

# Identification of metacognition skills of physics education students in magnetic electricity courses

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## Abstract

Metacognition is the ability to plan, monitor, and evaluate. Metacognition has a significant role in obtaining information, understanding, reading, solving problems, and controlling oneself. In physics learning, metacognitive skills are important because they help students understand complex concepts, including those in electricity and magnetism. These topics are essential in physics but often difficult for students since they involve abstract ideas. This study aims to identify the metacognition ability of physics education students in the electricity and magnetism course. The survey method was used in this research. The data collection technique used a questionnaire through Google Forms. In this study, the instrument used was a closed-ended questionnaire. The sampling technique used was simple random sampling. The percentage of planning ability: 58.30%, mostly answered 'doubtful'; monitoring ability: 58.30%, mostly answered 'agree'; and evaluation ability: 61.10%, mostly answered 'agree'. This percentage was obtained from the data of 36 respondents. In conclusion, students demonstrate varying levels of metacognitive abilities, with stronger monitoring and evaluation skills but weaker planning skills. Practically, these findings imply the need for instructional strategies that explicitly support the development of students' planning abilities in physics learning.

**Keywords:** Evaluation, Magnetic electricity, Metacognition, Planning, Monitoring

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## I. Introduction

Metacognition, broadly defined as the ability to think about and regulate one's own thinking processes, has emerged as a fundamental construct in educational psychology and discipline-based education research over the past four decades [1]. Since Flavell's foundational work in the 1970s, researchers have increasingly recognized that metacognitive abilities encompassing planning, monitoring, and evaluation play a pivotal role in how learners acquire, understand, and apply knowledge across academic domains [2]. In the context of science education, particularly physics learning, metacognitive skills are not merely supplementary to content mastery but are integral to developing the deep conceptual understanding required for navigating complex and abstract subject matter [3]. Students who possess well-developed metacognitive awareness demonstrate greater capacity to set learning goals, select appropriate strategies, monitor their comprehension in real-time, and make necessary adjustments when encountering difficulties [4]. These self-regulatory processes enable learners to move beyond rote memorization toward meaningful learning that persists and transfers to novel contexts. The discipline of physics presents unique cognitive challenges that render metacognitive skills particularly consequential. Physics demands that students grapple with abstract concepts often removed from everyday

experience, apply mathematical reasoning to physical phenomena, integrate multiple representations of the same concept, and solve ill-structured problems requiring strategic decision-making [5].

Among the most challenging topics in the physics curriculum is electricity and magnetism, a domain replete with invisible forces, fields, and complex relationships that defy intuitive understanding [6]. Research has documented persistent difficulties students experience in grasping foundational concepts such as electric and magnetic fields, the relationship between time-varying fields, and the application of Maxwell's equations [7]. A recent investigation revealed that even after traditional instruction, students struggle to apply the concept of magnetic field circulation appropriately, often defaulting to symmetry-based reasoning without considering the actual configuration of field lines [8]. These findings underscore the necessity for learners to engage in metacognitive reflection about their own understanding and problem-solving approaches when studying electromagnetism. Despite the recognized importance of metacognition in physics learning, a significant gap exists in the literature concerning the specific metacognitive profiles of physics education students who are simultaneously learning physics content while preparing to become future physics educators. This population occupies a unique position in the educational ecosystem. Their metacognitive competence not only influences their own academic success but also shapes their capacity to foster metacognitive development in their future students [9]. What is known as "metacognitive competence," that is, the ability to monitor, manage, and reflect on one's own learning process in a way that can later be modeled and taught to students, is crucial for prospective teachers [10]. However, existing research has predominantly focused on metacognition in either K-12 students or engineering undergraduates, leaving the specific characteristics of physics education students' metacognitive abilities largely unexplored [11].

