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How Extensively do Teachers Train Students' Metacognition Abilities in Physics Learning in High School?

Okta Alpindo[1,2,a)], Edi Istiyono[1], Widihastuti[1]

[1]Department of Educational Research and Evaluation, Postgraduete School, Universitas Negeri Yogyakarta, Yogyakarta 55281, Indonesia
[2]Faculty of Teacher Training and Education, Universitas Maritim Raja Ali Haji, Tanjungpinang 29115, Indonesia

✉: [a)]oktaalpindo.2022@student.uny.ac.id

Abstract

Metacognition refers to the capacity to comprehend and regulate one's own cognitive processes. By cultivating students' metacognitive skills in physics education, they will acquire the ability to understand and govern their own thinking. This, in turn, will enhance the effectiveness of physics instruction by fostering student engagement and enabling them to rectify their own errors. However, previous studies have revealed a scarcity of physics teachers who integrate metacognitive training into their teaching practices. Thus, the aim of this research is to investigate the extent to which high school physics teachers in the Riau Islands Province engage in metacognitive training for their students. Employing a qualitative approach with a phenomenological method, data was collected through interviews conducted with physics teachers from local high schools. This study's participants are physics teachers in the Kepulauan Riau Province. There are a total of 25 physics teachers participating in the study. The sampling technique employed in this research is purposive sampling. During these interviews, the researchers posed open-ended questions to elicit insights into physics teachers' experiences with the cultivation of metacognitive skills in their students during physics lessons. According to the study's findings, physics teachers in the Riau Islands Province are indeed training their students in indicators of metacognitive abilities. However, we observed that some teachers remain unaware that the exercises they assign inherently serve as indicators of metacognitive skills. This lack of awareness is attributed to a deficient understanding among teachers regarding the nature of metacognition.

Keywords: metacognition abilities, physics learning, teacher strategy, phenomenology

INTRODUCTION

The field of physics education has undergone significant changes in terms of its methods and approaches. Many schools and universities are now utilizing digital technology and multimedia to aid in visualizing difficul and abstract physics concepts (Rahim et al., 2022; Sunaryo et al., 2022). Furthermore, many physics teachers are adopting project-based approaches (Yanti et al., 2019; Widyaningsih & Yusuf, 2019; Santyasa et al., 2020; Makkonen et al., 2021) and problem-based approaches (Fauzana, et al., 2019; Pane et al., 2021; Kanyesigye et al., 2022a; Kanyesigye, et al., 2022b; Fonseca et al., 2022) to motivate students and help them better understand physics concepts.

One important aspect of physics education today is the emphasis on developing critical thinking skills (Bonafide et al., 2021; Wenno et al., 2022; Asrizal et al., 2022; Putra et al., 2023) and analytical skills (Pirrie et al., 2020; Serevina et al., 2020; Abdullah et al., 2021; Firdaus et al., 2017). Students are not only learning about physics concepts but also learning how to apply those concepts in real-world situations. Current physics education places greater emphasis on the use of scientific methods and problem-solving in the context of physics.

Physics education also integrates social and ethical aspects (Meyer et al., 2022; Yapijakis & Chrousos, 2022; Scanlon et al., 2021; Agazzi, 2021). Students are taught to consider the social and environmental impact of physics technology, as well as the ethical consequences of its use. This helps students understand that physics is not just about theoretical concepts but also about its influence on society and the world around them.

Physics education also pays attention to gender equality and diversity in the classroom. Physics teachers strive to create an inclusive and engaging learning environment for all students, regardless of gender, cultural background, or abilities (Cwik & Singh, 2022; Wulandari et al., 2021; Sahidu et al., 2021). Students are given opportunities to develop their physics skills without feeling intimidated or discriminated against.

Furthermore, physics education emphasizes the development of life skills that can be applied in future careers (Docktor & Mestre; 2014). Students learn skills such as teamwork, clear communication of ideas, and critical thinking, all of which are highly valuable in the workplace and everyday life. Current physics education aims to create students who have strong physics skills and are prepared for the workforce or higher education.

