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# Metacognition in General Science to Improve the Academic Performance of Students

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Abstract

This study explored the impact of metacognition on academic performance in general science among 90 students at General Mariano Alvarez Technical High School in Barangay Poblacion 1, General Mariano Alvarez, Cavite. Utilizing an experimental design, a pre-test and post-test were administered to both control (traditional) and experimental (metacognition) groups. The sample predominantly comprised 14-year-old males. Initial results showed low performance levels in both groups. However, post-test results indicated a significant improvement, with the traditional group showing high performance and the metacognition group exhibiting very high performance. Statistical analysis revealed a significant difference between pre-test and post-test scores within both groups, highlighting the effectiveness of the metacognitive intervention. The findings suggest that students in the metacognition group outperformed their peers in the traditional group, demonstrating the substantial benefit of metacognitive strategies in enhancing academic performance.

Keywords: metacognition, academic performance, General Science, metacognitive tasks, metacognitive strategies



## INTRODUCTION

Science education is vital to the Philippine education system since it allows individuals to adopt a more critical mindset. Frequently, the relevance of science has been attributed to its connection to technology, which, from the government's perspective, is a priority sector for economic development (Elkington, 2015).

However, the nation is currently experiencing a notable decline in science learning performance. Numerous Filipino students struggle to comprehend and appreciate the value of science education. Surprisingly, a majority of these students show a lack of interest in science subjects, which is often attributed to insufficient motivation and adoption of ineffective learning practices. Although they excel in tasks that involve rote memorization, there is a decline in their higher-order thinking skills (HOTS) (Rahimi & Katal, 2011). Additionally, students perform well on assessments focused on rote recall but they show poor performance on tests measuring comprehension and analytical abilities.

Teachers play a crucial role in equipping students with required skills and information to master the subject (Wilson, 2009). They act as a facilitator of knowledge within the classroom. Moreover, their relationship with their students is also essential to students' academic performance. For students to appreciate, be motivated, and embrace science, scientific education must be in line with international benchmarks (Malicsi, 2008).

The declining quality of students' responses to critical questions necessitates immediate intervention to address this longstanding issue. One contributing factor is students' fear of answering open-ended questions due to excessive concern with grammatical accuracy. This preoccupation with grammar hinders their ability to articulate ideas, beliefs, and point of view effectively. While studies indicate that the state of science education in the country is at risk, targeted interventions are needed to improve students' critical thinking.

The critical and reflective thinking of students is deteriorating, which can be attributed to the complexity of language used and student's poor learning capability and motivation. In addition, most science subjects require memorization of new complex terms. While studies highlight the decline in students' thinking ability, academic performance improves with enhanced critical thinking skills (Mahmoudi & Khonamri, 2010; Camahalan, 2006; Birjandi et al., 2006).

Former education Secretary Leonor Magtolis Briones emphasized the need to improve teaching science and technology education. Furthermore, the current president underscored the importance of strengthening science instruction in schools to support the country's economic growth.

In light of these conditions, this study aims to determine whether metacognition is effective as a teaching strategy in science and its potential to improve academic performance. To be specific, the research investigates whether the students' performance improves when teachers enhance students' metacognition knowledge, assign metacognitive tasks, and teach metacognitive strategies.

LITERATURES

Metacognition and Theoretical Foundations. Metacognition, a central focus in cognitive developmental research over the past four decades (Louca-Papaleontiou, 2008; Goh, 2008), encompasses various definitions and theoretical underpinnings. Often described as "beyond thinking" or the "seventh sense," it represents a critical mental process utilized by successful learners (Birjandi et al., 2006). Defined as an awareness of necessary skills, strategies, and resources for effective task performance, metacognition involves self-regulatory mechanisms ensuring task completion (Baker & Brown, 1984). Key features include self-appraisal, reflecting on understanding and mental states, and self-management, guiding problem-solving processes (Cross & Paris, 1988; Paris et al., 1990). Modern research initially neglected metacognition until recent decades (Schoenfeld, 1992), highlighting its growing importance in educational contexts and beyond. Goh (2008) stated that metacognition was first introduced in cognitive psychology, describing it as the process of thinking about one's thinking or the ability to be conscious of one's mental processes. Birjandi et al., (2006) said that metacognition is sometimes termed the 'seventh sense' and it is one of the mental processes successful learners use.

