievement measures, the study does not establish students' actual Physics competence or causal relationships among the variables. Instead, it provides descriptive and correlational evidence to inform subsequent Physics curriculum planning and evaluation (Vosniadou et al., 2024).

Assumptions of the Study

The study is guided by the conceptual assumption that metacognitive awareness, learning motivation, and strategic learning behaviors are interrelated aspects of students' academic experiences. Metacognition involves recognizing learning difficulties, monitoring comprehension, and adjusting approaches to learning (Flavell, 1979), while motivation reflects students' expectations of success and the value they assign to academic tasks (Eccles & Wigfield, 2020). It further assumes that students' self-reported learning characteristics can provide descriptive indicators of instructional needs, particularly in cognitive processing, study planning, resource management, and metacognitive monitoring. Previous research identifying associations between self-regulated learning strategies and Science achievement provides a basis for examining these relationships (He et al., 2024). These assumptions guide the investigation rather than predetermine its findings. The study recognizes that self-reported measures do not directly establish actual learning behaviors or Physics competence. Likewise, observed statistical associations cannot demonstrate causation, and the proposed instructional framework requires independent validation before its effectiveness can be established (Dörrenbächer-Ulrich & Bregulla, 2024).

Objectives of the Study

The general objective of this study is to examine undergraduate students' self-reported metacognitive skills, learning strategies, and learning motivation, determine their associations with one another and with previous Science academic performance, and utilize the findings as a basis for developing a proposed instructional planning framework for Physics curriculum development. Specifically, the study aims to describe the respondents' demographic and academic profiles in terms of age, gender, year level, academic program, previous Science grades, and section; assess their overall metacognitive skills and individual metacognitive indicators; evaluate their cognitive, metacognitive, and resource-management learning strategies; determine their learning motivation in terms of interest, persistence, confidence, effort, and perceived career relevance; examine the significant associations among metacognitive skills, learning motivation, and learning strategies; determine the relationships between these learning constructs and previous Science academic performance; and formulate a proposed Physics instructional and curriculum development framework based on the identified learning characteristics and instructional needs.

Conceptual and Theoretical Framework

The study is anchored in metacognition, self-regulated learning, situated expectancy-value theory, and curriculum development models. Metacognitive theory explains how learners become aware of, monitor, and regulate their cognitive processes. Flavell's (1976, 1979) conceptualization emphasizes learners' ability to recognize their understanding, identify difficulties, and adjust learning approaches. Complementing this perspective, self-regulated learning involves planning, monitoring performance, and reflecting on learning outcomes. Research has established associations between self-regulated learning strategies and Science achievement (He et al., 2024). These perspectives support the examination of metacognitive skills and cognitive, metacognitive, and resource-management strategies as related but distinct learning constructs. Situated expectancy-value theory explains students' motivation through their expectations for success, perceived task value, and learning context (Eccles & Wigfield, 2020). This perspective supports examining interest, persistence, confidence, effort, and perceived career relevance as indicators of learning motivation. It also explains why students may recognize the importance of Science while experiencing difficulties understanding complex concepts. The study also draws on curriculum development models that emphasize systematic instructional planning. Tyler's (1949) model highlights the alignment of educational objectives,

learning experiences, content organization, and evaluation. Taba's (1962) model emphasizes diagnosing learners' needs and involving teachers in curriculum development. Together, these models provide a foundation for translating identified learning characteristics into instructional objectives, appropriate learning activities, and assessment procedures. The conceptual framework examines associations among metacognitive skills, learning motivation, and learning strategies, together with their respective relationships with previous Science grades. These relationships inform a proposed Physics instructional framework emphasizing conceptual scaffolding, visual representation, study planning, metacognitive monitoring, and structured problem solving. The framework is intended for subsequent expert review, pilot implementation, and empirical evaluation rather than immediate adoption as a validated curriculum model (Dörrenbächer-Ulrich et al., 2024).

