

The Impact of Metacognition on The Academic Performance of Medical Students: A Randomized Clinical Trial

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ABSTRACT

Metacognition is the ability to self-regulate and monitor cognitive processes by reflecting on one's own knowledge. When conceived as a tool to facilitate learning, it should be associated with the principles of andragogy. This study analyzes the impact of metacognition on learning using different teaching methodologies. Participants were divided into four groups of six individuals: active methodology (AM); traditional methodology (TM); active methodology + metacognition (AM+M); traditional methodology + metacognition (TM+M). Each group attended in-person classes, with or without metacognition depending on the group. Learning retention was assessed through objective tests after 30, 60 days, and six months.

Keywords: Metacognition, executive function, medical education, and academic performance

1. INTRODUCTION

The concept of executive functions refers to a group of cognitive processes that encompass skills for planning, monitoring, and organizing complex activities toward a specific goal. In this sense, neurological connections in the prefrontal cortex enable individuals to organize and structure their environment and allow them to control their behavior through attention, reflection, and reasoning from different perspectives. The main components of these functions involve working memory, cognitive flexibility, and inhibitory control. The importance of the interaction between executive functions and social skills is therefore highlighted, showing that the development of these skills directly impacts academic performance and adaptation to challenging contexts (Boer & Elias, 2022). In addition to these aspects, self-regulation of confidence in one's own performance also plays an essential role in modulating executive functions, directly influencing decision-making and behavior control in learning and problem-solving situations (Fleming, 2023).

With this information in hand, it is clear that the learning process is associated with the control of planning and management of cognitive activities. Based on this assumption, metacognition is related to this same regulatory objective (Acco & Werner, 2021). In this context, John H. Flavell was one of the pioneers in

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defining metacognition as a specific area of study, characterizing it as self-regulation that focuses on the cognitive system itself, that is, a reflection on one's own knowledge. This process involves planning, goal setting, organization, and self-monitoring of the knowledge acquisition process. From the perspective of cognitive neuroscience, we observe the component of metaknowledge (an individual's knowledge about their own cognitive process) and metacontrol, which involves a person's self-regulation mechanisms, such as planning and adapting behavior based on the results obtained (Fleur, Bredeweg, & van den Bos, 2021). Strategies to strengthen metacognition in higher education, especially in health courses, include structured interventions that encourage students to monitor and evaluate their own learning processes. Such approaches have been shown to be effective in improving academic performance and developing autonomy in learning (Medina, Castleberry, & Persky, 2017). Thus, metacognition has been studied in medical education, indicating that students who develop greater metacognitive awareness perform better academically and are more motivated to learn (Siqueira, Silva, Oliveira, & Nunes, 2020).

Given this, when referring to the psycho-emotional perspective, a longitudinal study conducted in England, the Twins Early Development Study (TEDS), associated genetic factors with non-cognitive skills and found that these play a substantial role in academic performance. Non-cognitive skills are characteristics that encompass an individual's ability to adjust their attention and regulate their impulses; they cover three domains, namely motivation, self-regulation strategies, and personality (Malanchini et al., 2024). Based on this, these characteristics are an important resource for the active use of metacognition, implying better academic performance in medicine. The relationship between metacognitive awareness and academic performance is also prominent in medical students, indicating that those who have greater awareness of their own cognitive processes demonstrate better academic results and greater adaptation to the demands of the course (Nguyen et al., 2023). It can be inferred that the development of these skills not only improves academic performance but also influences professional training, promoting greater adaptability and resilience in medical students.

Furthermore, in addition to their impact on education, improving the transmission, acquisition, and retention of knowledge, metacognitive processes are also applicable in medical practice. They involve a critical analysis of thinking that can guide action during medical practice, helping to avoid intuitive or automatic thoughts that may be subject to cognitive biases (Garudadri, 2024). In the context of medicine, the ability to monitor and adjust one's own clinical reasoning has been associated with greater diagnostic accuracy and improved decision-making, reducing errors that could compromise the quality of patient care (Wang, Chen, & Huang, 2023).

