JPPIPA 10(7) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

The Analysis of Students' Metacognitive Skills in Physics through Problem-Solving Strategies in Physics Education Students

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Received: January 28, 2024
Revised: June 15, 2024
Accepted: July 25, 2024
Published: July 31, 2024

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DOI: 10.29303/jppipa.v10i7.7102

Abstract: This study aims to analyze the metacognitive skills of students through problem-solving learning strategies in the subject of Basic Physics 1. The research sample consists of students enrolled in the Basic Physics 1 course in the Physics Education Study Program at Pattimura University, Ambon, for the 2023/2024 academic year. This study uses a descriptive quantitative and qualitative research type, with a one-shot case study design. The instruments used in this research include: (1) A questionnaire to assess students' metacognitive skills, (2) An observation sheet to observe students' problem-solving activities, and (3) A student response questionnaire to evaluate students' responses to problem-solving learning. Data analysis in this study is conducted using descriptive quantitative analysis to describe the data as is in percentage form and explain the data or events qualitatively with explanatory sentences. The data analysis techniques used include descriptive quantitative analysis, which covers the results of the metacognitive skills questionnaire, observations of problem-solving activities, and the response questionnaire. The results of the metacognitive skills questionnaire showed a percentage of 57.58%, categorized as fairly good. The student response to problem-solving learning received a percentage of 52.27%, categorized as fairly good. The observation of problem-solving activities yielded a percentage of 57%, also categorized as fairly good.

Keywords: Basic Physics 1; Metacognitive skills; Problem-Solving Model

Introduction

The efficiency of learning is not measured by students' ability to achieve maximum scores but by the presence of cognitive activity (Ssemugenyi, 2023). Cognitive activity becomes more meaningful and efficient when it involves metacognition (Güner & Erbay, 2021). Metacognitive skills help students solve learning problems (Celia, 2022). Metacognition plays an important role in regulating and controlling students' cognitive processes (Darmawan et al., 2020; Rengkuan et al., 2023). Without adequate metacognition, students may struggle to understand complex topics in a learning environment because they may fail to plan, set goals, use effective strategies, and monitor and reflect on the learning process (Liu & Liu, 2020).

Metacognition relates to students' ability to reflect, understand, and control their learning (Scraw and Dennison, 1994). Metacognition can build students' awareness of their strengths and weaknesses in planning, controlling, and evaluating what they will and have done (Bakar & Ismail, 2019). Additionally, metacognitive skills can enhance students' understanding, allowing it to be retained in their memory for a long time, and positively impacting their learning outcomes (Van Der Stel & Veenman, 2014; Rivas et al., 2022). Every student is capable of gaining understanding in learning, choosing the right steps, preparing and organizing time, and monitoring learning progress to solve physics problems. This issue seems to occur in all countries worldwide, especially among students who have not yet improved in physics learning (Lavonen et al., 2021).

How to Cite:
Sapulete, H., Sopacua, F., & Sopacua, V. (2024). The Analysis of Students' Metacognitive Skills in Physics through Problem-Solving Strategies in Physics Education Students. *Jurnal Penelitian Pendidikan IPA*, *10*(7), 4453–4460. https://doi.org/10.29303/jppipa.v10i7.7102

Metacognitive skills are necessary for successful learning because they allow students to regulate cognitive abilities and identify their shortcomings until improvements are made in subsequent activities (Leasa et al., 2024). In line with this, metacognitive skills can help students become more focused in organizing their learning and solving physics problems correctly (Gok, 2010; Djudin, 2023). Therefore, metacognition is crucial for understanding learning in physics because students must manage their cognitive tactics and strategies to build meaning and learning experiences (Hollingworth & McLoughlin, 2001).

Metacognition and problem-solving are among the skills recommended for every student in the 21st century to develop in the face of advances in science and technology. Problem-solving and metacognitive skills are vital in education because they are related to an individual's ability to learn and achieve academic goals (Domokos & Huey, 2023). Problem-solving skills enable individuals to address issues in various fields, while metacognition allows individuals to monitor their thinking and learning to improve their performance (Cer, 2019). Problem-solving and metacognitive skills are essential for students in learning physics because these skills allow them to actively engage with scientific concepts and phenomena (Akben, 2020). By developing problem-solving and metacognitive skills, students are better prepared to succeed in physics learning and pursue careers in physics (Salonen et al., 2017). Therefore, enhancing problem-solving and metacognitive skills in science education can benefit students both academically and personally (Utami et al., 2023).