Sustainable Development Goal and Multidisciplinary Sustainability Relevance

The study primarily aligns with Sustainable Development Goal 4 (Quality Education) through its emphasis on improving the quality and effectiveness of science instruction. By examining metacognitive skills, learning motivation, and learning strategies, the research provides a basis for identifying students' learning needs and designing responsive instructional experiences. This direction is consistent with educational frameworks emphasizing scientific literacy, inquiry, and evidence-based learning (National Research Council, 2012; OECD, 2023a; DepEd, 2016). The study also has a relevant connection to SDG 9 (Industry, Innovation and Infrastructure) through its proposed use of evidence-informed instructional approaches and educational resources, including simulations, visual representations, and structured problem-solving activities. This alignment concerns educational innovation and the development of scientific competencies rather than demonstrated industrial or technological outcomes. In terms of sustainability, the research contributes primarily to educational and institutional sustainability by proposing a curriculum planning process grounded in learner needs, instructional alignment, formative assessment, and continuous improvement. Its emphasis on metacognitive monitoring, independent study strategies, and scientific reasoning supports the development of learning competencies that students can apply beyond individual courses. The proposed framework also encourages the systematic review of instructional practices through collaboration among Physics educators, curriculum specialists, and assessment experts. However, these contributions remain prospective because the framework has not undergone expert validation, classroom implementation, or effectiveness testing. Further evaluation is necessary to establish its educational impact and potential contribution to sustainable curriculum improvement (Organisation for Economic Co-operation and Development, 2023b).

2. METHODOLOGY

Research Design

The study utilized a nonexperimental descriptive-correlational research design to describe students' metacognitive skills, cognitive and self-regulatory learning strategies, learning motivation, and previous Science academic performance. Descriptive analysis characterized the respondents and their reported learning behaviors, while correlational analysis examined relationships among the learning constructs and their associations with previous Science grades. Because no experimental intervention or manipulation of variables was conducted, the findings were interpreted as statistical associations rather than evidence of causal relationships.

Research Locale or Study Setting

The study involved undergraduate students enrolled in BS Psychology and BS Nursing programs in Cabanatuan City, Philippines. The educational setting provided a context for examining learning characteristics among students taking science-related courses. Although the findings

were intended to inform Physics curriculum development, the investigation focused on general Science learning experiences rather than direct assessment of Physics-specific academic achievement.

Participants or Data Sources

The study analyzed responses from 89 undergraduate students, comprising 51 BS Psychology students (57.3%) and 38 BS Nursing students (42.7%). Participants were selected through purposive sampling based on their enrollment in science-related courses. Most respondents were aged 15–20 years (87.6%), female (83.1%), and enrolled in their first or second year of undergraduate study. The dataset included demographic information, academic program, year level, previous Science grades, and self-reported learning characteristics. All 89 respondents were included in the analysis of learning constructs, while 84 records contained usable numeric grade information for correlation analysis. The sample characteristics and nonprobability sampling approach limit the generalizability of the findings to other academic programs and educational settings.

Research Instruments or Materials

Data were obtained using questionnaire measures covering metacognitive skills, learning strategies, learning motivation, problem-solving attitudes, and critical-thinking ability. The Metacognitive Skills Scale (MSS) assessed students reported metacognitive knowledge, regulation, and awareness through 29 items. The Learning Strategy Questionnaire measured cognitive, metacognitive, and resource-management strategies, while the Science Motivation Questionnaire II (SMQ-II) assessed motivation through indicators of interest, persistence, confidence, effort, and perceived career relevance. The Problem-Solving Skills Scale included indicators of problem-solving attitudes and critical-thinking ability. The metacognitive measure was analyzed using an overall composite and individual item responses because the available documentation did not establish an item-to-dimension scoring key. The motivation measure contained five indicators treated as a descriptive composite rather than independently validated subscales. The additional problem-solving and critical-thinking sections contained 20 and 12 items, respectively. Because no scoring key was available for the problem-solving attitude items, no overall composite was calculated for that section. The critical-thinking responses were analyzed exploratorily, with four negatively worded items reverse-scored. Instrument documentation and scoring limitations were considered when interpreting the results (Alhazbi et al., 2024).

Data Gathering Procedure

The study used questionnaire responses obtained from undergraduate BS Psychology and BS Nursing students taking science-related courses. Purposive sampling was employed to identify eligible participants. The collected information included demographic and academic characteristics, previous Science grade entries, and self-reported responses concerning metacognitive skills, learning strategies, motivation, problem-solving attitudes, and critical-thinking ability. The responses were organized into a dataset for descriptive and correlational analysis. Previous Science grades were recorded in grade bands, with usable entries converted into approximate numeric values for statistical analysis. The available manuscript does not specify the questionnaire administration dates, mode of distribution, or detailed sequence of data collection; therefore, these procedures cannot be described further without additional documentation.

