Cognitive and metacognitive learning strategies as correlates of university students' mathematics proficiency

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ABSTRACT

Mathematics remains one of the most difficult disciplines in the school curriculum. As such, strategies to address these difficulties are being implemented by educators over the years. This study aimed to determine the influence of the cognitive and metacognitive learning strategies on the mathematics proficiency of university freshmen. Specifically, it sought to assess how students' use of various cognitive and metacognitive strategies relates to their performance in mathematics. A descriptive-correlational research design was employed to describe the prevailing levels of these learning strategies and examine their association with mathematics proficiency. Data were gathered from 80 randomly selected freshmen students through a validated researcher-made questionnaire and record analysis of their mathematics grades. Results revealed significant positive correlations between control, elaboration, rehearsal, planning, monitoring, and evaluation strategies with mathematics proficiency. The study recommends providing additional mathematics support to struggling students such as remedial and tutorial classes and integrating cognitive and metacognitive learning strategies into the mathematics syllabi. These findings imply that strengthening students' cognitive and metacognitive awareness can significantly improve their ability to learn and perform in mathematics. Furthermore, integrating these strategies into instructional design may help develop more independent, reflective, and effective learners, leading to higher mathematics achievement.

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1. INTRODUCTION

Mathematics, a fundamental discipline in the curriculum, poses significant challenges for many college students. Difficulties extend beyond mere calculation and encompass a broader spectrum of issues, including conceptual understanding [1]–[3], problem-solving [4]–[6], and procedural fluency [7], [8]. Numerous meta-analyses and systematic reviews consistently indicate that a substantial portion of the student population struggles with these mathematical competencies [9]–[14]. The repercussions of these challenges are far-reaching, hindering academic progression [15], [16], limiting career options [17], and negatively impacting overall confidence [18], [19].

In the Philippine educational context, these challenges are reflected in national assessments and international large-scale studies. Results from the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS) have repeatedly shown that Filipino students perform below the global average in mathematical literacy and problem-solving. Locally, the Commission on Higher Education (CHED) and the Department of Education (DepEd) have emphasized the persistent gaps in students' mathematical foundations, particularly during the transition from secondary to tertiary education. These learning gaps often stem from fragmented mathematical instruction, limited application of higher order thinking skills, and a predominant reliance on rote memorization rather than conceptual understanding. Consequently, many college students enter higher education with insufficient mastery of prerequisite mathematics skills, leading to high failure rates and low confidence in quantitative courses.

To address these persistent difficulties, educators have implemented various pedagogical strategies to address the needs of at-risk students in mathematics by focusing on teaching academic content [20]–[22]. However, reviews of recent studies have revealed that most such intervention programs do not help students attain their academic goals [9], [23]–[25]. As noted, students continue using maladaptive learning methods due to a failure to recognize the constructive potential of the feedback they receive. Incorporating the correct use of feedback into classroom instruction involves the use of cognitive and metacognitive learning strategies [26], [27].

Several literature and studies have revealed that effective learning is dependent upon effective information processing centered upon cognitive and metacognitive skills [28]–[31]. As such students' use of learning strategies for self-regulation tends to increase their academic success. Cognitive strategies, such as control, elaboration, organization, and rehearsal facilitate information processing and retention [32]. Conversely, metacognitive strategies including planning, monitoring and evaluation empower learners to regulate their own learning [33], [34].

While the benefits of cognitive and metacognitive strategies are well-established in various academic domains, their specific impact on mathematics performance requires further investigation. To date, limited research has explored how these strategies contribute to students' mathematical proficiency, particularly among university students. This study aimed to bridge this knowledge gap by examining the relationship between cognitive and metacognitive learning strategies and mathematics achievement in this population. Specifically, it aimed to answer the following research questions:

- What are the students' levels of cognitive learning strategies in terms of control, elaboration, organization, and rehearsal?
- What are the students' levels of metacognitive learning strategies in terms of planning, monitoring, and evaluation?
- What is the level of students' mathematics proficiency?
- Is there a significant relationship between cognitive learning strategies and mathematics proficiency?
- Is there a significant relationship between metacognitive learning strategies and mathematics proficiency?