Metacognitive abilities are required to achieve the goals of physics education. Metacognition refers to the ability to understand and control one's own thinking processes (Akturk & Sahin, 2011; Sart, 2014; Kralik et al., 2018). In physics education, students are taught to be aware of their own processes in understanding physics concepts, identify difficulties in comprehension, and take action to overcome those difficulties. Additionally, students are taught to reflect on and evaluate their own understanding and identify the most effective learning strategies. Metacognitive abilities are not only useful in physics education but also in everyday life and future careers as they help students overcome challenges and improve their performance in various fields.

Metacognitive abilities play a crucial role in physics education. These abilities refer to students' ability to understand and regulate their own thinking processes regarding how they learn and solve problems (Winarti et al., 2022; Irma et al., 2021; Gok, 2010; Sart, 2014; Haeruddin et al. 2020). In physics education, students need to understand complex physics concepts and apply them in various situations. Metacognitive abilities help students learn more effectively and overcome challenges they encounter in physics education. Students with strong metacognitive abilities can monitor and regulate their understanding of physics concepts, identify misconceptions, and find ways to improve them. Metacognitive abilities also help students develop attitudes and skills for independent learning, such as time management, creating study plans, and choosing appropriate learning methods (Ozturk, 2017; Mahdavi, 2014; Fleur et al., 2021). Thus, effective physics education requires strong metacognitive abilities in students. Schools and teachers need to provide adequate support in developing students' metacognitive abilities, so that they can learn more effectively and independently in understanding physics concepts.

However, based on previous research, teachers face difficulties in knowing and training students' metacognitive abilities. These difficulties are caused by several factors, such as the lack of valid and reliable evaluation tools or instruments to measure students' metacognitive abilities (Ozturk, 2017), teachers' lack of skills and experience in using evaluation tools or instruments to measure students' metacognitive abilities (Gok, 2010), limited time and resources available to observe and evaluate students' metacognitive abilities, teachers' limited understanding of metacognition concepts and how to observe and measure students' metacognitive abilities, and students' tendency not to express their thoughts clearly or their inability to reflect on their own learning processes (Fleur et al., 2021). To address these difficulties, teachers can take several actions, such as enhancing their understanding of metacognition concepts, developing effective evaluation instruments, providing meaningful feedback to students, and encouraging students to reflect on and evaluate their own learning methods.

Additionally, teachers can involve students in the evaluation process of their metacognitive abilities and provide opportunities for students to discuss their thinking processes in learning.

Certainly, discussing the need for a teacher to understand students' metacognitive abilities in physics learning is crucial. In the context of physics learning, understanding physics concepts and processes requires critical and analytical thinking. By knowing students' metacognitive abilities, teachers can assist students in understanding their own thinking and learning processes. Furthermore, teachers can adjust learning strategies that are most suitable for each student based on their metacognitive abilities. Moreover, metacognitive abilities can also help students in organizing and monitoring their own learning processes. With the guidance of teachers in developing these metacognitive skills, students can become more independent learners. Consequently, they can understand how they learn and think, recognize their strengths and weaknesses, and improve themselves.

In a broader context, understanding students' metacognitive abilities can also help enhance students' learning outcomes and academic achievements. This is because students who can effectively monitor and regulate their own learning processes can learn more effectively. As a result, they can acquire better knowledge and apply it in various situations, including outside the classroom. Furthermore, understanding students' metacognitive abilities can help teachers facilitate more structured and effective learning. In this regard, teachers can provide more specific guidance and support to students to help them develop their metacognitive abilities.

In conclusion, students' metacognitive abilities can help them learn more effectively and improve their learning outcomes. A teacher who understands students' metacognitive abilities can assist them in understanding their own learning and thinking processes. This can help teachers adjust learning strategies and provide more specific guidance and support for each student. Consequently, students can become more independent in their learning and achieve better learning outcomes. Therefore, this research aims to determine the extent to which physics teachers in high school train students' metacognitive abilities.

METHODS

This study is qualitative research using the phenomenological method. Phenomenological design is used for this study because this type of research analyzes perceived or experienced phenomena (Flynn & Korcuska, 2018). The research aims to understand how physics teachers train metacognition ability in students. The participants of this study are physics teachers in the Kepulauan Riau Province. There are a total of 25 physics teachers participating in the study. The participants include physics teachers from schools located in the cities of Batam and Tanjungpinang, as well as the districts of Bintan, Natuna, Anambas, Lingga, and Tanjungbalai Karimun.