Data Analysis

Data were analyzed using descriptive statistics, including frequencies, percentages, means, and standard deviations, to summarize respondents' demographic characteristics, academic profiles, and learning constructs. Internal consistency was examined using Cronbach's alpha for the overall metacognitive composite and exploratory critical-thinking measure. The metacognitive scale yielded a Cronbach's alpha of .881, while the exploratory critical-thinking composite yielded .626. Spearman's rank-order correlation was employed to determine associations among metacognitive skills, learning motivation, and learning strategies and their relationships with previous Science grades. All statistical tests were two-tailed, with the significance level established at $\alpha = .05$. Correlations among learning constructs involved 89 respondents, while associations with previous Science grades were calculated using 84 usable numeric records. Previous Science grade bands were converted into approximate midpoint values, including the numeric response of 5.00. Because lower grade-point values indicated better academic performance, negative correlation coefficients were interpreted as associations between higher self-reported learning scores and better previous Science grades. However, the use of approximate grade-band midpoints and the treatment of the 5.00 response require verification against the institution's official grading system. The statistical findings were interpreted as associations without establishing causality or Physics-specific achievement (Alhazbi et al., 2024).

Ethical Considerations

The study involved questionnaire responses from undergraduate BS Psychology and BS Nursing students enrolled in science-related courses. The collected data included demographic and academic information, previous Science grades, and self-reported measures of metacognitive skills, learning strategies, motivation, problem-solving attitudes, and critical-thinking ability. To protect participants' privacy and confidentiality, the research dataset was intended to be processed in a de-identified format, with usernames, email addresses, and other direct personal identifiers excluded from the analysis and research outputs. These considerations guided the responsible handling and presentation of participants' information throughout the study.

3. RESULTS AND DISCUSSION

3.1 Main Findings on Students' Learning Characteristics

3.1.1 Demographic and Academic Profile of Respondents

The study involved 89 respondents, predominantly aged 15–20 years (87.6%) and female (83.1%). Most were second-year (46.1%) or first-year (40.4%) students. BS Psychology students comprised 57.3% of the sample, while BS Nursing students accounted for 42.7%. Previous Science grades varied, with the largest proportion reporting grades of 2.01–2.25 (27.0%), followed by 2.26–3.00 (20.2%) and 1.51–1.75 (19.1%). Five respondents had no usable numeric grade information, and the section variable was excluded from interpretation because of inconsistent labeling. The demographic distribution indicates that the findings primarily reflect the learning characteristics of younger undergraduate students, particularly women in their early academic years. The concentration of respondents within two academic programs limits generalizability to other student populations.

3.1.2 Metacognitive Skills of Students

The respondents obtained an overall metacognitive mean of 3.85 (SD = 0.37), with satisfactory internal consistency (Cronbach's $\alpha = .881$). The highest item means concerned awareness of subjects that were easier or more difficult to learn (M = 4.43) and recognition of learning errors

(M = 4.41). Comparatively lower adjusted means were observed for monitoring time (M = 3.16), awareness of learning strategies (M = 3.39), and awareness of learning conditions (M = 3.58). These findings indicate that students generally reported recognizing their learning strengths, difficulties, and mistakes, although monitoring and deliberate strategy selection were comparatively less developed. This pattern supports the instructional relevance of metacognitive monitoring and reflection in Science and Physics learning. Osman et al. (2025) emphasized the potential contribution of metacognitive strategies to Physics conceptual understanding and problem solving, while Leblond et al. (2026) demonstrated the feasibility of incorporating self-regulated learning prompts into undergraduate Physics instruction. Nevertheless, the present findings reflect self-reported metacognitive characteristics rather than directly observed Physics learning performance (He et al., 2024).

3.1.3 Cognitive, Metacognitive, and Resource-Management Learning Strategies

Among the learning-strategy dimensions, metacognitive strategies obtained the highest mean (M = 4.04, SD = 0.70), followed by resource-management strategies (M = 3.99, SD = 0.66) and cognitive strategies (M = 3.80, SD = 0.70). Reflecting on effective study methods (M = 4.17) and checking understanding while studying (M = 4.15) were frequently reported metacognitive practices. Identifying key ideas and important terms (M = 4.08) received the highest cognitive-strategy rating, whereas creating diagrams, charts, or concept maps received the lowest (M = 3.31). Among resource-management indicators, studying in a suitable environment (M = 4.15) was rated highest, while scheduling regular study time (M = 3.69) was rated lowest. The findings suggest relative strengths in reflective learning, comprehension monitoring, and identifying essential information, alongside comparatively lower use of visual representations and consistent study scheduling. These patterns are relevant to Science instruction, which requires students to integrate verbal, visual, graphical, and mathematical representations. Tuveri et al. (2026) emphasized the importance of coordinating linguistic, visual, and symbolic representations in Science problem framing. Consequently, explicit instruction in diagram construction, concept mapping, and study planning may address the identified learning needs, although the present data do not establish students' actual representational competence (Luo & Zhou, 2024).