Based on the research questions, the following null hypotheses were tested: i) H_01: there is no significant relationship between cognitive learning strategies and mathematics proficiency; and ii) H_02: there is no significant relationship between metacognitive learning strategies and mathematics proficiency.

2. METHOD

2.1. Research design

This study employed a descriptive-correlational research design to address the research inquiry to investigate the relationship between cognitive and metacognitive learning strategies and mathematics proficiency among university freshmen students. Descriptive design was used to characterize the respondents' level of cognitive and metacognitive learning strategies as well as their mathematics proficiency, while correlational design was used to determine the association between these learning strategies and mathematics proficiency.

2.2. Participants and sampling technique

Prior to the data collection, written informed consent was obtained from the participants which outlines the study's objectives, procedures, voluntary participation, and data confidentiality measures. Moreover, stratified random sampling was employed to ensure adequate and balanced representation of students across the various academic programs in the university. In this procedure, the entire population of freshmen was first divided into distinct strata based on their enrolled college or degree program. Each stratum therefore represented a homogeneous subgroup with similar academic affiliations. After establishing the strata, the researchers determined the proportional allocation for each subgroup by computing the percentage of students belonging to that college or program relative to the total freshman population. Using these proportions, a corresponding number of participants was then randomly selected from each stratum. This method ensured that the final sample closely reflected the actual distribution of freshmen across academic programs, thereby enhancing the representativeness and generalizability of the study's findings. This approach minimized sampling bias and ensured that variations in mathematics proficiency and learning strategies among academic disciplines were appropriately captured.

Participants of the study consisted of 80 freshmen who have taken mathematics general education course (mathematics in the modern world) in the previous semester from a particular university in Mindoro, Philippines. This sample size was primarily constrained by the number of students enrolled in the targeted mathematics course during the semester of data collection, as well as by logistic considerations such as class schedules, research timelines, and the need for complete and verifiable academic records. Nonetheless, the use of stratified random sampling helped maximize the representativeness of the sample by ensuring proportional inclusion of students from different academic programs. Although a larger sample could potentially increase statistical power and generalizability, the chosen sample size remains sufficient for detecting meaningful correlations and providing reliable insights within the context of the study.

2.3. Research instruments

A researcher-made questionnaire using a five-point Likert scale was developed to gather data on participants' demographic profile, cognitive learning strategies, and metacognitive learning strategies. The cognitive learning strategies component (20 items) assessed control, elaboration, organization, and rehearsal strategies, while the metacognitive learning strategies component (15 items) focused on planning, monitoring, and evaluation strategies. The initial pool of items was generated based on an extensive review of relevant literature and existing validated instruments on learning strategies. To establish content validity, the draft questionnaire was evaluated by a panel of five experts in educational psychology, mathematics education, and research methodology, who assessed each item for relevance, clarity, and alignment with the constructs being measured. Their feedback guided the revision and refinement of several items to enhance wording precision and conceptual coverage. A pilot test involving 30 students with similar characteristics to the target population was conducted to check the clarity and comprehensibility of the items. Reliability was then determined using Cronbach's alpha coefficient, yielding high internal consistency for both the cognitive (α=0.882) and metacognitive (α=0.912) scales. However, confirmatory factor analysis was not conducted due to limitations in the sample size.

Moreover, record analysis was used to obtain the proficiency of the students in their mathematics course. A single course grade was utilized as a proxy for mathematics proficiency because it provides an objective, standardized, and readily available measure of students' actual performance in a formal academic setting. Course grades reflect students' mastery of the prescribed learning competencies, as they are derived from multiple assessments such as quizzes, examinations, problem-solving tasks, and class activities. Using an official grade also minimizes respondent bias and ensures consistency across the sample, making it a practical and valid indicator of students' overall mathematics proficiency within the context of the university curriculum.

