

Metacognitive Skills of Pre-Service Biology Teachers: An Analysis through Laboratory Activities

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Article History

Received: 30 September 2025

Approved: 10 November 2025

Published: 13 November 2025

Keywords

pre-service biology teachers, metacognitive, laboratory activities, practicum,

ABSTRACT

Metacognitive abilities are a crucial component of the learning process, significantly contributing to the effectiveness of teaching and learning, particularly in preparing future educators. Practicums, as an integral part of science learning, provide opportunities for pre-service biology teachers to practice their metacognitive skills through the process of planning experiments, solving problems, and reflecting on the experimental results. This study aimed to investigate the metacognitive awareness of biology education students in practicum lectures. The study employed a quantitative descriptive design using a survey method, without any treatment applied to the research object. The survey focused on assessing the metacognitive awareness of biology education students during practicum sessions, categorised into two key aspects: knowledge of cognition and regulation of cognition. A total of 112 students participated in this study, selected using a purposive sampling technique. The Metacognitive Awareness Inventory (MAI) was utilised as the primary instrument for data collection. The findings revealed that the knowledge of the cognition aspect achieved an average score of 80.3, classified as high. Meanwhile, the regulation of the cognition aspect scored slightly lower at 79.7, but is still categorised as high.

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INTRODUCTION

Education in the 21st century requires students to have systematic thinking skills that focus not only on mastering knowledge, but also on the ability to manage how they learn. One important skill that plays a role in this is metacognition. Metacognition enables individuals to be aware of, regulate, and

evaluate their own thinking processes so that the learning strategies they choose become more effective. The concept of metacognition was first introduced by John Flavell in the early 1970s. In line with this, Anderson & Krathwohl also developed a taxonomy based on Bloom's Taxonomy, which is considered more relevant to the

current learning context (Badan Standar, 2022). This taxonomy emphasizes the need to engage in thinking or cognitive processes in order to master knowledge from the factual knowledge to conceptual knowledge, procedural knowledge, and metacognitive knowledge (Anderson, 2001).

Learning metacognitive skills in higher education is important because students are required not only to understand the material, but also to be able to plan, monitor, and evaluate their learning strategies. Metacognition is understood as the act of being aware of one's own cognitive structure and learning characteristics (Sengul & Katranci, 2012). Metacognitive skills are part of the learning activities carried out by teachers or lecturers. One effective form of learning to train metacognition is practical activities. Practicums, as an integral part of science learning, provides space for pre-service biology teachers to practice metacognitive skills through the process of planning experiments, problem solving, and reflecting on the results obtained (Wilson, 2018).

Metacognitive skills honed through practicum not only benefit scientific concept mastery, but also impact the professional development of pre-service biology teachers by becoming accustomed to planning and monitoring experiments, students learn to organize systematic learning strategies. Pre-

service teachers with good metacognitive abilities are continuously motivated to improve their skills and quality (Yurттаş Kumlu & Şahin, 2022). They will often evaluate and reflect on their teaching methods in order to adapt to students' learning techniques so that students feel comfortable (Griffith, 2016). Well-developed metacognition will also help teachers improve the effectiveness of learning. Metacognition can also be seen as one of the important factors that support learning success, both for students as pre-service teachers and for the students they will teach in the future (Fauzi & Sa'diyah, 2019).

In practical activities, cognitive understanding is evident when students are able to discuss their observations, ask appropriate questions, and use appropriate investigative steps. Meanwhile, cognitive organization is reflected when they plan experiments, carry out procedures, and evaluate the results obtained based on the assumptions made (Kipnis & Hofstein, 2008). A number of studies also show a positive relationship between metacognitive skills and cognitive achievement. Coutinho (2007) demonstrated a positive relationship, reinforcing that practicum functions not only to train psychomotor skills but also to develop students' thinking skills and metacognitive awareness.