3.1.4 Learning Motivation of Students

The overall learning-motivation mean was 3.97 (SD = 0.72). Students reported the highest agreement with the belief that Science learning would benefit their future careers (M = 4.24), followed by persistence in learning difficult Science topics (M = 4.09). Interest in learning scientific concepts and effort toward achieving good Science results each obtained a mean of 4.03. Confidence in understanding complex Science topics received the lowest mean (M = 3.47), with greater response variability (SD = 1.04). The results indicate that students recognized the career relevance of Science and reported willingness to persist despite academic difficulties, although their confidence in understanding complex concepts was comparatively lower. This distinction is consistent with situated expectancy-value theory, which recognizes perceived task value and expectations for success as related but distinct motivational components (Eccles & Wigfield, 2020). The findings suggest the importance of combining authentic scientific applications with scaffolded explanations, guided practice, and formative feedback to support students' conceptual confidence (Ulu & Yerdelen-Damar, 2024).

3.2 Relationships Among Metacognitive Skills, Motivation, and Learning Strategies

3.2.1 Association Between Metacognitive Skills and Learning Motivation

Spearman's rank-order correlation revealed a statistically significant positive association between metacognitive skills and learning motivation ($\rho = .335$, $p = .0013$; $n = 89$). The coefficient indicated a relatively weak relationship, suggesting that students reporting greater metacognitive awareness also tended to report higher learning motivation. This association suggests that awareness and regulation of learning are related to students' motivational experiences. However, the modest correlation indicates that the constructs are distinct and should not be treated as interchangeable. The findings are compatible with the expectancy-value perspective on learning engagement (Eccles & Wigfield, 2020), although the correlational design does not establish whether metacognition influences motivation or vice versa.

3.2.2 Association Between Metacognitive Skills and Learning Strategies

Metacognitive skills were positively and significantly associated with learning strategies ($\rho = .542$, $p < .0001$; $n = 89$). The coefficient indicated a moderate relationship, showing that respondents with higher metacognitive scores generally reported more frequent use of learning strategies. The relationship suggests that students' awareness and regulation of learning are associated with purposeful cognitive, metacognitive, and resource-management behaviors. This interpretation is consistent with research linking self-regulated learning strategies and Science achievement (He et al., 2024). Nevertheless, the measures were self-reported, and the observed association does not demonstrate that stronger metacognitive skills directly produce more effective learning behaviors (Luo & Zhou, 2024).

3.2.3 Association Between Learning Motivation and Learning Strategies

Learning motivation and learning strategies demonstrated the strongest positive association among the examined constructs ($\rho = .707$, $p < .0001$; $n = 89$). This statistically significant relationship indicates that students reporting higher motivation also tended to report greater use of learning strategies. The finding suggests a close relationship between students' willingness to engage in Science learning and their reported use of strategic study behaviors. However, the relatively strong correlation may partly reflect shared self-report methods, overlapping questionnaire content, or unmeasured influences. Accordingly, the result should not be interpreted as evidence that motivation causes increased strategy use. The relationship instead identifies motivation and strategic learning as interconnected areas for instructional consideration (Dörrenbächer-Ulrich & Bregulla, 2024).

3.3 Relationships Between Learning Constructs and Previous Science Academic Performance

3.3.1 Metacognitive Skills and Academic Performance

Among the 84 respondents with usable numeric grade information, metacognitive skills demonstrated a statistically significant negative correlation with previous Science grade values ($\rho = -.279$, $p = .0101$). Because lower grade-point values represented better academic performance, the negative coefficient indicated that higher metacognitive scores tended to accompany better previous Science grades. This finding suggests that reported metacognitive awareness and regulation are associated with academic performance in Science. The relationship is consistent with the instructional relevance of self-regulated learning discussed by

He et al. (2024). However, the association was modest and depended on approximate grade-band midpoint coding. Consequently, it cannot establish a causal effect of metacognition on achievement or demonstrate Science-specific competence (He et al., 2024).