Recent psychological studies on metacognition have emphasized its role in consciousness, awareness, and understanding of thinking and problem-solving (Campione, 1987). Metacognition can be categorized into two main domains: metacognitive knowledge and metacognitive processes. Metacognitive knowledge involves understanding how one's mind works, including knowledge about oneself, tasks, and strategies for executing them. In contrast, metacognitive processes encompass activities such as planning, monitoring, and regulating one's cognitive processes. These processes are crucial for effectively employing learning strategies, termed metacognitive strategies, across different learning tasks.

These two domains are intricately connected in the learning process. Metacognitive knowledge serves as the foundation for learners to effectively manage and monitor their own learning experiences, while metacognitive processes involve the practical application of this knowledge. Boghian (2016) highlighted that metacognitive knowledge can compensate for deficits in IQ and schema among learners, underscoring its pivotal role in educational settings. Conversely, without the application of metacognitive processes, metacognitive knowledge remains ineffective (Williams and Burden, 2000). Awareness of one's cognitive processes during activities such as reading, writing, and problem-solving enhances learning outcomes (Paris & Winograd, 1990), as learners gain insight into their performance across different contexts.

Educational Implications and Teaching Strategies. Bernardo, Limjap, and Roleda (2007) suggests that there may be glaring problems with the classroom experience that students themselves can see. Similarly, research by Sadera, Torres, and Rogayan (2020) underscored the challenges faced by ninth-grade students, including curriculum complexity, cognitive demands, lack of instructional resources, and classroom environment issues. To address these challenges, educators are urged to employ diverse pedagogical approaches to guide students effectively through the learning process (Borgmann & Wegner, 2011; Wegner & Minnaert, 2012). Moreover, contemporary educational environments increasingly expect students to take ownership of their learning by actively engaging with course content and synthesizing concepts (Wegner, Minnaert, & Strehlke, 2013).

Metacognition theory offers promising potential for educators in creating adaptable and innovative educational settings (Borkowski & Muthukrishna, 1992). Research underscores that integrating metacognitive development strategies effectively can enhance students' learning outcomes (Davidowitz & Rollnick, 2003; Paris & Winograd, 1990; Thomas & McRobbie, 2001). Additionally, studies indicate a positive correlation between metacognition and problem-solving abilities (Bakiolu et al., 2015; Kaplan et al., 2016; Safari & Meskini, 2016; Serin, 2014), though findings on the effectiveness of metacognitive strategies in specific subjects like Chemistry and Physics vary (Antonio & Prudente, 2022; Fallesgon, 2015; Kodri Madang & Masagus Mhd, 2020; Tibrani & Susanti, 2020). Research highlights that metacognitive strategies are less commonly utilized compared to traditional teaching methods (Kistner et al., 2010; Leutwyler, 2009), necessitating further investigation into their application, especially in foundational subjects such as Science and Mathematics (Sanium & Buaraphan, 2019). It is suggested that future studies employ rigorous research designs to provide causal evidence regarding the effectiveness of metacognitive instruction in enhancing science learning (Zohar, 2013). Effective implementation of metacognitive activities requires guided instruction rather than independent learning to foster students' responsibility in planning, monitoring, and evaluating their learning tasks (Kramarski et al., 2002).

Creating an environment conducive to metacognitive development is crucial, as argued by Borkowski and Muthukrishna (1992), who advocate for environments that encourage deliberate planning and evaluation of mental processes to achieve learning goals. Metacognitive strategies, such as self-questioning and reflection, play an integral role in this process, facilitating the development of students' metacognitive skills (Boekaerts & Simons, 1995; Blakey & Spence, 1990).

Metacognition and Academic Performance. Campione (1987) identified three key elements crucial for enhancing performance: comprehensive domain knowledge, specific operational procedures within the domain, and general task-independent processes. Meanwhile, De Corte (1996) emphasized that exemplary performance involves structured domain-specific knowledge, heuristic methods, affective components, and metacognition. Research by Schneider (2010) and Efklides & Vauras (1999) corroborates that learners who employ metacognitive strategies experience improved memory development and enhanced learning outcomes.