The sampling technique employed in this research is purposive sampling. The researcher selects samples based on specific criteria relevant to the research objectives (Etikan, 2016; Obilor, 2023). This technique was chosen because the researcher selects physics teachers in the Riau Islands who have more than 10 years of teaching experience.

The data was collected through interviews. The interview material includes the strategies and learning methods used by physics teachers to train students' metacognition ability. Additionally, the interviews also inquire about the difficulties experienced by physics teachers in training students' metacognition ability. The collected interview data is then analyzed using the steps of Reduction, Coding, Themes, and Conclusions outlined by Milles & Huberman. Data reduction essentially involves sharpening, categorizing, directing, discarding unnecessary data, and organizing data in such a way as to draw final conclusions and verify them. Data presentation is carried out in the form of matrices, tables, or charts, providing an overview of valid data that has been collected and tested for accuracy. Drawing conclusions involves deriving conclusions from the research results that have been conducted. Drawing conclusions is the answer to the formulation of the problem (research question) established in the research plan. The analysis is facilitated using the software, Atlas.ti. All participant identities in this study are kept confidential. Throughout the research process, the researcher informed the participants that the data obtained is solely for research purposes, will not be used for other purposes, and will not affect the participants' future.

RESULTS AND DISCUSSION

The participants in this study consisted of 25 physics teachers from the Riau Islands Province. The participants comprised of 16 females and 9 males. They were distributed across 2 cities and 5 districts in the Riau Islands. The participants included 8 physics teachers from Batam City, 5 physics teachers from Tanjungpinang City, 5 physics teachers from Bintan District, 3 physics teachers from Lingga District, 2 physics teachers from Tanjungbalai Karimun District, 1 physics teacher from Natuna District, and 1 physics teacher from Anambas District. Interviews were conducted by providing 6 questions related to metacognitive ability indicators. Six components of student metacognition when solving physics problems, such as: (1) knowledge of cognition, (2) planning, (3) monitoring, (4) evaluation, (5) debugging, and (6) information management (Taasoobshirazi and Farley, 2013; Taasoobshirazi et al., 2015; Haeruddin, Prasetyo, et al. 2020).The following are the conclusions obtained from the interview results.

Knowledge of cognition: declarative, procedural, and conditional

The question posed during the interview was, "How do you ensure that students are confident in solving the given physics problems?" The summarized responses from the teachers regarding their methods of instilling confidence in students when tackling physics problems are as follows:

1. Creating a supportive environment. Establishing a positive and supportive learning environment is essential. It involves fostering an atmosphere where students feel secure to express their thoughts, ask questions, and seek clarification without the fear of judgment or criticism. Recognizing their efforts and progress and promoting mutual respect among students within the classroom setting is crucial.
2. Emphasizing strengths and accomplishments. Guiding students to identify and develop their strengths is key. Focusing on their achievements and recognizing what they have already accomplished helps build their self-confidence. Offering positive and specific feedback on their progress, even on smaller tasks, plays a significant role.
3. Teaching problem-solving strategies. Equipping students with effective problem-solving strategies is essential. Educating them on how to approach problems using structured steps, breaking them down into manageable components, and testing potential solutions helps build their confidence. When they successfully overcome problems using these strategies, they become more self-assured in tackling larger challenges.
4. Providing suitable challenges. Assigning tasks and challenges that match students' abilities is important. If the tasks are too easy, students may become disengaged and lack motivation. Conversely, if the tasks are too difficult, students may feel overwhelmed and lose confidence. Striking the right balance between challenge and students' skills is crucial.
5. Encouraging collaboration and peer support. Promoting collaboration and peer support among students contributes to building their confidence. Through teamwork, students can support each other, share knowledge, and learn from one another. This fosters a sense of camaraderie and helps students realize they are not alone in facing challenges, as others can help.
6. Encouraging risk-taking. Encouraging students to take risks and venture into new territories is important. Communicating that failure is a natural part of the learning process and that learning from failures is a steppingstone to success is crucial. By providing students with opportunities to explore new ideas and approaches, educators help them develop confidence in tackling challenges and embracing uncertainty.
7. Providing individualized support. Recognizing that each student has unique needs, providing individualized support is essential. Taking the time to listen to students, offering guidance, and helping them overcome obstacles they encounter contributes to building their confidence.