3.3.2 Learning Motivation and Academic Performance

Learning motivation showed a statistically significant negative association with previous Science grade values ($\rho = -.339$, $p = .0016$; $n = 84$). This was the strongest association with academic performance among the three learning constructs. Given the grading direction, higher motivation scores generally corresponded to better previous Science grades. The finding suggests that motivation is meaningfully associated with students' previous Science academic performance, although the relationship remains modest. Situated expectancy-value theory provides a conceptual explanation for the relevance of students' perceived capability, task value, and persistence in academic engagement (Eccles & Wigfield, 2020). Nevertheless, the study does not establish that motivation directly improves grades, and the results remain subject to limitations in grade coding and self-reported measurement (Verdugo & Martínez-Líbano, 2026).

3.3.3 Learning Strategies and Academic Performance

Learning strategies demonstrated a statistically significant negative correlation with previous Science grade values ($\rho = -.264$, $p = .0153$; $n = 84$). The negative coefficient indicated that students reporting greater use of learning strategies tended to have better previous Science grades, although the association was relatively weak. This result supports the relevance of strategic learning behaviors to Science academic performance and is consistent with evidence associating self-regulated learning strategies with Science achievement (He et al., 2024). However, the modest relationship suggests that reported strategy use alone does not account for academic performance. Interpretation also requires caution because previous grades were converted from broad categories into approximate numeric values, including a 5.00 response whose status under the institutional grading system requires verification (Luo & Zhou, 2024).

3.4 Exploratory Findings on Problem-Solving and Critical-Thinking Indicators

3.4.1 Problem-Solving Attitudes

The problem-solving attitude measure contained 20 items representing different problem-solving tendencies. Because no established scoring key was available, an overall composite score was not calculated. One indicator concerning the systematic analysis and organization of facts when encountering problems obtained a mean agreement score of 3.14 among 87 respondents. The finding provides limited descriptive information about students' reported problem-solving attitudes. However, the absence of a validated scoring structure prevents reliable interpretation of an overall problem-solving construct. Consequently, the responses cannot establish students' actual problem-solving ability or proficiency in solving Science problems.

3.4.2 Critical-Thinking Ability

The 12-item critical-thinking measure produced an exploratory composite mean of 2.83 ($SD = 0.28$; $n = 89$) after reverse-scoring four negatively worded items. The measure demonstrated modest internal consistency (Cronbach's $\alpha = .626$) using a four-point response scale. The result offers preliminary descriptive evidence of students' self-reported critical-thinking characteristics. However, the modest reliability coefficient and reliance on self-reported

responses limit the measure's interpretive strength. The findings therefore should not be considered definitive evidence of critical-thinking competence or objective Science problem-solving performance. Further instrument validation is necessary before drawing stronger conclusions.

3.5 Implications for Science Instruction and Curriculum Development

3.5.1 Identified Instructional Needs

The findings identified comparatively lower scores for confidence in understanding complex Science concepts (M = 3.47), use of diagrams and concept maps (M = 3.31), and regular study scheduling (M = 3.69). Variation in metacognitive monitoring and strategy awareness was also observed. These descriptive patterns were accompanied by statistically significant associations among metacognitive skills, motivation, learning strategies, and previous Science academic performance. These findings provide a basis for identifying instructional priorities in conceptual confidence, visual representation, study planning, and metacognitive regulation. The National Research Council's (2012) framework emphasizes integrating scientific concepts, crosscutting ideas, and scientific practices, while OECD (2023) and DepEd (2016) highlight scientific literacy, evidence interpretation, and practical application. Accordingly, Science instruction may benefit from integrating these priorities into coherent learning activities and assessment practices, subject to subsequent evaluation (Organisation for Economic Co-operation and Development, 2023b).