2.4. Data collection

Data collection was carried out after securing approval from the university research ethics committee and the participating academic departments. The researcher coordinated with course instructors to schedule the administration of the questionnaire during regular class hours to ensure maximum participation and minimal disruption to academic activities. At the start of the session, the researchers briefly introduced the study, reiterated its purpose, and explained the voluntary nature of participation. Participants then signed informed consent forms before completing the paper-and-pencil survey, which took approximately 30 minutes. After the retrieval of the completed questionnaires, the researchers requested official class records from the registrar and concerned instructors to obtain students' final mathematics course grades. All collected data were kept confidential, organized, and encoded for subsequent statistical analysis.

2.5. Data analysis

Descriptive statistics such as frequency, mean, and rank were used to characterize the respondents' demographic profile and the level of cognitive and metacognitive learning strategies. The calculated means for cognitive and metacognitive learning strategies were described in terms of the following range and verbal description used in the university: very high (4.50-5.00), high (3.50-4.49), moderate (2.50-3.49), low (1.50-2.49), and very low (1.00-1.49). On the other hand, the following range and description was used to categorize the mathematics proficiency of the participants: proficient (90 and above), above average (85-89), developing proficiency (80-84), below average (75-79), failed (74 and below). Pearson product-moment correlation coefficient was employed to determine the relationship between students' cognitive and metacognitive learning strategies and their mathematics proficiency.

3. RESULTS AND DISCUSSION

This study investigated the influence of the cognitive and metacognitive learning strategies to the mathematics proficiency of the university freshmen. Despite numerous literatures on the potential benefits of these learning strategies to various academic domains, its influence on mathematics has not been fully explored. Utilizing validated, researcher-made questionnaires, cognitive learning strategies were measured in terms of four components: control, elaboration, organization and rehearsal strategies while metacognitive learning strategies were measured in terms of planning, monitoring and evaluation strategies.

3.1. Cognitive learning strategies

As presented in Table 1, respondents exhibited a high level of control strategy, as evidenced by the overall mean of 3.67. This suggests a strong aptitude for identifying essential learning objectives within the mathematics curriculum. Respondents are conscious of their learning process and can effectively identify what is important to focus on. Building upon this skill can lead to more focused and efficient study habits [35], [36]. The emphasis on pinpointing important content areas is particularly noteworthy, as it aligns with metacognitive theories of effective learning [37]. However, the ability to seek additional information when encountering difficulties is crucial for independent learning [38], [39]. To address the identified weakness, it is essential to develop students' information-seeking skills by providing explicit instruction on effective research strategies, teaching students how to use library resources and online databases, and encouraging them to seek help from teachers, peers, or other available resources when facing challenges.

Table 1. Students' level of cognitive learning strategies

Components	Mean	Description
Control	3.67	High
Elaboration	3.31	Moderate
Organization	3.28	Moderate
Rehearsal	3.96	High

On the other hand, respondents demonstrated a moderate level of elaboration strategy, with an overall mean score of 3.31. While students displayed a tendency to explore alternative problem-solving approaches, their ability to connect mathematical concepts to real-world applications and integrate knowledge from other subjects was less pronounced. This suggests that while students may possess some problem-solving flexibility, their capacity to construct deeper meaning through connections is limited [40]. This has implications for their overall mathematical learning and problem-solving abilities [41]. To enhance students' elaboration strategies, instructional practices should focus on fostering connections between mathematical concepts and real-world applications, as well as integrating mathematics with other disciplines [42]. Specifically, teachers can incorporate more real-world problem-solving scenarios into their lessons, encouraging students to apply mathematical knowledge to authentic situations. Moreover, interdisciplinary projects that connect mathematics with other subjects can help develop a broader perspectives and deeper understanding of the interconnectedness of knowledge.