Problem-solving and metacognition are closely related. The relationship between metacognition and problem-solving can be likened to a perpendicular connection: when metacognition is strong, students' problem-solving abilities are also strong, and vice versa (Leasa, Batlolona, et al., 2023). Metacognition helps students find the necessary information and apply it in solving problems (Kuzle, 2013). Problem-solving skills are crucial for students because they are confronted with problems daily, whether they are aware of them or not (Safari & Meskini, 2016). Problem-solving abilities in various aspects are strongly linked to metacognitive skills, especially when applied to solving physics problems given to students (Taasoobshirazi & Farley, 2013). For students to solve problems effectively, a learning model that encourages problem-solving is needed, such as the Problem-Solving model (Dessie et al., 2024). Problem-Solving is a complex process that involves several cognitive operations, such as gathering and selecting information, heuristic strategies, and metacognition (Schoenfeld, 2016; Leasa, Fenanlampir, et al., 2023). There are three important metacognitive skills in problem-solving: self-monitoring, planning, and evaluation. Problem-solving is a scientific way of thinking to find solutions to problems (Syaiful & Aswan, 2002). Problem-solving occurs in everyday life and can involve everything from identifying the problem to finding a solution. In an academic environment, problem-solving is usually related to discipline-based problem-solving challenges (Frey et al., 2022).

Findings indicate that in the Basic Physics 1 course, most students have not yet demonstrated the metacognitive skills needed to solve physics problems (Sapulete et al., 2023). Knowing one's own metacognitive skills is crucial for solving problems. One must seek and discover their own metacognitive skills. In this study, the focus is on metacognitive activities that occur during problem-solving tasks. Therefore, the metacognitive activities observed include those limited to three components: planning, monitoring, and evaluation. These three components form an interconnected sequence within metacognitive activities. The metacognitive process takes place during problem-solving.

Several studies have shown that metacognition plays an important role in the learning process and can predict an individual's academic success. Students with good metacognition demonstrate better academic achievement (Zulkiply, et al., 2008; Coutinho, 2010; Singh, 2012, in Dewi, 2014). Students with high metacognitive awareness can solve problems more effectively than those with low metacognitive awareness (Rahman, et al., 2010, in Dewi, 2014). The purpose of this research is to analyze students' metacognitive skills through problem-solving learning strategies in the Basic Physics 1 course.

Method

Research Design

This study uses a descriptive quantitative research type with a one-shot case study design. The experiment's design is a one-shot case study because there is only one group that is shown a series of slides, each containing several images of circles. While watching the slides, the subjects are exposed to a social influence (X) in the form of the opinion of an unknown person sitting next to them, watching the same slides. The dependent variable is the difference between the subject's answers and those of the unknown person sitting next to them (O) (Harris, 2006). This design is an improvement over a single group design with only post-treatment measurement. A single group design can still be interpreted by referring to pattern matching or coherence conditions (Knapp, 2016).

X	O

Description
X = Treatment given (independent variable)
O = Observation (Dependent variable)

Participants

The research sample consists of 20 students from Class A, who are enrolled in the Basic Physics 1 course in the Physics Education Study Program at Pattimura University, Ambon, for the Odd Semester of the 2023/2024 academic year.

Research Instruments

The instruments used in this research include: (1) A questionnaire to assess students' metacognitive skills, (2) An observation sheet to observe students' problem-solving activities, and (3) A student response questionnaire to evaluate students' responses to problem-solving learning.

Research Procedure

The research procedure includes: (1) Initial observation, (2) Development of research instruments, (3) Instrument validation, (4) Testing in the research class, (5) Data collection, (6) Reflection, (7) Report preparation, (8) Revision, and (9) Final report.

Data Analysis Techniques

Data analysis in this study is conducted using descriptive quantitative analysis to describe the data as is, in percentage form, and to explain the data or events qualitatively with explanatory sentences. The analysis of metacognitive skills, students' responses to problem-solving learning, and problem-solving activities is calculated using theFormula 1:

$$Percentage = \frac{\sum obtained\ score}{\sum overall\ score} x\ 100 \qquad (1)$$

Result and Discussion

Metacognitive Skills

This section discusses metacognitive skills as assessed using a metacognitive skills questionnaire in the Basic Physics 1 course. The questionnaire covers three indicators of metacognitive skills: 1) Planning, 2) Monitoring, and 3) Evaluation. Each of these indicators includes five statements related to activities in solving problems within the Basic Physics 1 course, with a sample size of 20 students. The percentage of achievement for each metacognitive skill indicator is shown in Figure 1.