3.5.2 Proposed Instructional Strategies for Science Learning

Based on the identified learning needs, the manuscript proposes scaffolded conceptual instruction, explicit visual-representation activities, structured study planning, metacognitive monitoring, and systematic problem-solving routines. Suggested activities include worked examples, guided practice, peer explanations, free-body diagrams, concept maps, circuit diagrams, weekly study schedules, spaced review, think-aloud demonstrations, and error analysis. Proposed assessment approaches include diagnostic questions, concept quizzes, learning logs, reflection sheets, representation rubrics, and structured problem-solving tasks. These instructional approaches are intended to address students' reported learning characteristics while promoting conceptual understanding, strategic learning, and scientific reasoning. Their proposed integration into Science instruction emphasizes alignment among learning outcomes, teaching activities, and assessment evidence. However, the recommendations are derived from descriptive and correlational findings rather than an implemented intervention. Their effectiveness therefore remains untested and requires classroom-based evaluation (Vosniadou et al., 2024).

3.5.3 Proposed Physics Curriculum Development Framework

The study proposes a needs-responsive Physics instructional framework organized around five interconnected phases: diagnosis of learner needs, specification of learning outcomes, design of aligned learning experiences, formative and summative assessment, and curriculum review and refinement. The framework addresses conceptual understanding, scientific representations, metacognitive regulation, study management, and structured problem solving. Suggested implementation involves initial curriculum review, small-scale classroom piloting, examination of student work and assessment evidence, and subsequent instructional refinement. The proposed framework translates the identified learning needs into an organized

curriculum planning process. It emphasizes collaboration among science teachers, curriculum specialists, and measurement experts to ensure that learning objectives, instructional activities, and assessment procedures are appropriately aligned. Nevertheless, the framework remains a proposed instructional design rather than an empirically validated intervention. Expert review, pilot implementation, objective Science assessments, and systematic evaluation are necessary before its effectiveness or suitability for wider adoption can be established (Fernández Ortube et al., 2024).

4. CONCLUSIONS AND RECOMMENDATIONS

The study established significant positive associations among metacognitive skills, learning motivation, and learning strategies among 89 undergraduate BS Psychology and BS Nursing students. Respondents demonstrated an overall metacognitive mean of 3.85, with metacognitive learning strategies obtaining the highest mean (M = 4.04), followed by resource-management (M = 3.99) and cognitive learning strategies (M = 3.80). Learning motivation was relatively high (M = 3.97), particularly regarding the career relevance of Science, although confidence in understanding complex concepts, use of visual representations, and regular study scheduling received comparatively lower ratings. All three learning constructs were significantly associated with previous Science academic performance among 84 respondents with usable grade data, with higher self-reported scores generally corresponding to better grades. These findings provide a basis for developing a needs-responsive Science instructional framework emphasizing conceptual confidence, metacognitive monitoring, strategic learning, visual representation, and systematic problem solving. However, the observed relationships are correlational and do not establish causation or demonstrate Science -specific competence.

Physics teachers should strengthen students' conceptual understanding and confidence through scaffolded instruction, guided practice, peer explanation, formative feedback, and explicit instruction in visual representation and systematic problem solving. Curriculum developers should integrate metacognitive planning, monitoring, reflection, and error analysis into instructional materials, while school administrators should support teacher development in inquiry-based Science instruction, formative assessment, and educational simulation tools. Students should establish consistent study schedules, practice spaced review and self-testing, and reflect on learning difficulties. The proposed Physics instructional framework should undergo expert validation, small-scale pilot implementation, and systematic evaluation before wider adoption. Future researchers should also validate the questionnaire structure and scoring procedures and incorporate objective Science achievement and problem-solving assessments to establish more reliable evidence of learning outcomes.

The study was limited by its sample of 89 students from two academic programs within a single institutional setting, restricting the generalizability of the findings. Its reliance on self-reported measures may have introduced recall, response-style, and social-desirability biases, while the absence of objective Physics achievement and problem-solving assessments prevented direct evaluation of students' actual Science competence. Furthermore, the nonexperimental descriptive-correlational design did not establish causal relationships or demonstrate the effectiveness of the proposed instructional framework. These limitations should be considered when interpreting the findings and conducting subsequent curriculum validation and evaluation studies.