Therefore, since metacognition is the first step in questioning acquired knowledge, this tool requires students to be aware of and discern their way of thinking (Jerusalem Merkebu, Veen, Hosseini, & Varpio, 2024). All this mental effort makes students participate productively and actively in the construction of their knowledge, broadly covering their cognitive functions and possibly improving academic performance. Therefore, this study aims to evaluate the impact of metacognition on learning in medical students using different teaching methodologies. The integration of metacognitive strategies in clinical teaching has shown significant benefits, helping students improve their diagnostic reasoning and reduce medical errors (Garudadri,

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2024). Therefore, this study aims to evaluate the impact of metacognition on learning in medical students using different teaching methodologies.

2. MATERIALS AND METHOD

2.1 Research classification

This is a quasi-experimental, descriptive model with qualitative and quantitative approaches.

2.2 Data collection procedure

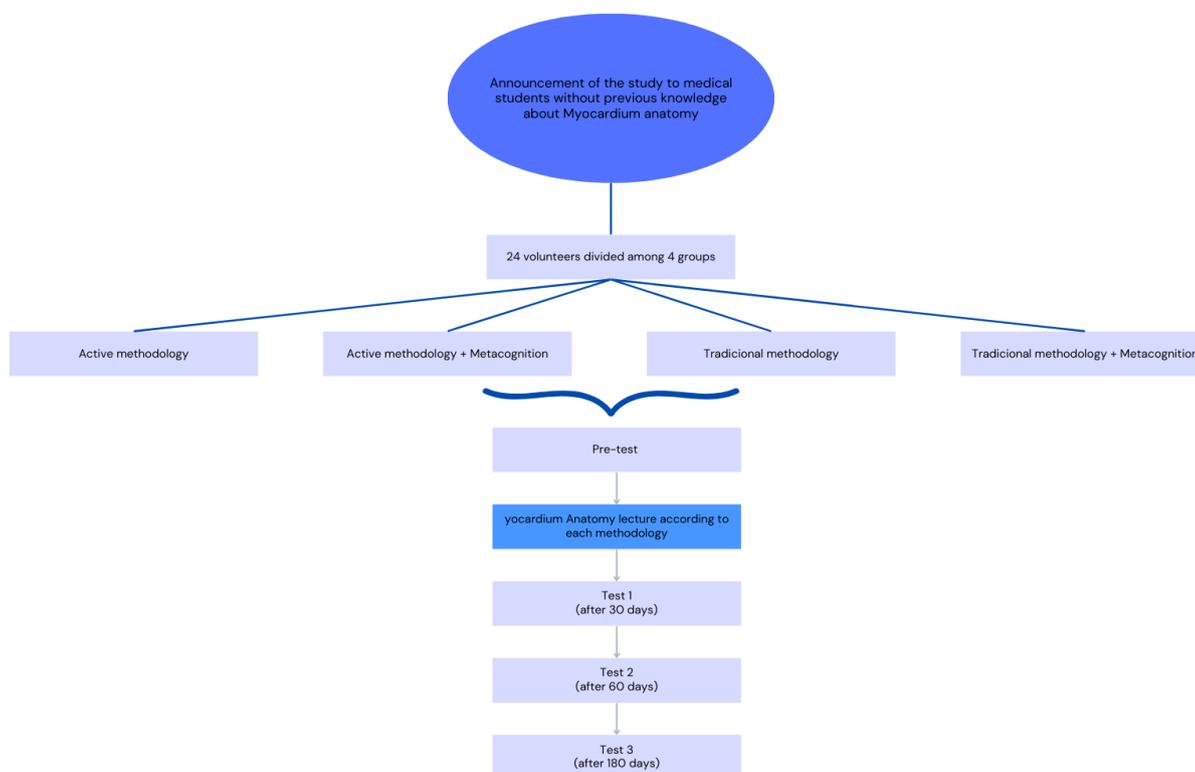
To obtain the data, participants were divided into four groups of six individuals: active methodology (AM); traditional methodology (TM); active methodology + metacognition (AM+M); traditional methodology + metacognition (TM+M). For each group, classes were held in person at different times, with the theme Human Anatomy: Vascularization of the Heart.

For TM and TM+M, a lecture was given, while for AM and AM+M, a flipped classroom was used, with content made available in advance via video lessons.

Immediately before the theoretical moment, a pre-test with 10 questions of different cognitive levels was conducted for all groups. For the MT+M and MA+M groups, after the theoretical moment, the metacognitive experience was conducted (Versteeg et al., 2021).

In addition, after 30, 60 days, and six months, new tests were administered using the same model to these participants to assess knowledge retention over time.