Improving metacognitive abilities requires students to possess and be aware of three types of knowledge, namely declarative, procedural, and conditional. Declarative knowledge relates to what a person knows, in the form of factual information, terms, concepts, or theories that can be expressed either verbally or in writing. This knowledge forms the basis for students in understanding the material being studied. Furthermore, procedural knowledge refers to how a process or strategy is carried out, including the steps, techniques, and procedures that need to be done to complete a task. This knowledge enables students to not only understand concepts but also be able to apply them systematically. Meanwhile, conditional knowledge provides a higher dimension because it relates to when and why a strategy is used (Schraw & Dennison, 1994). Students with good conditional knowledge are able to determine strategies that are appropriate to the context, understand the reasons for the success of a procedure, and compare the effectiveness of one strategy with another (Pathuddin, 2016). These three types of knowledge complement each other in supporting student success in laboratory or practical activities.

In addition to knowledge, metacognitive abilities also include regulation of cognition, which is the skill of organizing, controlling, and evaluating thought processes. Regulation of cognition

consists of five main indicators. First, *planning*, which is the ability to formulate goals, choose strategies, and determine steps before engaging in learning activities. Second, *information management strategies*, which are skills for organizing and managing information to make it easier to understand and remember, for example through notes, concept maps, or mnemonics. Third, *comprehension monitoring*, which is the awareness to monitor the extent to which understanding of the material has been achieved, as well as the ability to recognize gaps in understanding. Fourth, *debugging strategies*, which are efforts to correct errors or obstacles by trying other more appropriate approaches. Fifth, *evaluation*, which is the ability to assess the effectiveness of learning strategies and reflect on the results achieved for future improvement (Pathuddin, 2016).

Research related to metacognition in the context of biology practicums, especially among pre-service teacher students, is still relatively limited. Most of the research that has been conducted still focuses on measuring metacognition in classroom theory learning or merely on conceptual evaluation aspects (Adiansyah et al., 2022; Yasir et al., 2020), while the implementation and measurement of metacognition in laboratory activities have not been explored in depth. This study was conducted to reveal the metacognitive awareness of pre-service biology teachers in practical activities and

how these skills contribute to their learning strategies and academic achievement.

RESEARCH METHODS

Methods

This study uses a quantitative descriptive approach with a survey method. A quantitative descriptive approach was chosen in which this study aims to describe phenomena systematically, factually, and accurately without giving special treatment to the research objects (Sugiyono, 2019). The survey method was used to obtain data from respondents through a previously prepared instrument, enabling researchers to collect information about the research variables directly from the subjects. The focus of the research was to reveal the level of metacognitive awareness of students in the biology education study program in practical lecture activities. The research subjects consisted of students from the Biology Education Study Program who took practical courses in the 2024/2025 academic year. Respondents were selected using purposive sampling, resulting in a total of 112 students as research participants.

Data Collection

The research instrument used was a questionnaire designed to explore students' metacognitive profiles. The questionnaire consisted of 29 statements with a 1–4 Likert scale to measure the level of mastery of

metacognitive abilities. This questionnaire instrument was adapted from the *Student Activity Reflection Inventory Instrument* developed by (Paidri et al., 2017) and has been tested for validity and reliability as a measuring tool with a Cronbach's Alpha value of 0.91.

Data Analysis

The statements in the instrument represent two categories of metacognitive components, namely knowledge of cognition and regulation of cognition. The knowledge of cognition aspect includes declarative knowledge (knowledge about oneself and strategies), procedural knowledge (knowledge about the use of strategies), and conditional knowledge (when and why to use strategies). The regulation of cognition aspect includes planning (goal setting), information management strategies (organization), comprehension monitoring (assessment of learning and strategies), debugging strategies (strategies for correcting errors), and evaluation (analysis of performance and strategy effectiveness) (G., Schraw & Dennison, 1994). The level of metacognitive awareness is presented in **Table 1**.

Table 1. Metacognitive Awareness Level

Value Range	Metacognitive Awareness Level
86-00	Very High
76-85	High
60-75	Moderate
55-59	Low
0-54	Very Low

Source: Fauzi & Sa'diyah (2019)

RESULTS AND DISCUSSION

Metacognitive ability is part of the learning processes carried out by educators. Metacognition is generally understood as a person's knowledge and awareness of their own thinking processes and the ability to regulate those processes (Flavell, 1979). Metacognitive aspects include two main components, namely knowledge of cognition and regulation of cognition (G., Schraw & Dennison, 1994).