Regulation of cognition: information management

The interview question used for this indicator was, "Do you train students to solve physics problems using diagrams? Please explain your answer!" Here are the summarized responses from teachers regarding how they train students to solve physics problems using diagrams:

1. Introduce the concept of visualization. Start by explaining to students the importance of visualization in understanding physics concepts. Explain that diagrams can help them depict physical situations, identify relevant variables, and visualize possible solutions.
2. Show examples of using diagrams in physics. Provide real-life examples of using diagrams in the context of physics. For instance, display images representing object motion, acting forces, or electrical circuit diagrams. Discuss how these diagrams aid in understanding the related physics concepts.
3. Practice visual modeling. Encourage students to depict physical situations using diagrams. Present them with questions or statements about physics problems and ask them to draw corresponding diagrams. Help them understand how to represent objects, direction arrows, coordinate systems, or graphs to convey relevant physical information.
4. Use physics diagrams. Teach students to use commonly used physics diagrams, such as force diagrams, vector diagrams, or motion diagrams. Provide guidance on how to utilize these diagrams to represent related physics concepts like forces, acceleration, or motion paths.
5. Teach reading and interpretation of graphs. Train students in reading and interpreting graphs related to physics concepts. Provide them with graphs depicting relationships between physics variables, such as displacement vs. time or force vs. distance graphs. Help them identify patterns and relate the graphed information to the corresponding physics concepts.
6. Assign problem-solving tasks based on diagrams. Assign students problem-solving tasks that require them to use diagrams to solve physics problems. For example, provide written physics problems and ask students to draw diagrams before seeking mathematical solutions.
7. Discuss and evaluate understanding. Discuss the solutions generated by students based on the diagrams they created. Help them identify errors or difficulties that may arise during the visual modeling process. Provide constructive feedback and encourage them to revise and enhance their visual modeling skills.

Regulation of cognition: monitoring

The interview question used for this indicator is, "How do you train students to monitor their problem-solving in physics?" Here are the summarized interview responses from physics teachers regarding the methods to train monitoring skills:

1. Provide a clear understanding of goals and success criteria. Ensure that students understand the objectives of the tasks or projects they are working on, as well as the criteria that will be used to evaluate their success. Discuss expectations and what is expected in their work.
2. Teach self-assessment methods. Help students develop the ability to assess their own work. Teach them how to assess the quality of their work based on the pre-established criteria. Provide them with guidelines and rubrics to assist them in evaluating their own work.
3. Teach the use of assessment tools. Introduce students to assessment tools such as checklists or assessment sheets that they can use to monitor their work. Inform them about various elements to consider and note when reviewing their work.
4. Involve students in the assessment process as much as possible. Encourage students to actively participate in the assessment process. By involving them in providing input and feedback on their own work and their classmates' work, they will be better able to identify strengths and weaknesses in their own work.
5. Provide time for reflection. Give students time to reflect on and contemplate their work. Encourage them to think about what they have learned, the challenges they have faced, and the steps they can take to improve the quality of their work in the future.

6. Encourage planning and organization. Teach students to create detailed schedules or work plans for their projects or tasks. By planning their work and managing their time effectively, they will be better able to monitor their progress and ensure that they achieve the set goals.
7. Provide continuous feedback. Give clear and specific feedback to students on their work. Praise their successes but do not hesitate to provide constructive advice for improvement. By receiving regular feedback, students will be able to identify areas that need improvement and enhance the quality of their work.
8. Foster an inclusive and collaborative classroom. Encourage cooperation and collaboration among students in evaluating each other's work. This helps students to monitor and provide feedback to one another.