The participants were medical students from the Barão de Mauá University Center in classes 32 and 33 of the course, who had no prior contact with the material taught in class.



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Figure 1. Flowchart of the study design showing group allocation and assessment timeline.

Note. Flowchart of the study design with participants divided into four groups (MA, MA+M, MT, MT+M), application of the pretest, lesson on myocardial anatomy according to the adopted methodology, and three subsequent tests after 30, 60, and 180 days to assess knowledge retention.

2.3 Ethical considerations

This study was approved by the Research Committee of Barão de Mauá University Center under approval number 7.312.819, in accordance with the National Health Council Resolution No. 466/ 12.

3. RESULTS

Based on the application of the methodology used and explained above, a variable impact of the different teaching approaches—with and without metacognition—on the academic performance of medical students over time was observed. The results obtained through the tests show that both the active methodology and the inclusion of metacognition positively influenced the students' average scores, especially in the short term. The data obtained based on the average number of correct answers per student in each group were analyzed descriptively and comparatively in order to assess knowledge retention and the effect of metacognition associated with different pedagogical strategies.

The tests, with 10 multiple-choice questions of different cognitive levels, were administered at four different times (time 0 - pre-test; 30 days - test 1; 60 days - test 2; 180 days - test 3) to the four groups of different teaching methodologies, associated or not with metacognition. Each group contained the minimum required number of six volunteers. The average number of correct answers per student in each test was calculated, as shown in Table 1. Next, there is a graphical analysis of the table, which visually explains the performance and evolution of each group in Graph 1.

The graphical demonstration of the average number of correct answers shows that active methodologies resulted in higher average scores than traditional ones in all tests. Test 1 showed the greatest evolution for all groups, and in it, the average of the active methodology associated with metacognition significantly exceeded the average of the traditional methodology, with a difference of 3.17 points. Disregarding the pre-test, the lowest score was for the traditional methodology group in tests 1 and 2, and the highest score was for the active methodology + metacognition group in test 1. In addition, the comparison between groups of the same type of methodology (both traditional and active) shows that those associated with metacognition obtained higher scores, especially in the short term (test 1). Except for test 3, the use of active methodology, whether associated with metacognition or not, promoted higher average scores than traditional methodology.

In the active methodology, the association of metacognition no longer promotes higher average scores in test 2. In the traditional methodology, however, the association of metacognition continues to promote a higher average score in test 2, indicating that its association in this (traditional) context seems to promote better results for longer. In general, the association of metacognition and the use of active methodology seem to promote better results in the short term (30 days), rapidly improving (and in a numerically more significant way) the students' performance on the test (see the jump in the average number of correct answers between

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the pre-test and test 1). In the medium term (60 days), this effect of the association of metacognition stabilizes in the context of traditional methodology and even declines in the context of active methodology.

Subsequently, a further analysis will be carried out to compare pre- and post-test performance, using Student's t-test for paired data, and between the four groups, to compare the evolution of the groups' average performance at each moment of assessment (0, 30, 60, and 180 days), using Analysis of Variance (ANOVA) of repeated measures. Thus, it will be possible to relate these data to the methodology used and the presence or absence of metacognition. Given this, there will be an interpretation of the frequency distribution of responses for each profile, in order to assess the level of impact of metacognition from the perspectives of the two methodologies involved.

Table 1. Table showing the average number of correct answers per student according to different teaching methodologies.

Methodology	Pre-test	Test 1	Test 2	Test 3
Active	2,67	5,66	5,66	5
Active+Metacognition	3	6,5	5,16	4,5
Traditional	2,16	3,33	3,33	4,33
Traditional+metacognition	2,16	4	4,16	4,83