The results of this study discuss knowledge about cognition, which consists of three sub-aspects, namely Declarative Knowledge, Procedural Knowledge, and Conditional Knowledge. 1) Declarative Knowledge is knowledge about what is known, including facts, concepts, and information that can be explicitly explained by students; 2) Procedural Knowledge is knowledge about how to carry out practical activities, such as specific steps or procedures in solving problems. 3) Conditional Knowledge is knowledge about when and why these strategies or procedures are used, so that students can adjust their learning strategies to the practical activities being studied.

The results of cognitive regulation include five important indicators, namely: 1) Planning refers to the ability to plan goals and procedures before conducting practical activities; 2) Information Management

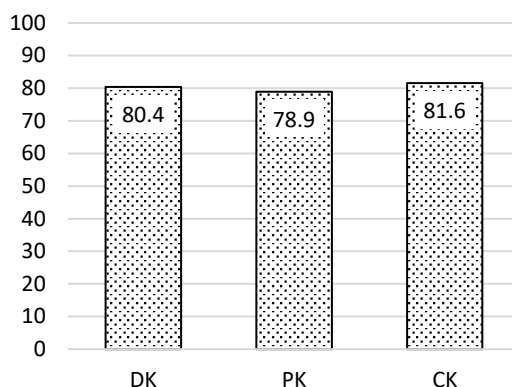
Strategies relate to how students organize, remember, and use information effectively in a practical activity; 3) Comprehension Monitoring indicates the ability to monitor and evaluate the extent to which understanding of the material has been achieved; 4) Debugging Strategies are used when students realize there are errors or obstacles and then try to fix them with alternative strategies. Finally, 5) Evaluation is the ability to assess the effectiveness of strategies and reflect on the learning outcomes obtained.

In the study, each sub-aspect was usually given a score, then the average was calculated to obtain an overview of the level of metacognitive awareness of students, both in terms of knowledge and cognitive regulation (G., Schraw & Dennison, 1994). The results of the analysis of the metacognitive abilities of students in the biology education study program are divided into two aspects, namely Knowledge of Cognition and Regulation of Cognition, as shown in **Table 2**.

The results of the study, as shown in **Table 2**, indicate that the metacognitive awareness of pre-service biology teachers falls in the high category, both in terms of Knowledge of Cognition and Regulation of Cognition. More specifically, the values of these aspects are presented in **Figure 1**.

Table 2. Metacognitive Awareness of Pre-service Biology Teachers

Metacognitive Aspects		Result
Knowledge of Cognition	Declarative Knowledge	80.4
	Procedural Knowledge	78.9
	Conditional Knowledge	81.6
	Average	80.3
Regulation of Cognition	Planning	77.7
	Information Management Strategies	80.9
	Comprehension Monitoring	77.3
	Debuging Strategis	83.3
	Evaluation	79.4
	Average	79.7

**Figure 1.** Metacognitive Awareness in the Aspect of Knowledge of Cognition

Source: Author's Document

The results presented in **Figure 1** show that each sub-aspect of Declarative Knowledge (DK) scored 80.4, Procedural Knowledge (PK) scored 78.9, Conditional Knowledge (CK) scored 81.6, with an average Knowledge of Cognition score of 80.3, which is in the high category. The results for the aspects of Knowledge of Cognition (**Figure 1**), namely DK, PK, and CK, show a high category. This is because the students' metacognition is reflected in their awareness of their own cognitive structure and learning characteristics. This is expected to show that students with high metacognitive awareness tend to be better at managing their learning strategies, thereby

achieving more optimal academic results. Coutinho (2007) has revealed a positive relationship between metacognitive skills and student academic achievement. Metacognitive strategies are a way of learning to increase awareness and empower thinking skills in observing one's own learning, controlling cognitive activities, and ensuring that cognitive goals are met (Heny et al., 2018). Students are guided to reflect on their thinking processes. Metacognitive activities play an important role in helping them monitor their understanding, assess the effectiveness of problem-solving strategies, and make necessary adjustments to strategies, thereby

contributing to a significant improvement in learning outcomes (Sadykova et al., 2024). Metacognitive skills not only support academic achievement but also serve as important preparation for students, especially future teachers, to develop reflective abilities in their future teaching practices.