The context of electricity and magnetism courses warrants particular attention for several reasons. First, the abstract nature of electromagnetic concepts places heavy demands on students' metacognitive capabilities, as learners must constantly monitor their understanding of phenomena that cannot be directly observed [12]. Second, other research shows that metacognition in electricity and magnetism is significantly correlated with conceptual understanding and critical thinking, suggesting that these abilities develop simultaneously in these domains [13]. Third, studies examining instructional interventions in electromagnetism have found that while experiential learning models can enhance conceptual understanding and critical thinking, metacognitive gains do not automatically follow from content instruction alone [14]. This finding implies that metacognitive abilities in this domain may require explicit attention and assessment, yet baseline data on physics education students' metacognitive skills in electromagnetism courses remain scarce. The present study addresses this gap by investigating the metacognitive abilities of physics education students enrolled in an electricity and magnetism course, with specific focus on the three core components of metacognitive regulation: planning, monitoring, and evaluation. Planning refers to learners' ability to set goals, allocate resources, and select appropriate strategies before engaging with learning tasks. Monitoring encompasses the ongoing awareness of comprehension and performance during task engagement, including the capacity to detect errors or misunderstandings as they occur.

Evaluation involves post-task reflection on the effectiveness of strategies employed and the quality of outcomes achieved [15]. Recent work has highlighted that among these components, procedural knowledge and monitoring play particularly critical roles in physics problem-solving success, while the reflection stage is most strongly influenced by metacognitive awareness [16]. Understanding the distribution of these abilities among physics education students can provide valuable insights for curriculum design and instructional practice. While previous studies have examined metacognition in physics contexts, several important questions remain unanswered. First, what is the current level of metacognitive skills among physics education students, specifically in the domain of electricity and magnetism? Second, how do the three components of metacognitive regulation, planning, monitoring, and evaluation, manifest differently in this population? Third, what are the implications of these findings for the preparation of future physics teachers? The present study was designed to address these questions by systematically identifying metacognitive abilities among physics education students enrolled in an electricity and magnetism course. By establishing empirical baseline data on students' self-reported metacognitive skills across planning, monitoring, and evaluation dimensions, this research aims to contribute to the growing body of knowledge on metacognition in discipline-specific contexts. The significance of this investigation extends beyond descriptive contribution. From a theoretical perspective, understanding how metacognitive regulation operates in the challenging domain of electromagnetism can refine existing models of domain-specific metacognition [17].

From a practical standpoint, identifying areas of relative strength and weakness in physics education students' metacognitive abilities can inform the design of targeted interventions to enhance these skills. Such interventions are particularly crucial for prospective teachers, who must not only possess metacognitive competence themselves but also develop pedagogical content knowledge for fostering metacognition in their future students [18]. In line with the statement that a learning approach that explicitly incorporates metacognitive elements can improve theoretical understanding and applied knowledge in physics education [19]. However, the effective implementation of such approaches requires that teacher educators first understand their students' metacognitive profiles. Furthermore, this research responds to recent calls in the physics education research community for more nuanced investigations of metacognition in specific content domains [20]. Rather than treating metacognition as a generalizable trait that operates uniformly across contexts, contemporary scholarship emphasizes the importance of examining how metacognitive processes are shaped by the particular conceptual demands of different physics topics [21]. Electricity and magnetism, with its unique combination of mathematical formalism, visual-spatial reasoning, and conceptual abstraction, provides an ideal context for such domain-specific investigation. Therefore, this study aims to identify the metacognitive abilities of physics education students in the electricity and magnetism course, with a specific focus on the three components of metacognitive regulation: planning, monitoring, and evaluation. By employing a survey methodology to capture students' self-reported metacognitive practices, this research seeks to establish empirical evidence regarding the current state of metacognitive skills in this population. The findings will contribute to the knowledge base on physics teacher preparation, inform instructional design in electromagnetism courses, and provide a foundation for future intervention studies aimed at enhancing metacognitive competence among prospective physics educators. In an era where physics education increasingly emphasizes the development of lifelong learning skills alongside content mastery [22], understanding and fostering metacognitive abilities has never been more urgent.

## II. Methods

### Type of Research

The survey method was used in this research. This study aims to identify the metacognition ability of physics education students in magnetic electricity courses. Survey research is used to solve actual large-scale issues with a vast population, so a large sample size is needed. In line with the above opinion, in survey research, information is collected from respondents using a questionnaire. There are three main characteristics of the Survey method: 1) Information data is collected from large groups of people to describe various aspects and characteristics such as knowledge, attitudes, beliefs, and abilities of the population; 2) Information data is obtained from submitting questions (written and can also be oral) from the population, 3) Information data is obtained from samples, not from the population.