Numerous studies have demonstrated a link between metacognition and enhanced academic performance among students (du Toit & Kotze, 2009; Magno & Lajom, 2008; Camahalan, 2006; Rock, 2005; Magno, 2005; Elliot, McGregor, & Gable, 1999; Lopez, Little, Oettingen, & Baltes, 1998; Schraw, 1998; Butler & Winne, 1995; Blakey, 1990; Schneider, 1985; Kluwe, 1982). However, much of the existing research focuses narrowly on specific tasks or learning domains such as reading, writing, problem-solving, and economics (Veenman & Beishuizen, 2004; Zhang, 2001; Leutner & Leopold, 2000; Van Kraayenoord & Schneider, 1999; Otero et al., 1992; Nist et al., 1999; Afflerbach, 1990). Consequently, there remains a scarcity of studies investigating the impact of metacognition on academic performance in Science (Boghian, 2016; Louca-Papaleontiou, 2003; Zohar, 1999).

Glaser et al. (1992) revealed that students' metacognitive abilities vary across different tasks, highlighting a disparity in research focus between disciplines such as reading and science. Despite this disparity, Veenman et al.

(1997; 2003; 2004) contend that metacognitive skills exhibit a general applicability across various contexts, suggesting a need to explore how these skills can be effectively transferred across different learning domains (Veenman & Spaans, 2005; Salomon & Perkins, 1989).

Therefore, this research identifies a critical need to evaluate the impact of metacognition on students' overall academic performance in science under controlled conditions. Employing a pre-test and post-test design, the study aims to ascertain whether integrating metacognitive strategies enhances students' academic achievement in general science. Specifically, it aims to analyze participant demographics, compare performance between controlled and experimental groups across pre and post-tests, assess differences in mean scores between traditional and metacognitive groups, and evaluate the overall gains made by participants. Additionally, the study hypothesizes no significant differences in student scores pre-test and post-test, nor between traditional and controlled groups during post-tests. Statistical analyses including percentage, weighted mean, and two-tailed t-tests were utilized to process the data, revealing insights that enhance academic performance through heightened awareness of cognitive processes among participants in the experimental group.

The results of this study will provide valuable insights and practical benefits to multiple stakeholders. For teachers, it offers strategies to enhance students' cognitive abilities and deepen their understanding of science through metacognition, encouraging them to reflect on their learning processes. Students stand to benefit by discovering that science learning can be engaging and enjoyable with metacognitive approaches, fostering skills like problem-solving, independent thinking, and creativity. Curriculum planners can use the findings to introduce innovative teaching methods that optimize the teaching-learning process and improve student performance. Additionally, this study will contribute to the broader academic community by serving as a reference for researchers investigating the efficacy of metacognition across different subjects, guiding them in identifying optimal contexts for its application in educational settings.

## METHODS

Population and Sampling. The experiment took place at General Mariano Alvarez Technical High School, Poblacion 1, General Mariano Alvarez, Cavite, Division of Cavite, from November to December 2022. The study's participants consisted of ninety grade nine students, divided into metacognitive and control groups.

Research Design. The research employed an experimental method, specifically utilizing a pretest-posttest control group design. This design involved comparing the academic performance in science between a control group and an experimental group, where the metacognition (experimental) group received an intervention focused on metacognition during lessons while the traditional (control) group did not receive this intervention. The study assessed the impact of metacognition by administering a summative test after exposure to the experimental conditions, while keeping all other variables constant (Calderon & Gonzales, 2020).

Data Gathering Procedure. A randomized pretest and posttest were conducted to evaluate any significant differences in outcomes between the control and experimental groups. Both groups underwent two sets of tests: the first served as a pretest, and the second as a posttest, with data collected simultaneously. The study developed and validated a teacher-made test to ensure its reliability and validity as a measurement tool aligned with the study's criteria.

Data Analysis. Data from the pretest and posttest were processed using the Statistical Package for Social Sciences (SPSS) program for mean calculations, mean differences, standard deviations, t-values, and significance levels ($p < 0.05$).

RESULTS

Table 1
*Respondents' Profile in terms of Gender and Age*

| Profile | Description | f | % |
|---|---|---|---|
| Gender | Male | 52 | 58 |
| | Female | 38 | 42 |
| | Total | 90 | 100 |

| Profile | Description | F | % |
|---|---|---|---|
| Age | More than 16 yrs. old | 0 | 0 |
| | 16 yrs. Old | 11 | 12 |
| | 15 yrs. Old | 30 | 33 |
| | 14 yrs. Old | 49 | 55 |
| | Total | 90 | 100 |

Table 1 presents the profile of the respondents in terms of gender and age. There are a total of 90 respondents in the study, 52 or 58% of them are males and 38 or 42% of them are females. This implies that majority of the respondents are males.