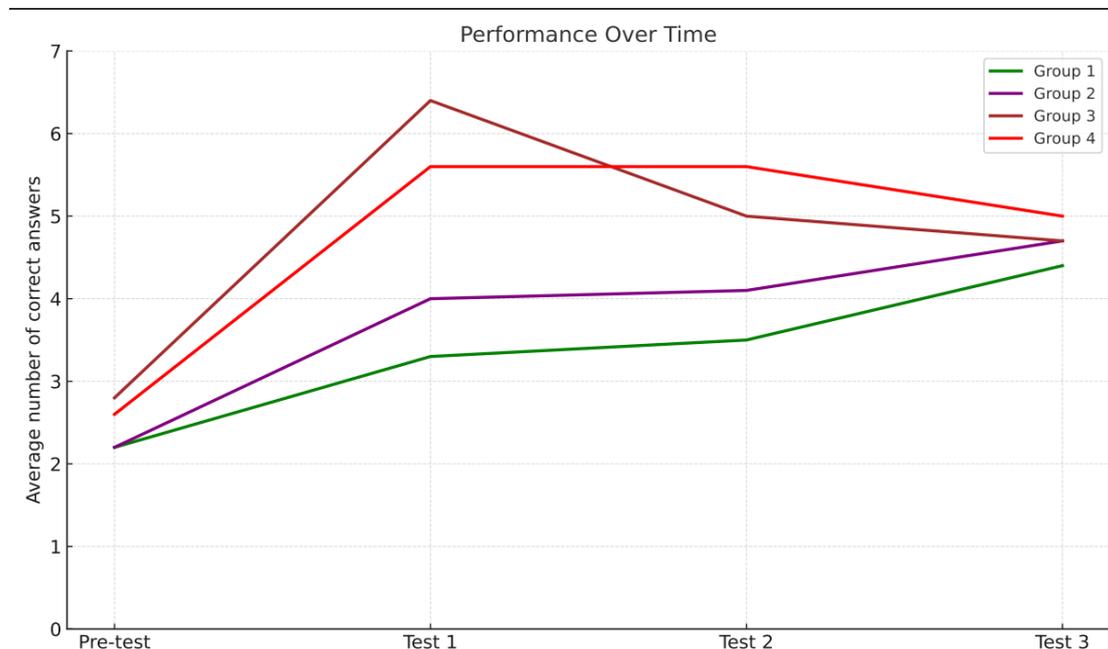


Figure 2. Average number of correct answers per group over four assessment points

Note. Average number of correct answers per group across four assessment moments (Pre-test, Test 1, Test 2, and Test 3). Group 1 (green), Group 2 (brown), Group 3 (purple), and Group 4 (red) showed different performance trends over time, with Groups 3 and 4 maintaining higher scores.

4. DISCUSSION

The methodology of the article *Effectiveness in Fostering Metacognition: Analysis Into the State of Metacognition within South African Physical Science Classrooms with the Aim of Improving Attainment* involved a qualitative analysis in Physical Science classrooms in South Africa, with the aim of evaluating the use and effectiveness of metacognitive strategies in the teaching-learning process. The research was based on observations of teaching practices, interviews with teachers, and questionnaires administered to students. The results indicate that developing students' awareness of their own learning processes can contribute to improved understanding and academic outcomes. This finding corroborates the idea that metacognition improves performance in the short term by helping students overcome immediate difficulties (Rajcoomar, Morabe, & Breed, 2022).

Similarly, the article *Simple Metacognitive Prompts for Enhancing Student Learning: An Interdisciplinary Study* investigates the use of simple metacognitive prompts, which are instructions or questions designed to encourage students to reflect on their learning process. The methodology involved applying these prompts to students in different disciplines, collecting qualitative and quantitative data to assess their impact on reflection, comprehension, and content retention. The results indicate that the use of metacognitive prompts can significantly improve learning by promoting greater awareness and control over the students' learning process. Thus, these findings highlight the relevance of investigating the association of metacognitive models with different teaching methodologies, seeking to continuously improve the teaching-learning process (Domokos & Huey, 2021).

The article “*Leveraging Deep Reinforcement Learning for Metacognitive Interventions across Intelligent Tutoring Systems*,” published in April 2023, investigates how metacognitive interventions based on deep reinforcement learning can be applied in intelligent tutoring systems to improve student learning. The results indicate that these adaptive interventions help close the metacognitive skills gap among students, better preparing them for future learning.

Similar to the methodology of this article, this study used a quantitative approach, collecting data from student interactions to evaluate the effectiveness of metacognitive interventions, comparing learning outcomes before and after the implementation of adaptive interventions. The impact of the interventions is measured in terms of improvement in students' academic performance and the development of metacognitive skills.