5. REFERENCES

Alhazbi, S., Al-ali, A., Tabassum, A., Al-Ali, A., Al-Emadi, A., Khattab, T., & Hasan, M. A. (2024). Using learning analytics to measure self-regulated learning: A systematic review of empirical studies in higher education. *Journal of Computer Assisted Learning, 40* (4), 1658–1674. https://doi.org/10.1111/jcal.12982

Department of Education. (2016). *K to 12 basic education curriculum: Science curriculum guide*. https://www.deped.gov.ph/wp-content/uploads/2019/01/Science-CG_with-tagged-sci-equipment_revised.pdf

Dörrenbächer-Ulrich, L., & Bregulla, M. (2024). The relationship between self-regulated learning and executive functions—a systematic review. *Educational Psychology Review, 36*, Article 95. https://doi.org/10.1007/s10648-024-09932-8

Dörrenbächer-Ulrich, L., Dilhuit, S., & Perels, F. (2024). Investigating the relationship between self-regulated learning, metacognition, and executive functions by focusing on academic transition phases: A systematic review. *Current Psychology, 43*, 16045–16072. https://doi.org/10.1007/s12144-023-05551-8

Eccles, J. S., & Wigfield, A. (2020). From expectancy-value theory to situated expectancy-value theory: A developmental, social cognitive, and sociocultural perspective on motivation. *Contemporary Educational Psychology, 61* (1), Article 101859. https://doi.org/10.1016/j.cedpsych.2020.101859

Fernández Ortube, A., Panadero, E., & Dignath, C. (2024). Self-regulated learning interventions for pre-service teachers: A systematic review. *Educational Psychology Review, 36*, Article 113. https://doi.org/10.1007/s10648-024-09919-5

Flavell, J. H. (1976). Metacognitive aspects of problem solving. In L. B. Resnick (Ed.), *The nature of intelligence* (pp. 231–236). Lawrence Erlbaum Associates.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. *American Psychologist, 34* (10), 906–911. https://doi.org/10.1037/0003-066X.34.10.906

He, G., Chen, S., Lin, H., & Su, A. (2024). The association between initial metacognition and subsequent academic achievement: A meta-analysis of longitudinal studies. *Educational Psychology Review, 36*, Article 81. https://doi.org/10.1007/s10648-024-09922-w

Leblond, L., Wang, Y., Malcos, J. L., & Sperling, R. A. (2026). Using digital prompts to support physics students' self-regulated learning. *Physical Review Physics Education Research, 22* (1), Article 010114. https://doi.org/10.1103/cftx-hfw5

Luo, R.-Z., & Zhou, Y.-L. (2024). The effectiveness of self-regulated learning strategies in higher education blended learning: A five years systematic review. *Journal of Computer Assisted Learning, 40* (6), 3005–3029. https://doi.org/10.1111/jcal.13052

National Research Council. (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. The National Academies Press. https://doi.org/10.17226/13165

Organisation for Economic Co-operation and Development. (2023a). *PISA 2022 assessment and analytical framework*. OECD Publishing. https://doi.org/10.1787/dfe0bf9c-en

Organisation for Economic Co-operation and Development. (2023b). *PISA 2022 results (Volume I): The state of learning and equity in education*. OECD Publishing. https://doi.org/10.1787/53f23881-en

Osman, N., Mahmud, S. N. D., & Arsad, N. M. (2025). A systematic review of metacognitive dynamics in secondary physics education. *International Journal of Evaluation and Research in Education, 14* (5). https://doi.org/10.11591/ijere.v14i5.32722

Taba, H. (1962). *Curriculum development: Theory and practice*. Harcourt, Brace & World.

Tuveri, M., Steri, A., & Fanti, V. (2026). Semiotic problem framing: A new framework to guide students and teachers in conceptual understanding and teaching of physics. *European Journal of Physics, 47* (1), Article 015712. https://doi.org/10.1088/1361-6404/ae2445

Tyler, R. W. (1949). *Basic principles of curriculum and instruction*. University of Chicago Press.

Ulu, Y., & Yerdelen-Damar, S. (2024). Metacognition and epistemic cognition in physics are related to physics identity through the mediation of physics self-efficacy. *Physical Review Physics Education Research, 20* (1), Article 010130. https://doi.org/10.1103/PhysRevPhysEducRes.20.010130

Verdugo, C. A., & Martínez-Líbano, J. (2026). Self-regulation of learning and its implications for academic performance and well-being of university students in health sciences: A systematic review. *International Medical Education, 5* (2), Article 34. https://doi.org/10.3390/ime5020034

Vosniadou, S., Bodner, E., Stephenson, H., Jeffries, D., Lawson, M. J., Darmawan, I. N., Kang, S., Graham, L., & Dignath, C. (2024). The promotion of self-regulated learning in the classroom: A theoretical framework and an observation study. *Metacognition and Learning, 19*, 381–419. https://doi.org/10.1007/s11409-024-09374-1