In terms of age, there are 49 respondents (55%) under 14 years old, 30 respondents (33%) under 15 years old, and 11 respondents (12%) under 18 years old. The majority of the respondents are 14 years old.

Table 2
*Level of Performance Between Control and Experimental Group During Pre-Test and Post-Test*

| Groups | Level of Performance | Pre-test | | Post-test | |
|---|---|---|---|---|---|
| | | f | % | f | % |
| Traditional Group | Very High | 0 | 0.00 | 8 | 17.78 |
| | High | 0 | 0.00 | 27 | 60.00 |
| | Moderate | 18 | 40.00 | 10 | 22.22 |
| | Low | 27 | 60.00 | 0 | 0.00 |
| | Very Low | 0 | 0.00 | 0 | 0.00 |
| Metacognition Group | Very High | 0 | 0.00 | 37 | 82.22 |
| | High | 0 | 0.00 | 8 | 17.78 |
| | Moderate | 17 | 37.78 | 0 | 0.00 |
| | Low | 28 | 62.22 | 0 | 0.00 |
| | Very Low | 0 | 0.00 | 0 | 0.000 |

As shown in table above, the performance of the students in traditional Pre-test is low with the highest frequency of 27 or 60% while for post-test, the highest frequency is 27 or 60%, with a level of performance high. As to metacognition, for pre-test, the highest frequency is 28 or 62.22%, low and for the post-test, the level of performance is very high with a frequency of 37 or 82.22%. The data presented indicates a significant improvement in the performance of students in both the control and experimental groups from the pre-test to the post-test.

Table 3
*Level of Performance Between Traditional and Metacognition Group During Pre-test and Post-test*

| Groups | Test | Mean | Mean Difference | df | T | Sig-2-tailed |
|---|---|---|---|---|---|---|
| Traditional | Pre-test | 12.06 | -9.24 | 44 | 98.69 | .000 |
| | Post-test | 21.31 | | | | |
| Metacognition | Pre-test | 11.9111 | -14.6444 | 44 | -28.958 | .000 |
| | Post-test | 26.5556 | | | | |

Table 3 shows the significant difference in the performance of the students in both the traditional and metacognition groups. The mean of the pre-test in the traditional group is 12.06 while the mean post-test is 21.31. The mean difference is -9.24 and the sig-2 tailed value .000. As to the metacognition group, the mean of the pre-test is 11.9111 while the mean of post-test is 26.5556. The mean difference in -14.6444 and the sig-2 tailed value .000.

The mean difference for the metacognition group (-14.6444) is greater than that of the traditional group (-9.6444). While both teaching methods led to significant improvements in student performance, the metacognitive approach was significantly more effective.

Table 4
*Significant Difference in the Performance of the Students in Traditional and Metacognition Groups During Pre-Test and Post-Test*

| Groups | Test | Mean | Mean Difference | df | T | Sig-2-tailed |
|---|---|---|---|---|---|---|
| Traditional | Pre-test | 12.06 | .155 | 44 | .239 | .81 |
| Metacognition | Pre-test | 11.91 | | | | |
| Traditional | Post-test | 21.31 | -5.244 | 44 | -16.57 | .00 |
| Metacognition | Post-test | 26.55 | | | | |

The Sig (2-tailed) value of .812 for the comparison between the traditional and metacognition groups' pre-test scores is greater than .05. This implies that there is no statistically significant difference in the initial performance levels of the students in the two groups before the intervention. The students started with similar levels of performance in both groups.

The Sig (2-tailed) value of .000 for the comparison between the traditional and metacognition groups' post-test scores is less than .01. This indicates a statistically significant difference in the performance of students after the intervention. The post-test scores of the two groups are significantly different, suggesting that the type of intervention (traditional vs. metacognitive) had a notable impact on their academic performance.

The results of the study that show that strategies have a positive effect on academic performance conform with the findings of Boekaerts and Simons (1995), and Blakey and Spence (1990). They posited that the strategies the learners use before, during, and after learning help develop their metacognitive skills which leads to better academic performance. This was also supported by du Toit & Kotze (2009) who posited those metacognitive strategies lead to the most successful learning.

Based on the results of the study, the use of metacognition in general science improves the academic performance of students, as evidenced by the significant difference in the results of the post-test of the traditional and metacognition groups. This indicates that the intervention used prior to the post-test was effective, as scores increased and there is a significant difference between pre-test and post-test results. Student performance on the traditional and metacognition post-tests differs considerably. In the metacognition group, the students perform exceptionally well.