Regulation of cognition: evaluation

The interview question used for this indicator is, "Do you train students to perform self-evaluation in solving physics problems? Explain your answer!" Here are the summarized interview responses from the teacher regarding the methods to train self-evaluation skills:

1. Teach the concept of self-evaluation. Start by explaining the concept of self-evaluation to students. Help them understand that self-evaluation is the process of examining, assessing, and reflecting on their own performance or learning. Explain its benefits in enhancing self-awareness, identifying strengths and weaknesses, and planning improvement actions.
2. Provide self-evaluation models. Show students examples of good self-evaluations through demonstrations or written samples. Provide guidance on what needs to be assessed, how to consider evaluation criteria, and how to reflect on their learning outcomes. These self-evaluation models will help students understand the format and process of self-evaluation.
3. Provide rubrics or evaluation criteria. Give clear rubrics or evaluation criteria to students. These rubrics can include aspects to be evaluated, such as the quality of work, understanding of concepts, clarity of arguments, or critical thinking skills. Teach students to refer to these rubrics when self-evaluating.
4. Encourage structured reflection. Prompt students to reflect on their learning outcomes in a structured manner. Provide guiding questions that help them identify their strengths and weaknesses in relation to learning objectives. For example, "What did I do well in this project?", "What still needs improvement?", or "What have I learned about my learning process?"
5. Train qualitative and quantitative assessment. Help students develop the ability to perform qualitative and quantitative assessments of their own work. This can involve providing rating scales, using well-designed multiple-choice options, or giving written feedback. Train students to use data and concrete evidence in their evaluations.
6. Encourage goal setting. Guide students to set specific learning goals based on their self-evaluations. Encourage them to plan concrete and realistic improvement actions. Help them see the relationship between self-evaluation and learning enhancement.
7. Provide opportunities for sharing and discussion. Create an inclusive and open classroom environment where students can share and discuss their self-evaluations. Encourage students to provide feedback and constructive suggestions to their peers. This will help them understand different perspectives and broaden their insights.
8. Allocate time for routine reflection. Set regular time in the class schedule for reflection and self-evaluation. It can be after completing each assignment or project, or in the form of weekly reflection sessions. By considering self-evaluation as an integral part of the learning process, students will become accustomed to this activity and see its benefits in their personal development.

Regulation of cognition: debugging

The interview question used for this debugging indicator is, "How do you train students to collaborate in solving physics problems? Explain your answer!" Here are the summarized interview responses from the teacher regarding the methods to train collaboration skills:

1. Explain the importance of collaboration. Start by explaining why collaboration is important in problem-solving. Discuss the benefits of working together, such as sharing ideas, active engagement, and deeper understanding through collaboration. Help students see that collaboration can lead to better solutions than working alone.
2. Form working groups. Divide students into working groups consisting of two to four members. Ensure each group has a combination of students with diverse skills and knowledge to complement each other. Encourage students to interact and collaborate within these groups.
3. Provide roles and responsibilities. Assign clear roles and responsibilities to each group member. For example, one student can be the group leader who organizes and directs discussions, while others are responsible for taking notes or presenting the group's work to the class. Ensure that each group member feels involved and has meaningful contributions.
4. Teach communication skills. Provide students with guidance on effective communication skills, such as active listening, sharing opinions politely, and building persuasive arguments. Train students to communicate clearly, support each other, and appreciate the perspectives and contributions of other group members.
5. Teach conflict resolution. When students collaborate, conflicts or differences of opinion may arise. Teach students conflict resolution skills, such as empathetic listening, seeking win-win solutions, and finding compromises. Help them understand that disagreements are normal, and it is important to resolve conflicts in a constructive manner.
6. Assign tasks that encourage collaboration. Assign tasks that require students to rely on each other to solve problems. These tasks can include group projects, group discussions, or role-playing simulations where students must collaborate to achieve common goals. Ensure these tasks are designed in a way that necessitates students to work together and support each other.
7. Provide feedback and reflection. After completing the tasks, provide feedback to each group and group member. Discuss the successes and challenges they faced while collaborating. Encourage students to reflect on their collaboration experiences, including what they have learned about collaboration and how they can improve teamwork in the future.
8. Set good examples of collaboration. As a teacher, you are an important role model in teaching collaboration. Demonstrate a collaborative attitude in your interactions with students and provide examples of good collaboration through classroom discussions, joint projects, or teamwork between the teacher and students. This will help students see the value and practice of collaboration in real-life contexts.