Similarly, respondents demonstrated a moderate level of organization strategy, with an overall mean of 3.28. While students appeared to value the creation of summaries and review materials, their utilization of graphic organizers was notably low. This suggests a potential gap in students' organizational skills, particularly in visually representing information. The moderate use of outlines and mnemonic devices indicates a mixed picture of students' ability to structure and remember information effectively. This finding implies the need for improved organizational skills, particularly in visual representation and information structuring. To enhance students' organizational skills, teachers should prioritize incorporating a variety of organizational tools and strategies into their instruction. Emphasizing the use of graphic organizers, such as mind maps, concept maps, and flowcharts can help students visually represent information [43], identify relationships between concepts [44] and improve students' ability to structure and remember information [45].

On the other hand, respondents exhibited a high level of rehearsal strategy, with an overall mean score of 3.96. This suggests that students rely heavily on rote memorization and practice exercises to learn mathematics. This indicates that students may be prioritizing procedural knowledge over conceptual understanding in mathematics. Studies revealed that while practice is essential for skill development, an overemphasis on this approach can limit students' ability to think critically, solve complex problems, and apply mathematics to real-world situations [42], [46], [47]. The strong preference for notetaking indicates a reliance on external cues for recall, which may hinder long-term retention. To foster deeper learning, teachers should shift the focus from rote memorization to meaningful understanding. Incorporating problem-solving activities, collaborative learning, and real-world applications can help students develop a deeper appreciation for mathematics. Furthermore, teaching students effective note-taking strategies that encourage active engagement with the material, such as summarizing key ideas or connecting concepts, can improve their ability to retain information and transfer knowledge to new situations. It is essential to balance rehearsal strategies with higher-order thinking skills to ensure that students develop a well-rounded mathematical foundation.

3.2. Metacognitive learning strategies

As shown in Table 2, respondents exhibited a moderate level of planning strategy, with an overall mean score of 3.30. While students appeared to recognize the importance of setting goals, their ability to translate these goals into concrete action plans was less evident. This suggests that while students may have a general awareness of the benefits of planning, they may lack specific skills in developing and implementing effective study strategies. To address this, teachers should focus on teaching students how to break down large goals into smaller, achievable steps [48], [49]. Teaching them how to manage their time effectively, such as creating schedules and prioritizing tasks, can also be beneficial [50]. Additionally, incorporating opportunities for students to practice planning and goal setting within the classroom can help them develop these essential skills so that they can become more independent and efficient learners.

Table 2. Students' level of metacognitive learning strategies

Components	Mean	Description
Planning	3.30	Moderate
Monitoring	3.63	High
Evaluation	3.45	Moderate

On the other hand, respondents demonstrated a high level of monitoring strategy, with an overall mean score of 3.63. This suggests that students are relatively adept at tracking their progress and understanding their learning processes. However, the disparity between the high scores related to awareness of actions and strategies and the lower score for adherence to study schedules is noteworthy. This indicates a potential disconnect between students' self-awareness and their ability to regulate their study behaviors effectively. Several studies suggested that teachers should focus on developing students' self-regulation skills [51]–[53]. This can be achieved through teaching time management, goal setting, and self-monitoring techniques as well as providing opportunities for students to practice these skills in a supportive environment can also be beneficial. Moreover, helping students to identify personal factors that may interfere with their study habits can empower them to develop strategies to overcome these challenges.

Respondents demonstrated a moderate level of evaluation strategy, with an overall mean score of 3.45. Students appeared to rely heavily on summative assessments provided by teachers and their ability to engage in self-evaluation and goal reflection was less pronounced. This implies a potential overreliance on external validation and a limited capacity for self-assessment. Studies recommended that developing students' self-assessment and goal-setting abilities among students should be prioritized [54], [55]. Providing opportunities for students to reflect on their learning processes and establish personal learning goals can help them gain a better awareness of their own strengths and weaknesses. Moreover, teaching students on how to evaluate the effectiveness of different study strategies can empower them to become more independent learners and to help them take ownership of their learning and develop the skills necessary for lifelong success.