Another quantitative study was conducted with data collection through questionnaires, interviews, and performance observations, seeking to measure the impact of interventions on student performance. The article entitled “*Personalized strategies for academic success in learning anatomy*” explores how personalized strategies, combining metacognitive and technological adaptation, can improve anatomy learning in medical students. The research used technological tools alongside self-reflection and self-regulation practices. The results indicated that these approaches increased motivation, confidence, and content retention, showing that the integration of metacognition and technology is effective in optimizing academic learning (Stambuk-Castellano et al., 2024).

The relationship between metacognition and confidence has also been widely discussed. The article *Metacognition and Confidence: A Review and Synthesis* reviews studies on this relationship, highlighting that

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the ability to monitor and regulate one's own thinking has a significant impact on student confidence. Developing these skills can thus improve performance in a variety of tasks, from learning to decision-making. This development of confidence is especially relevant for the implementation of active teaching methodologies, such as the study presented here, which requires greater autonomy on the part of students.

In another approach, the review *Strategies for Improving Learner Metacognition in Health Professions Education* explores educational practices to enhance the metacognitive skills of students in the health professions. The study reviews strategies such as targeted questioning, behavior modeling, and the promotion of reflection, concluding that these approaches can help students monitor and adjust their learning processes, resulting in improvements in both academic performance and the development of essential skills.

In turn, the study *Relationship Between Metacognitive Awareness of Undergraduate Students and Students' Academic Performance at Vietnam Military Medical University* explores the relationship between metacognition and academic performance in medical students. The results indicate that high metacognition is directly associated with better academic performance. However, the research points out that the study was conducted in a teaching hospital with a predominantly military sample, which may have positively influenced the students' metacognitive and self-regulation skills, given that this group demonstrated a significantly higher average in these aspects.

In addition, the study *What Were You Thinking? Medical Students' Metacognition and Perceptions of Self-Regulated Learning* presents a qualitative analysis of metacognition in third-year medical students, conducted at Leiden University Medical Center (LUMC). The data indicate that, although students assess their knowledge and learning ability based on assessment results, this practice is often associated with superficial learning and memorization. The study suggests that teaching methods that encourage critical thinking and metacognitive reflection are necessary for deeper development of student learning. On the same topic, a study was conducted using quantitative and qualitative tools at the University of São Paulo, which analyzed the relationship between metacognitive self-awareness and motivation to learn in a sample of 185 clinical cycle students. It was found that students with a mastery approach goal orientation profile, whose focus emphasizes academic self-improvement over assessment performance, have greater mastery of cognitive regulation. Thus, both studies are aligned with the findings of the current study, highlighting the importance of incorporating active methodologies that promote metacognition at all stages of medical education. USP

In addition, another study investigated changes in the metacognition of health students in an anatomy course. It observed that, especially at the beginning of the course, students demonstrate greater receptivity to metacognitive activities. Such activities have a more significant impact on individuals with intermediate performance, highlighting the need to adapt teaching approaches to maximize their effectiveness (Boszko, Rosa, & Delord, 2023). Additionally, *Exploring medical students' metacognitive and regulatory dimensions of diagnostic problem solving* analyzed the level of metacognitive competence in resolving diagnostic hypotheses, exploring, unlike the first article, a group of 72 sixth-year students. From this, it was concluded that a significant number of students reach the end of the course without the ability to recognize when a problem has been fully understood or how to monitor their thinking during diagnostic reasoning. Thus, it is understood that in health courses, with extensive and challenging subjects, metacognition associated with self-

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regulation of learning can therefore significantly improve academic results and should be implemented from the outset, aiming at better long-term performance. However, despite evidence of the effectiveness of metacognition in aiding learning, there is still a lack of studies focused on improving teacher training, which is an essential step in ensuring the effective application of metacognition in the educational environment, regardless of school level.

5. CONCLUSION

Given this, it can be concluded that metacognition seems effective in improving test results in the short term, for both traditional and active methodologies. This is very relevant, given that students are expected to overcome their difficulties and improve their performance as soon as possible, especially in the face of bimonthly assessment schedules. However, in the long term, active teaching methodology, whether associated with metacognition or not, seems to have no further effect on test performance. It may be that students have their own mechanisms for seeking to understand the topics and overcome their difficulties in the long term, or that a prolonged period of working on the same topic (90 days) brings everyone to equivalent levels of understanding. In short, the use of active methodology and the association of metacognition promoted better results in the short term, promoting a rapid increase in understanding of the topic, but in the long term, learning seems to be more a matter of the student's pace than the methodology used.

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