Regulation of cognition: planning

The interview question used for this indicator is, "How do you train students to make plans before solving physics problems? Explain your answer!" Here are the summarized responses from 25 physics teachers in the Riau Islands Province:

1. Provide examples of good planning. Show students examples of good planning in various contexts. For example, you can model the planning process before starting a class assignment or provide examples of planning in everyday life, such as creating a schedule or planning activities.
2. Teach the steps of planning. Provide students with a guide on the steps of planning. This can include general steps such as understanding the problem, identifying goals, gathering information, planning actions, and evaluating outcomes. Teach them to break down these steps systematically.
3. Encourage critical thinking. Encourage students to think critically about the problems they face. Prompt them to analyze the situation, identify relevant factors, and consider various

possible solutions. Help them understand the importance of research and gathering information before planning.

4. Teach priorities and time management. Help students understand the importance of setting priorities in their planning. Teach them to identify the most important tasks and plan their time effectively. Provide time management strategies, such as creating task lists or using tools like calendars or task organizers.
5. Provide planning structure. Provide a format or template that helps students plan their steps in a more structured way. For example, you can provide a checklist format for them to complete or use visual tools like concept maps or flowcharts to help them organize ideas and steps.
6. Train group planning. Encourage students to work in small groups and create plans together. In this context, students can discuss, share ideas, and receive input from their peers. Train them to integrate different perspectives into their planning and build consensus in decision-making.
7. Provide feedback and reflection: After students make plans and execute their steps, provide constructive feedback, and encourage them to reflect on the planning process. Discuss what has worked well and what needs improvement. Help them see the relationship between good planning and more successful outcomes.
8. Provide opportunities for practice: Give students opportunities to apply planning in real-life contexts. Encourage them to face problems or tasks that require planning before acting. Provide support and guidance as they execute their plans.

Based on the interview results, it can be concluded that teachers generally train metacognitive skills through metacognitive skill indicators. However, teachers are not yet familiar with the concept of metacognition, resulting in ineffective training processes. Therefore, to address this issue, training for teachers to develop metacognitive skills is necessary (Prytula, 2012; Jiang et al., 2016; Branigan & Donaldson, 2020).

CONCLUSION

This research was conducted only in the Riau Islands Province with the participation of physics teachers from each district and city in the Riau Islands Province. The results of this research can be used as a basis for developing teaching materials that can train students' metacognitive abilities in physics learning. Additionally, it can also be used as a basis for developing instruments to measure metacognitive abilities.

Developing teaching materials that train students' metacognitive abilities in physics based on the results of this research is a good step. The research conducted in the Riau Islands Province with the participation of physics teachers from various districts and cities provides a diversity of perspectives and experiences, thus offering a more comprehensive understanding of metacognitive training.

Using the results of this research as a foundation, teaching materials can be designed to help students understand and develop their metacognitive abilities in physics learning. These teaching materials may include learning strategies that promote self-reflection, monitoring of understanding, planning, and self-evaluation. Effective teaching materials can guide students in recognizing and managing their own thinking processes, as well as help them develop better learning strategies.

Furthermore, the results of this research can also serve as a basis for developing instruments to measure metacognitive abilities. Valid and reliable measurement instruments can assist teachers and researchers in objectively evaluating students' metacognitive abilities. This enables them to identify areas where students need further support and monitor students' progress in metacognitive aspects.

In the development of teaching materials and measurement instruments, it is important to consider the context and characteristics of students beyond the Riau Islands Province. Variations in educational contexts, cultures, and student characteristics can influence the implementation and effectiveness of teaching materials and measurement instruments. Therefore, further adaptation and validation may be necessary to ensure suitability and validity in different contexts. Overall, using the results of this research as a basis for developing teaching materials and instruments to measure students' metacognitive abilities in physics learning is an important step in improving the quality of physics learning and teaching.

Based on the research findings and discussions, it can be concluded that physics teachers in the Kepulauan Riau province have been training students' metacognitive abilities. This training is provided through six indicators of metacognitive skills. However, it is evident that some physics teachers in the Kepulauan Riau province have a limited understanding of metacognitive abilities in general. They apply these techniques without fully grasping the underlying concepts.

The implication of this research impacts the development of teacher professionalism. Teachers who are aware of the importance of training their students' metacognitive skills will enhance their efforts in integrating metacognitive strategies into physics education. This may involve participating in training sessions or workshops focused on metacognitive skills.

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