Survey research design is a procedure in which researchers conduct surveys or administer questionnaires or scales to a sample to describe the attitudes, opinions, behaviors, or characteristics of respondents [23]. The survey method is a quantitative research method used to obtain data from the past or present about beliefs, opinions, characteristics, and variable relationship behavior, and to test several hypotheses about sociological and psychological variables from samples taken from certain populations, data collection techniques with observations (interviews or questionnaires) that are not in-depth, and research results tend to be generated [24].

This flowchart illustrates the steps in the research process, from planning to data analysis. This diagram provides a clear visual description of the research flow and facilitates an understanding of the process being carried out. Figure 1 presents a flow diagram of the steps in this research.

### Participant

Participants in this study were 36 undergraduate students enrolled in the Physics Education program at Sunan Kalijaga State Islamic University (UIN) Yogyakarta, Indonesia. All participants were recruited from three intakes: the 2021, 2022, and 2023 intakes, and were aged between 19 and 23 years. The sample consisted of a balanced gender distribution, with 18 female and 18 male students participating in the study. Two specific inclusion criteria were established for participant selection: first, that all individuals were officially registered as physics education students, and second, that they had completed or were currently enrolled in the Electricity and Magnetism course at the time of data collection. The sampling technique used in this study was simple

random sampling, a probability sampling method in which each member of the target population has an equal and independent chance of being selected to participate [25].

This approach was chosen based on the assumption that the population of physics education students at UIN Sunan Kalijaga who had taken the Electricity and Magnetism course was relatively homogeneous with respect to the variables studied, specifically their exposure to the course content and their academic level in the program. In the context of this study, the random selection procedure ensured that every eligible physics education student had an equal opportunity to be included in the study, thus supporting the objectivity of the findings and reducing the possibility of systematic sampling error that might compromise the validity of conclusions drawn about students' metacognitive abilities in electricity and magnetism. Therefore, future research in this area would benefit from clearly documenting population parameters, detailing randomization procedures, and reporting response rates to allow readers to assess the representativeness of the sample more accurately.

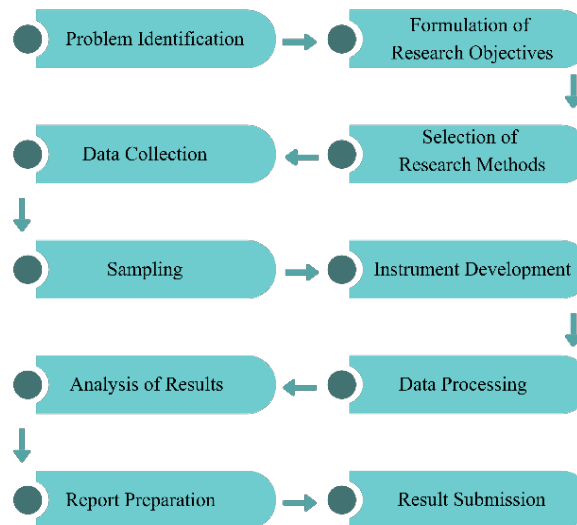


Figure 1. Flowchart

## Instrument

Research instruments are tools or facilities used by researchers to collect data, thereby simplifying their work and improving the quality of their results. Research instruments are more precise, comprehensive, and systematic, thus facilitating the data collection process [26]. Meanwhile, research instruments are tools used to measure observed natural and social phenomena [27]. In this study, the instrument used was closed-ended. The instrument is in the form of a closed questionnaire (closed-ended questionnaire). Closed questionnaire, which is a questionnaire made based on alternative answers available. Respondents choose the answers that match their situation. The questionnaire is distributed via Google Forms; each respondent is allowed to complete it only once. A questionnaire is a research instrument that contains a series of questions or statements to collect data or information, with respondents answering them freely according to their opinions [28].

This instrument contains statements with five alternative answers each. In this study, the Likert scale was modified to five response options, with scores ranging from 5 to 1. So that respondents only need to choose the answers that are already available and in accordance with their conditions. Alternative answers consist of five answer choices with gradations or levels. The score for each alternative answer is as follows: (SA) strongly agree (score 5), (A) agree (score 4), (U) undecided (score 3), (DA) disagree (score 2), and (SD) strongly disagree (score 1). The instrument used in this research is a questionnaire. The following questionnaire statements were given to respondents and are presented in Table 1.