With this, the research proposes the following metacognitive strategies in improving students' academic performance in science (Table 5):

Table 5
*Proposed Metacognitive Strategies*

Purpose: Using metacognitive strategies in secondary education has been shown to improve student's critical thinking, provide them with new tools for organizing their thoughts while learning, aid in media literacy, and instill in them the growth mindset that is so crucial to their academic and personal success (Norman, 2016).

| STEPS | DESCRIPTION | GUIDE QUESTIONS |
|---|---|---|
| 1. Engage in Self-Questioning or Reflection | During the planning phase of a task, an important metacognitive strategy that students can engage is self-questioning. Help your students to reflect and talk to themselves constructively and helpfully, they'll perform better academically. | • Why is this topic important?<br>• How will this lesson help me in the future?<br>• Is this similar to a previous task?<br>• What do I want to achieve?<br>• What do I need to work on?<br>• How can I best use my strengths to learn? |
| 2. Development | After a short reflection let your students set their own achievable goals. Before completing a task, it's important that students do goal setting right and set both long-term and short-term goals.<br><br>However, goal setting isn't just about the destination - it's about the journey as well. During the planning stage, students should also set themselves short-term goals as they serve two main purposes:<br><br>They keep your student on track - By breaking a task up into smaller, more easily attainable chunks, students will be able to keep track of their progress during the Doing phase which can help boost motivation.<br><br>They make your student more productive - Students are less like to procrastinate if they only have to focus on one small task at a time. By seeing how their small efforts are contributing to their long-term goal, students will develop a better sense of purpose. | • What do I already know about this topic?<br>• How does this topic relate to what we have previously studied?<br>• What should I do first?<br>• What do I need to do first?<br>• What do I want to achieve first?<br>• What are the strategies and skills I will use to be effective?<br>• What steps should I take or resources should I use to meet my challenges?<br>• How can my learning environment be improved? |
| 3. Engagement | During the engagement part of the always remind them and guide them to reflect on what they do. Just like during the planning stage of a task, it's also important that students engage in self-questioning whilst they're doing the task. This will not only allow them to see whether they're on track, but also to start reflecting on their performance and determine whether any goals need to be tweaked. Research shows that students who engage in metacognitive thought have better learning gains, memory recall and academic performance in areas such as reading comprehension and science. | • How can I connect this with what I already know?<br>• What questions do I have?<br>• What am I confused about?<br>• How does this work?<br>• What were the most important ideas or concepts?<br>What do I need to know more about?<br>How has this changed what I know?<br>How can I use this later? |
| 4. Assimilation | After successfully completing a task guide them, students may not remember what they struggled with, and may not realize how much they learned. It is important that students engage in self-evaluation so that the next time they complete a task, they can apply what they have learned and avoid making the same mistakes.<br><br>Teachers can also encourage self-evaluation by asking students to self-question. This involves students privately answering a set of questions to review what they have learned. | • What did I learn about this topic that I didn't know before?<br>• What content was challenging to learn?<br>• Do I understand it now? |

DISCUSSION

This study investigated the impact of metacognitive teaching strategies on student academic performance. Ninety participants, primarily young males aged 14, were involved. Initially, both the traditional and metacognitive groups displayed low performance levels. However, after the intervention, students in the metacognitive group achieved significantly higher scores compared to the traditional group. Notably, both groups showed significant improvement, highlighting the overall effectiveness of the teaching approach.

These findings suggest that incorporating metacognitive teaching strategies can significantly enhance student learning outcomes. This approach may be particularly beneficial in private and rural schools where such methods might be less commonly used.

To cultivate a more effective learning environment, several recommendations are made. First, teachers, especially in private and rural schools, should actively integrate metacognitive teaching strategies. This empowers students to understand their learning processes, ultimately improving academic achievement.

Second, educators in both private and rural settings are encouraged to continue using these strategies to help students maintain high performance. However, it is crucial to evaluate the effectiveness of these interventions and assess their long-term sustainability within specific school environments. This ongoing assessment ensures that the benefits of metacognitive teaching are sustained and tailored to the specific needs of each school.

Finally, future studies are recommended to explore the application of metacognitive strategies across various subjects, grade levels, and school types (private and rural). This will broaden the current knowledge base and support wider implementation.

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