3.3. Mathematics proficiency

Table 3 presents the students' level of mathematics proficiency as measured by their grades in the course: mathematics in the modern world. The clustered distribution of grades primarily within the 75–84 range, with a weighted mean of 81.46, indicates that the students' mathematics performance falls within the developing proficiency level. This suggests that while students demonstrate partial understanding of fundamental mathematical concepts, their skills remain below the level expected for full proficiency and require further strengthening. This implies that while most students have a foundational understanding of the subject matter, there is a lack of subject proficiency and there are potential areas of significant weakness within the student population. This may be attributed to several factors such as teacher effectiveness [56], [57], curriculum design [58], socio-economic factors [59], [60], student characteristics [61], and other internal and external factors [62]. Furthermore, the clustered distribution suggests a homogeneous group in terms of achievement, indicating the need for varied instructional approaches to cater to different learning styles and paces. Moreover, an in-depth assessment to identify specific areas of weakness within the student population so that a carefully-designed intervention may be provided to the students most especially those who are struggling with specific concepts.

Table 3. Students' level of proficiency in mathematics

Performance	Frequency	Percentage
90 and above	0	0.0
85–89	22	27.5
80–84	30	37.5
75–79	28	35.0
74 and below	0	0.0

Weighted mean: 81.46. Description: developing proficiency

3.4. Relationship between cognitive learning strategies and mathematics proficiency

Correlational analysis was conducted to examine the relationship between learning strategies and mathematics proficiency, as presented in Table 4. Results indicated significant positive correlations between all three learning strategies and mathematics proficiency (Table 1). Students who reported higher levels of control (r=0.299, p=0.041), elaboration (r=0.470, p=0.017), and rehearsal (r=0.340, p=0.032) strategies tended to exhibit higher levels of mathematical competence. The findings of the present study support the notion that effective learning strategies are associated with enhanced mathematics proficiency [28]–[31]. Specifically, the results demonstrate that control, elaboration, and rehearsal strategies are positively related to students' mathematical performance. These findings align with previous research emphasizing the importance of cognitive skills, deep processing, and practice in academic achievement [32].

Table 4. Correlational analysis between respondents' level of cognitive learning strategies and mathematics proficiency

Variables	r	p	Result
Level of control strategy vs. mathematics proficiency	0.299	0.041	Significant
Level of elaboration strategy vs. mathematics proficiency	0.470	0.017	Significant
Level of organization strategy vs. mathematics proficiency	0.207	0.062	Not significant
Level of rehearsal strategy vs. mathematics proficiency	0.340	0.032	Significant

The positive correlation between control strategies and mathematics proficiency suggests that students who effectively manage their learning time, set goals, and monitor their progress tend to achieve higher levels of mathematical competence. This finding emphasizes the significance of self-regulation in academic success [51]–[53]. Furthermore, the strong positive correlation between elaboration and mathematics proficiency indicates the importance of connecting new information to prior knowledge. Students are better able to construct a deeper understanding of the subject matter when elaborating on new concepts and relating them to existing knowledge. Finally, the positive relationship between rehearsal strategies and mathematics proficiency emphasizes the role of practice and memorization in mathematical skill development. Consistent practice reinforces learning and facilitates the retrieval of information from memory, which is necessary for problem-solving and mathematical computations.