Based on Table 1, the questionnaire was tested for feasibility using three validators to identify its shortcomings. After being tested on the validators, the results were analyzed using Aiken's V equation for content validity, yielding a validity value of 0.98, which exceeds the instrument threshold of 0.92, indicating that the questionnaire developed in this study is valid. After that, the instrument was analyzed for its reliability using the Alpha Cronbach equation and obtained a value of 0.85, which exceeds the instrument threshold limit of 0.8, so that the questionnaire developed in this study is reliable. Furthermore, for the preparation of instruments in this study, based on theory and the opinions of experts in the theoretical study that describes the

research variables, indicators were obtained to develop questions based on the components of metacognitive ability, namely planning, monitoring, and evaluating. The instrument is used to identify the metacognitive skills of physics education students in the magnetic electricity course at UIN Sunan Kalijaga Yogyakarta.

Table 1. Research Statement Questionnaire

No	Statement
1	I understand the basic concepts of magnetic electricity well.
2	I monitor my understanding while learning about electricity and magnetism.
3	I can relate the concepts of electricity and magnetism to everyday life.
4	I am confident in explaining the concepts of electricity and magnetism to others.
5	I make a plan about the material to be studied.
6	I set learning goals before attending lectures.
7	I evaluate my understanding of the material that has been learned.
8	I can identify my weaknesses in understanding magnetic electricity.
9	I often reflect after completing assignments or exams to assess my understanding.
10	Reflecting on my learning outcomes helps improve my understanding of magnetic electricity.
11	I manage my study time well to understand the concepts of electricity and magnetism.
12	I am able to overcome the difficulties I face when learning electricity.
13	I know the steps to take to solve problems related to electricity and magnetism.
14	I know effective learning strategies to understand magnetic electricity.
15	I can change my study strategy if I feel ineffective.
16	I analyzed the exam results to understand the mistakes made.
17	I actively discuss electricity and magnetism.
18	With my classmates, group discussions help me understand the material better.
19	I often ask lecturers or friends if I do not understand magnetic electricity material.
20	I use various learning resources (books, videos, articles) to understand magnetic electricity material.

### Data Analysis Technique

Data analysis is a procedure for analyzing data, techniques for interpreting the results of the analysis, and the data collection process that supports the analysis to make it easier, more precise, and more accurate [29]. The purpose of data analysis is to simplify data so that it is easier to read and interpret. In this study, the researchers used a quantitative analysis technique. The data analysis technique is intended to find answers to research statements about previously formulated problems. The research data were collected and analyzed using descriptive quantitative statistics. Meanwhile, descriptive statistics are statistics that function to describe or depict the object being studied through sample or population data, as it is, without analyzing and making conclusions that apply to society [30].

After the survey data collection, the next step is calculating the score to analyze the results. The data collected from the questionnaire will be automatically integrated and analyzed using Google Forms' built-in data analysis feature. This feature allows researchers to get summary statistics that include the percentage of respondents for each statement quickly and efficiently. Manual calculations can also be performed if necessary to ensure the accuracy and validity of the data.

$$P = \frac{\sum F}{\sum N} \times 100\% \quad (1)$$

$P$  is the percentage,  $F$  is the respondent's answer score, and  $N$  is the total maximum score.

### III. Results and discussion

This section will discuss the research results and analysis of the study entitled "Identification of Metacognitive Ability of Physics Education Students in Magnetic Electricity Course". The metacognitive abilities of physics education students consist of planning, monitoring, and evaluating.

## Planning

This statement is intended to determine the planning ability of respondents who are physics education students in magnetic electricity courses. This table presents survey results on student learning planning in magnetic electricity courses. It presents data on the percentage of students who agree with statements about their learning planning in magnetic electricity courses. The assessment is carried out using a Likert scale of 1-5, which shows the level of students' ability to plan in the magnetic electricity course. The details of the findings in the planning table can be shown in Table 2.