The results presented in **Figure 2** show the Regulation of Cognition aspect with a Planning (P) aspect score of 77.7. Information Management Strategies (IMS) is 80.9, Comprehension Monitoring (CM) is 77.3, Strategic Debugging (DS) is 83.3, Evaluation (E) is 79.4, with an average Regulation of Cognition aspect of 79.7, which is in the high category. Practicums requires active student involvement in testing hypotheses and analyzing data based on relevant theories, enabling them to build understanding independently. Through the application of practical-based learning, lecturers act as facilitators who encourage students to explore problems, find solutions, and construct concepts independently. The results for the Regulation of Cognition aspects, namely P, IMS, CM, DS, and E (**Figure 2**), show that these aspects are in the high category, ranging from 76 to 85. This process contributes to the development of students' metacognitive skills (Adnan & Bahri, 2018). In the context of biology practicums, metacognitive awareness helps students plan experimental steps, monitor

the progress of activities, and reflect on the results obtained. Thus, metacognition not only supports conceptual understanding but also strengthens the scientific process skills essential for pre-service biology teachers. Strengthening science process skills through metacognition alone is not enough, because its effectiveness is also greatly influenced by other internal factors, namely learning motivation.

Bahri & Corebima (2015) explain that learning motivation can be said to be a factor that greatly influences students' final learning outcomes in addition to metacognitive abilities. Regardless of how good students' metacognition is, learning will not be successful without the presence of internal support, namely learning motivation. Learning motivation is a mental force in a person's life that triggers learning activities to achieve learning objectives (Saeed & Zyngier, 2012). Masrura (2013) also states that if a person's motivation is higher than their fear of failure, high learning motivation will lead to high achievement. This supports the assumption that metacognitive regulation improves performance in various ways, including both the use of existing strategies and greater awareness of comprehension difficulties. Enhancing the metacognitive awareness of pre-service teachers should be accompanied by strategies to maintain and strengthen their intrinsic motivation.

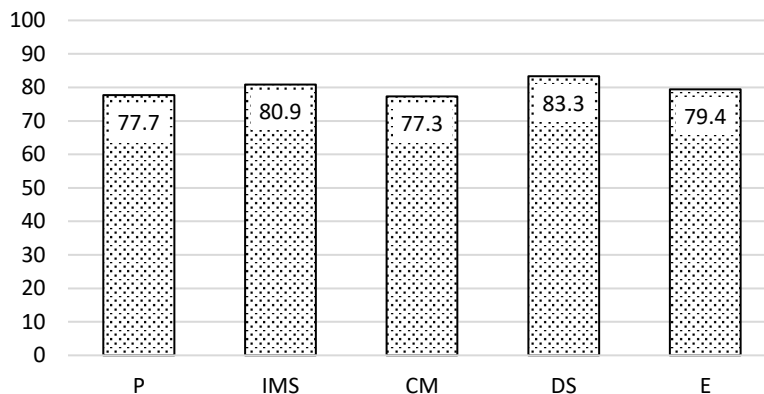


Figure 2. Metacognitive Awareness in the Aspect of Regulation of Cognition
Source: Author's Document

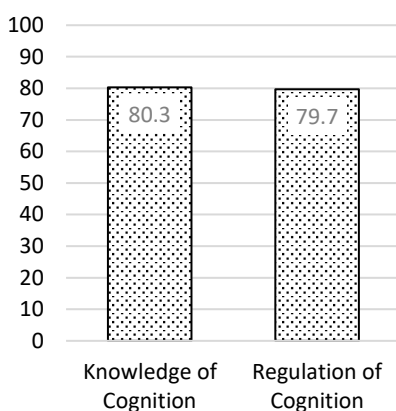


Figure 3. Average of Metacognitive Awareness
Source: Author's Document

On the other hand, (Veenman et al., 2006) states that metacognition contributes as much as 17% to student success in learning, while intellectual ability only contributes about 10%. This data clearly shows the need for educational institutions to effectively develop metacognitive awareness in order to support student success in learning. Metacognitive awareness is a strong foundation within learners that enables them to independently plan, monitor, and evaluate their learning without the help of others (Leasa et al.,

2024). Metacognitive awareness in biology learning is the key to becoming a good academic learner.