The absence of a significant correlation between organization strategy and mathematics proficiency (r=0.207, p=0.062) is unexpected, as prior literature generally supports the positive influence of organizational skills on academic performance. This finding warrants further investigation to identify potential confounding variables or alternative explanations. One possible interpretation is that while organization is a valuable study skill, its direct impact on mathematics achievement may be mediated by other factors such as the nature of the mathematics curriculum, instructional approaches, or assessment practices. In many Philippine higher education institutions, mathematics instruction remains largely procedural, emphasizing formulaic problem-solving and computational accuracy over conceptual integration. Consequently, students may rely more on rehearsal and control strategies than on organizational techniques when studying. Another possible explanation is that students' organizational behaviors—such as structuring notes or arranging study schedules—may not directly translate to deeper mathematical understanding unless coupled with metacognitive strategies like planning and monitoring. Future research could therefore examine how the effectiveness of organizational strategies interacts with teaching methods, curriculum design, and student motivation to better understand their role in supporting mathematics proficiency.

3.5. Relationship between metacognitive learning strategies and mathematics proficiency

Table 5 presents the correlational analysis between metacognitive learning strategies and mathematics proficiency. Results indicate significant positive correlations between planning (r=0.299, p=0.041), monitoring (r=0.337, p=0.038), and evaluation (r=0.360, p=0.025) and mathematics proficiency. These findings suggest a positive relationship between the use of metacognitive learning strategies and students' mathematical performance. The findings of the present study indicate the critical role of metacognitive learning strategies in enhancing mathematics proficiency [33], [34], [63].

Table 5. Correlational analysis between respondents' level of metacognitive learning strategies and mathematics proficiency

Variables	r	p	Result
Level of planning strategy vs. mathematics proficiency	0.299	0.041	Significant
Level of monitoring strategy vs. mathematics proficiency	0.337	0.038	Significant
Level of evaluation strategy vs. mathematics proficiency	0.360	0.025	Significant

Students who effectively engage in planning, setting goals, and organizing their learning are more likely to approach mathematics tasks with a clear purpose and direction. This proactive approach contributes to improved performance by facilitating efficient time management and resource allocation. Moreover, the positive association between monitoring strategies and mathematics proficiency emphasizes the significance of self-awareness and self-assessment [54], [55]. Students who effectively track their progress, identify areas of strength and weakness, and adjust their learning strategies accordingly demonstrate greater autonomy and control over their learning. Finally, the positive relationship between evaluation strategies and mathematics proficiency reveals the importance of reflective thinking [64], [65]. Through reflecting on their learning experiences, students gain valuable insights into their problem-solving processes, identify errors, and develop effective strategies for future tasks. While the current study provides evidence for the positive impact of metacognitive learning strategies on mathematics proficiency, further research is needed to examine the effectiveness of specific metacognitive interventions.

4. CONCLUSION

The findings of this study provide empirical evidence for the significant role of both cognitive and metacognitive learning strategies in enhancing mathematics proficiency. The study demonstrates that freshmen who consistently apply cognitive strategies such as control, elaboration, and rehearsal, along with metacognitive processes including planning, monitoring, and evaluating their learning, exhibit higher mathematics proficiency. These findings highlight the need for mathematics instruction to explicitly teach and embed learning strategies in the curriculum through activities like reflective learning journals, guided problem-solving checklists, and self-assessment tasks requiring students to explain and justify their solution processes.

Schools should also strengthen student support by offering structured programs such as peer tutoring, remedial mathematics sessions, and skills-focused workshops, while teachers should receive professional development that equips them to model think-aloud strategies, scaffold metacognitive questioning, and design lessons that promote reasoning and reflection. Technology-enhanced platforms, including adaptive learning systems and interactive simulations, may further individualize skill development and track strategic learning progress. While the study's cross-sectional nature and limited population restrict causal interpretation and generalizability, future research should examine the long-term effects of strategy use on academic growth, investigate how motivation and self-efficacy mediate these relationships, and compare the effectiveness of different instructional interventions for improving students' cognitive and metacognitive learning skills.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

This study is classified as exempt from ethics review as per policy of the University Ethics Review Committee.

DATA AVAILABILITY

Derived data supporting the findings of this study are available from the corresponding author, [PMC], on request.

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