Table 2. Planning Statement

NN	Statement	Scale (%)				
		1	2	3	4	5
11	I made a plan about the material to be studied.	0	5.6	47.2	36.1	11.1
22	I set my study goals before attending lectures.	0	16.7	38.9	36.1	8.3
33	I managed my study time well to understand the concepts of electricity and magnetism.	0	2.8	58.3	33.3	5.6
44	I felt able to overcome the difficulties I faced while learning electricity.	0	5.6	58.3	27.8	8.3
55	I use various learning resources (books, videos, articles) to understand magnetic electricity material.	0	2.8	5.6	61.1	30.6

Based on Table 2, the majority of respondents chose the neutral option (3). The research results in the planning section indicate that most respondents are still unable to perform planning in the electricity and magnetism course. From the research findings, a value of 58.30% was obtained, indicating that respondents answered a scale of 3 (neutral) regarding the statement about managing study time and overcoming difficulties while learning electricity and magnetism. Based on this percentage, it can be concluded that respondents are still unable to manage their study time and address learning-related issues effectively. The survey results show that students are already able to utilize various learning resources, especially in understanding the concepts of electricity and magnetism.

## Monitoring

This statement is intended to assess the monitoring ability of respondents who are physics education students in electromagnetism. This table shows the percentage of students who feel capable of monitoring their understanding while learning about electricity and magnetism. The assessment was conducted using a Likert scale of 1-5, which indicates the level of students' ability to perform monitoring in the electromagnetism course.

Table 3. Monitoring Statement

NN	Statement	Scale (%)				
		1	2	3	4	5
11	I am able to monitor my understanding while learning about electricity and magnetism.	0	2.8	33.3	58.3	5.6
22	I can identify my weaknesses in understanding the material of electricity and magnetism.	0	5.6	19.4	55.6	19.4
33	I know the steps to take to solve problems related to electricity and magnetism.	0	11.1	52.8	30.6	5.6
44	I am aware of effective learning strategies to understand the material on electricity and magnetism	0	5.6	36.1	50.0	8.3
55	I can change my learning strategies if they are not effective.	0	5.6	33.3	50.0	11.1

Based on Table 3, the majority of respondents chose the 4 (agree) option. The research results in the monitoring section indicate that most respondents are already able to perform monitoring in the electricity and magnetism course. Respondents are able to consider whether the strategies used are correct, think about any mistakes made in problem-solving, and recognize whether the solutions provided are reasonable. The data in the table show that the majority of physics education students can monitor effectively, especially in terms of

tracking their understanding while learning electricity and magnetism, and can identify their weaknesses in understanding the material of electricity and magnetism.

### Evaluating

This statement is intended to assess the evaluation ability of respondents who are physics education students in the electricity and magnetism course. This table displays the assessment of students' ability to evaluate their understanding of the material studied. The evaluation is conducted using a scale of 1-5, which indicates the level of students' ability to reflect and analyze errors.

Table 4. Evaluating Statement

NN	Statement	Scale (%)				
		1	2	3	4	5
11	I can relate the concepts of electricity and magnetism to everyday life.	0	2.8	25.0	61.1	11.1
22	I evaluate my understanding of the material I have learned.	0	2.8	33.3	50.0	13.9
33	I often reflect after completing assignments or exams to assess my understanding.	0	2.8	30.6	58.3	8.3
44	Reflection on my learning outcomes helps improve my understanding of electricity and magnetism.	0	0	25.0	58.3	16.7
55	I analyze my exam results to understand my mistakes.	0	2.8	5.6	61.1	30.6

Based on Table 4, the majority of respondents chose the 4 (agree) option. The results of the evaluation section indicate that most respondents are already able to perform evaluations in the electricity and magnetism course. The data obtained from this table can be used to determine the extent to which students can connect the concepts of electricity and magnetism with everyday life, evaluate their understanding of the material that has been studied, reflect after completing assignments or exams to assess their comprehension, and create a plan to identify what actions or improvements need to be made. This information can be used to enhance learning strategies so that students can be more effective in achieving their learning objectives.