The results presented in **Figure 3** show that the average metacognitive awareness in both aspects, namely Knowledge of Cognition (80.3) and Regulation of Cognition (79.7) are in the high category and relatively similar. These results are in line with research (Öza, 2016) on the metacognitive abilities of pre-service English teacher students, which shows that both metacognitive aspects tend to develop

in a balanced manner. These findings are also consistent with the statement by (Schraw, 1998) that the two components of metacognition (knowledge of cognition and regulation of cognition) can complement each other to improve academic achievement. Knowledge of Cognition provides a basis for understanding what students know, while Regulation of Cognition enables students to use that knowledge effectively through planning, monitoring, and evaluation.

Currently, the continuous development of metacognitive abilities is an important component in the education system to support the learning process (Whitebread et al., 2009). In the context of biology learning, the application of metacognition can be realized through various practical activities and simple research projects. For example, when students conduct photosynthesis experiments, they are trained to plan the steps of the experiment, predict possible outcomes, and monitor each stage of the procedure. After the experiment is complete, students are directed to reflect on any errors or obstacles that occurred, then evaluate the strategies chosen to determine whether the approach was effective or needs improvement. This process not only deepens their understanding of the concept of photosynthesis, but also fosters self-regulation skills that are important for prospective biology teachers in managing

future learning. This practicum course plays an important role in honing the pedagogical skills of prospective teachers. Through this activity, students not only gain direct experience in applying learning theories, but also learn to understand the dynamics of learners and the real context of the teaching and learning process. In addition, mastery of content knowledge, which is a deep understanding of the subject matter to be taught, is a very important aspect for prospective biology teachers. This knowledge not only supports teachers' ability to deliver material accurately and meaningfully, but also forms the basis for designing effective and relevant learning strategies for students (Wahyuningtyas et al., 2022).

The results of the study show that the level of metacognitive awareness of pre-service biology teacher students is relatively high, both in terms of Knowledge of Cognition (80.3) and Regulation of Cognition (79.7). The almost equal scores between the two aspects indicate that students have a good understanding of how their thinking processes work and are able to manage and direct these processes effectively in practical activities. In other words, students not only know the appropriate learning strategies, but can also apply them consciously and deliberately. This balance indicates the development of comprehensive metacognitive abilities,

which involve awareness of thinking (knowledge of cognition) and the ability to regulate the thinking process (regulation of cognition) as described by (Flavell, 1979). This finding is in line with the view of (Schraw & Dennison, 1994), which asserts that individuals with a high level of metacognitive awareness are able to regulate their learning independently, resulting in more optimal learning outcomes.

Metacognitive awareness plays an important role in regulating how students think, learn, and achieve results. The higher this awareness, the better the cognitive abilities they can develop (Amin & Adiansyah, 2020). In addition, (Eriyani, 2020) also found that metacognitive awareness is positively related to student achievement indices. Based on these findings, it can be concluded that the higher the students' metacognitive awareness, the better the learning strategies they choose, which ultimately leads to improved academic outcomes. That is why lecturers in teacher education programs are required to introduce, develop, and improve understanding of metacognitive concepts through learning activities for their students who will become professional teachers (Fauzi & Sa'diyah, 2019).

CONCLUSION

The metacognitive awareness of pre-service biology teachers in practical

activities is divided into several sub-aspects. The main aspects of metacognitive awareness are divided into two aspects, with the results for knowledge of cognition at 80.3, which is in the high category, and regulation of cognition at 79.7, which is also in the high category. These results indicate that the higher the students' metacognitive awareness, the better the learning strategies they choose, which ultimately leads to improved academic performance. This study is limited to the profile of metacognitive abilities, so further research is needed on the exact relationship between metacognitive abilities and students' cognitive abilities. As a practical implication, biology lecturers need to provide explicit training related to metacognitive strategies, use reflective journals in practical activities, and facilitate problem-based and inquiry-based learning to encourage students to plan, monitor, and evaluate their thinking processes independently. Furthermore, follow-up research with an experimental design is needed to test the effectiveness of a learning method in improving the metacognitive awareness and regulation of pre-service biology teachers, so that the contribution of metacognition to improving the quality of learning can be more strongly proven.

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