The present study investigated the metacognitive awareness of physics education students in the context of electricity and magnetism courses, focusing specifically on the three core components of metacognitive regulation: planning, monitoring, and evaluation. The findings reveal a differentiated pattern of self-reported metacognitive awareness across these components, with students expressing uncertainty regarding their planning abilities, demonstrating moderate confidence in their monitoring capabilities with notable limitations in specific areas, and reporting the strongest awareness in evaluation practices. These results warrant careful interpretation within the specific context of electromagnetism learning, acknowledging that what has been measured is students' perceptions of their metacognitive processes rather than direct evidence of metacognitive competence in action. The finding that 58.30% of respondents expressed uncertainty regarding their planning abilities represents a significant observation about how physics education students perceive their preparation for learning in electricity and magnetism courses. Planning encompasses the strategic processes that precede learning, including goal setting, time allocation, and selection of appropriate learning strategies [31].

The uncertainty expressed by a majority of participants suggests that these students do not feel confident in their capacity to deliberately structure their approach to mastering electromagnetism concepts. This perception is particularly noteworthy given that electricity and magnetism are widely recognized as one of the most conceptually demanding domains in the physics curriculum, requiring students to navigate abstract constructs such as electromagnetic fields, Maxwell's equations, and the relationship between time-varying electric and magnetic phenomena [32]. Students who lack confidence in their ability to plan effectively may be ill-equipped to manage the cognitive demands of this challenging subject matter. However, it is important to emphasize that this finding reflects students' self-perceptions rather than objective evidence of planning incompetence.

It is possible that students engage in planning behaviors but do not recognize them as such, or that they underestimate their planning capabilities due to limited familiarity with metacognitive terminology and concepts. The consistency of responses across planning items nevertheless suggests a genuine pattern of perceived uncertainty that merits pedagogical attention, regardless of whether it accurately reflects students'

actual planning behaviors [33]. When examining the monitoring component, the data present a more complex picture. A majority of respondents (58.30%) indicated agreement with statements related to their general monitoring abilities, suggesting that most students perceive themselves as capable of overseeing their understanding during learning and problem-solving. Monitoring refers to the ongoing awareness of comprehension and performance during task engagement, including the capacity to detect errors, recognize when understanding is incomplete, and adjust strategies [34]. The finding that a majority of students express confidence in this domain might initially appear encouraging, suggesting that physics education students are developing the capacity for real-time self-assessment. However, a more nuanced examination of specific monitoring-related items reveals important limitations that complicate this interpretation.

Notably, 52.80% of respondents expressed uncertainty or disagreement regarding their ability to compile problem-solving steps related to magnetic electricity. This specific finding provides a more precise window into students' perceived monitoring capabilities, indicating that while they may feel generally capable of monitoring comprehension, they lack confidence in the more sophisticated monitoring skills required to guide their problem-solving processes in real-time, strategically. This discrepancy between general monitoring confidence and specific uncertainty about problem-solving procedures aligns with established distinctions in the metacognition literature between different levels of monitoring sophistication. Meanwhile, there is a distinction between metacognitive experiences, which are the on-the-fly feelings and judgments that accompany task performance, such as feeling confused or realizing that a problem is difficult, and the more deliberate process of metacognitive control that involves actively regulating one's approach based on ongoing evaluation [35]. The findings suggest that while students may experience metacognitive feelings of difficulty or uncertainty when working on magnetic electricity problems, they may not yet have developed the metacognitive control mechanisms needed to adjust their problem-solving approaches when initial strategies prove inadequate strategically.

This interpretation is consistent with research documenting students' difficulties with problem representation and solution planning in electromagnetism. Meanwhile, students often have difficulty applying the concept of magnetic field circulation correctly, often tending to use symmetry-based reasoning without fully considering the actual configuration of the field lines [36]. Similarly, other studies have shown that students' knowledge in electromagnetism is often fragmented and unsystematic, leading to difficulties in constructing coherent solution paths to novel problems [37]. The uncertainty expressed by participants in this study regarding problem-solving steps may reflect their awareness of these knowledge-integration challenges, representing a metacognitive recognition of their own difficulties in translating conceptual understanding into procedural competence. The most positive finding of this study emerged in the evaluation component, with 61.10% of respondents indicating agreement with statements related to their ability to evaluate their understanding and learning processes in electricity and magnetism. Evaluation involves post-task reflection on the effectiveness of strategies employed, the quality of outcomes achieved, and the identification of areas for improvement [38]. The finding that a majority of physics education students perceive themselves as capable evaluators suggests that these students are developing the reflective habits essential for lifelong learning and professional growth.

This perceived strength in evaluation is particularly significant for prospective physics teachers, who must continuously assess their own understanding and pedagogical effectiveness throughout their careers [39]. Students who believe themselves capable of accurate self-evaluation are better positioned to identify knowledge gaps, recognize misconceptions, and seek appropriate remediation. However, as with the other components, it is important to acknowledge that self-perceived evaluation ability may not correspond directly to evaluation competence. Students may overestimate their capacity for accurate self-assessment, and the relationship between believing one evaluates effectively and actually doing so is not automatic. The pattern of findings across the three metacognitive components, planning uncertainty, mixed monitoring confidence with specific procedural limitations, and relative evaluation strength, invites consideration of why metacognitive awareness might develop unevenly in the context of electromagnetism learning. One plausible explanation relates to the nature of feedback available for each type of metacognitive process.

Evaluation may be the component for which students receive the most explicit feedback, both from external sources and from their own experience. When students complete problem sets or examinations in electricity and magnetism, they receive clear feedback about the correctness of their answers, providing tangible evidence against which to evaluate their understanding [40]. Similarly, instructional settings often include opportunities for reflection, review sessions, and discussions of common misconceptions, all of which may scaffold students' evaluative capacities. In contrast, planning is often a private process that occurs before

formal instruction or assessment begins, with limited external feedback about the quality or effectiveness of one's planning strategies. Students may rarely receive explicit guidance on how to plan effectively for learning electromagnetism, nor do they typically receive feedback connecting their planning choices to subsequent learning outcomes [41]. This lack of scaffolding and feedback for planning processes may contribute to the uncertainty students express in this domain. The specific difficulties students report with compiling problem-solving steps in magnetic electricity also reflect the unique conceptual demands of electromagnetism as a discipline.

Unlike some areas of physics where intuitive experiences provide some guidance for problem-solving, electromagnetism deals with entities and relationships that are largely inaccessible to direct observation. Students cannot see magnetic fields or directly perceive the relationship between changing electric fields and induced magnetic fields. This lack of intuitive grounding means that problem-solving in electromagnetism must rely heavily on formal representations and mathematical reasoning, placing particular demands on students' ability to translate between conceptual understanding, mathematical formalism, and procedural execution [42]. The uncertainty students express about compiling problem-solving steps may reflect genuine difficulty with these translation processes, which require not only knowledge of individual concepts but also the ability to integrate them into coherent solution procedures. This interpretation is supported by research demonstrating that students' knowledge in electromagnetism is often fragmented, with individual concepts understood in isolation but not effectively connected into the integrated knowledge structures needed for flexible problem-solving [43]. The finding that students report stronger evaluation than planning abilities is also consistent with developmental patterns observed in metacognition research more broadly.

Planning requires prospective thinking, anticipating future learning needs, and preparing strategies in advance, which may be more cognitively demanding than retrospective evaluation [44]. Additionally, many educational contexts place greater emphasis on reflection and review than on strategic preparation, potentially providing students with more opportunities to develop and practice evaluation skills. However, the relationship between evaluation and planning is fundamentally reciprocal: effective evaluation of past performance should inform future planning, creating a cycle of continuous metacognitive improvement [45]. The present findings suggest a potential disconnection in this cycle for physics education students. While they perceive themselves as capable of evaluating their learning, they may not be effectively translating evaluation insights into improved planning for future learning tasks. This disconnection, if confirmed by further research, would represent an important target for instructional intervention, as helping students forge stronger links between evaluation and planning could enhance the overall effectiveness of their metacognitive regulation. The variability in metacognitive awareness across components also highlights the importance of examining metacognition at a granular level rather than treating it as a unitary construct. Much of the existing research on metacognition in science education has focused on global measures of metacognitive awareness or self-regulation [46].

While such global measures have value, they may obscure important patterns of strength and weakness in specific metacognitive components that have differential relationships with learning outcomes in particular domains. The present findings suggest that physics education students may benefit from different types of support for different metacognitive component scaffolding for planning processes, targeted instruction in monitoring during problem-solving, and opportunities to connect evaluation insights to future planning. Identifying these component-specific needs would not be possible with a global metacognition measure alone. The domain-specific nature of these findings deserves particular emphasis. While general metacognitive abilities certainly exist, there is growing recognition that metacognitive processes are shaped by the specific conceptual demands of different content domains [47]. Students who demonstrate sophisticated monitoring in mechanics, where intuitive experiences provide some guidance, may struggle to apply similar monitoring skills in electromagnetism, where concepts are more abstract and counterintuitive. The findings of this study, situated specifically in the context of electricity and magnetism courses, should be understood as reflecting students' metacognitive awareness within this particular domain rather than as a characterization of their general metacognitive capabilities.

This domain-specificity has important implications for instruction, suggesting that metacognitive skills must be cultivated within the contexts where they will be applied rather than assuming automatic transfer from general study skills courses or from other physics domains [48]. The implications of these findings for physics teacher education are multifaceted. First, the uncertainty students express regarding planning abilities suggests a need for explicit instruction in strategic approaches to learning electromagnetism. Physics teacher educators should consider incorporating metacognitive scaffolding into electricity and magnetism courses, modeling

planning processes, and providing structured opportunities for students to develop and reflect on their own learning strategies. Such scaffolding might include guided activities in which students articulate learning goals before engaging with new material, identify potential conceptual challenges, and select appropriate strategies for addressing those challenges [49]. For prospective teachers, experiencing such scaffolding as learners may also help them develop the pedagogical knowledge needed to provide similar support to their own students in the future. Second, the specific difficulties students report with compiling problem-solving steps in magnetic electricity indicate a need for instructional approaches that explicitly develop procedural knowledge in this domain. Problem-solving workshops that emphasize not only correct solutions but also the metacognitive processes underlying effective problem representation and strategy selection could help students develop more robust monitoring skills.

Similarly, other research has shown that expert problem solvers in physics engage in qualitatively different monitoring processes than novices, including more frequent checks on solution progress and more sophisticated evaluation of alternative approaches [50]. Explicitly teaching these monitoring strategies and providing students with opportunities to practice them with feedback could help bridge the gap between students' general confidence in their monitoring abilities and their specific uncertainty about problem-solving procedures. Third, the relatively stronger evaluation abilities reported by students provide a foundation upon which to build. Students' willingness to engage in self-evaluation suggests openness to reflection that can be channeled into more sophisticated metacognitive practices. Physics teacher educators might leverage this evaluative capacity by incorporating structured reflection assignments into electricity and magnetism courses, asking students not only to solve problems but also to analyze their problem-solving approaches, identify effective strategies, and articulate plans for improvement. Such assignments could help students forge stronger connections between evaluation and planning, completing the metacognitive cycle. Additionally, helping students develop more accurate calibration between their self-evaluations and objective performance measures could enhance the effectiveness of their evaluation processes.

#### IV. Conclusions

This study highlights the importance of students' metacognitive abilities in the electricity and magnetism course, which is a complex topic in physics. Metacognition, defined as "thinking about thinking," encompasses awareness and management of an individual's cognitive processes. The research findings indicate that students have varying metacognitive abilities across three main components: planning, monitoring, and evaluation. While most students demonstrate exemplary skills in monitoring and evaluation, they struggle with planning, including time management and learning goals. This suggests that students better understand effective learning strategies to overcome difficulties in grasping the concepts of electricity and magnetism.

Students' monitoring abilities indicate that they are capable of identifying errors in the learning process, which is crucial for enhancing their understanding. A good evaluation also shows that students can reflect on their learning process and identify necessary improvement steps. However, challenges in planning can hinder their ability to learn effectively. Therefore, developing students' metacognitive skills in this course is essential to improving their understanding of complex material.

Overall, although there are challenges in planning, students' monitoring and evaluation abilities show good potential for enhancing their knowledge of the concepts of electricity and magnetism. Therefore, developing students' metacognitive skills in this course is crucial for improving their understanding of complex material and supporting their academic success in the future. The limitations of this study include a narrow focus on a single course, electricity and magnetism, and a population of physics education students, which means the results may not be generalizable to other disciplines. Additionally, this research relies on survey data that may not fully reflect students' metacognitive abilities. Further research is needed to explore strategies that can enhance metacognitive skills in various educational contexts and disciplines. Future studies could focus on broader courses to allow for a more diverse population.

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