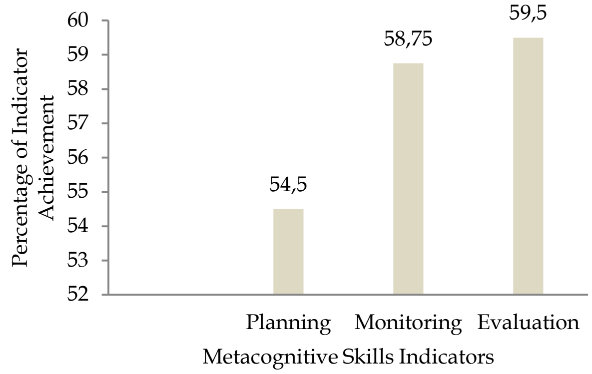

Figure 1. Percentage of Achievement for Metacognitive Skill Indicators

Metacognition is related to students' ability to reflect on, understand, and control their learning (Schraw and Dennison, 1994). Metacognition can develop students' awareness of their strengths and weaknesses in planning, monitoring, and evaluating. According to Schraw & Dennison (1994), the planning indicator refers to a person's ability to set goals and allocate objectives before learning. Based on the data in Figures 4.1 and 4.2, it was found that the percentage for the planning indicator was 54.5% with a total of 5 statements. The statement that received less than 50% metacognitive response was statement number 3, which concerns knowing which problems require more time to find solutions, with a percentage of 46.25%. This is because students have not yet fully understood the problems, determined the appropriate formulas to use, focused their attention on what is relevant to the problem, directed themselves to choose the appropriate steps in solving the problem, and have not yet recognized their habits or realized their lack of knowledge.

Flavell and other metacognition researchers describe three main components of metacognition, which can facilitate the practice of metacognitive teaching. First, it may be beneficial to explicitly teach students about metacognitive knowledge; for example, teachers should help students become aware of their strengths and weaknesses in learning, and what they know and do not know. Second, one might explicitly teach metacognitive skills; for example, teachers should provide students with effective learning strategies so that they can use them when studying. Third, it might be helpful to explicitly teach students about metacognitive experiences; for example, students' feelings related to learning tasks (Versteeg et al., 2021). Students with metacognitive skills can recognize their habits and realize their ignorance, which can be addressed through the learning process. Metacognitive skills help students focus on what is relevant to the problem and guide them to choose the appropriate steps in solving the problem through relevant questions (Prevost & Lemons, 2016). The results of the metacognitive skills questionnaire are shown in Figure 2.

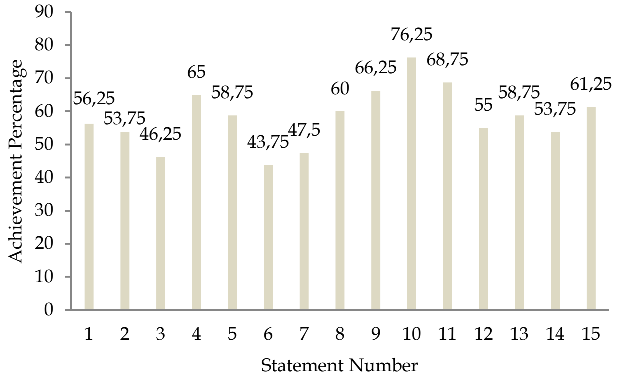

Figure 2. Results of the Metacognitive Skills Questionnaire

According to Schraw & Dennison (1994), the monitoring indicator refers to students' ability to sense, assess learning, and utilize strategies. Based on the data in Figures 1 and 2, it was found that the percentage for the monitoring indicator was 58.75% with a total of 5 statements under this indicator. Statements that received less than 50% metacognitive response were numbers 6 and 7. Statement number 6, concerning confidence in learning physics, had a percentage of 43.75% because students still fear answering physics questions and are hesitant to express their opinions when asked about solutions to problems. Research conducted by Batlolona et al. (2020) indicates that students' confidence levels can affect their ability to solve physics problems. If students lack sufficient confidence, they tend to struggle with physics questions. Statement number 7, regarding planning for problem-solving, had a percentage of 47.5% because students were not yet able to fully understand the given problem and did not know the exact point of the issue. Bouchée et al. (2022) stated that the planning stage requires conceptual understanding as a prerequisite for solving problems because, in creating a problem-solving plan, students must connect various concepts. The lack of conceptual understanding is one of the reasons students struggle with planning problem-solving strategies. The problem-solving planning stage is highly challenging for students.

According to Schraw & Dennison (1994), the evaluation indicator refers to students' ability to analyze their performance and the effectiveness of strategies after learning activities. Based on the data in Figures 1 and 2, it was found that the percentage for the evaluation indicator was 59.5% with a total of 5 statements under this indicator. There were no statements that received less than 50% metacognitive response because students often reviewed their answers, were confident that the strategies they used were appropriate, and were able to achieve their learning objectives in physics, regardless of whether their answers were correct or not. Research by Chin & Osborne (2008) indicated that high-achieving students can understand problems by comprehending the vocabulary in the questions, identifying all facts in the form of data or information in the test questions, connecting all the information identified, and concluding by identifying the question within the test as the objective to be achieved. They are able to create a problem-solving plan by selecting operations based on the identified data and are capable of executing the plan and reviewing the results by substituting the obtained results back into the initial equation. The consistency of this substitution with the initial equation indicates that the students' results are correct and that they have achieved their objective based on the solution to the problem they faced.

Problem-Solving Activities

This section discusses students' problem-solving activities as observed using an observation sheet covering 8 problem-solving activities. The results of the problem-solving activities are shown in Figure 3.

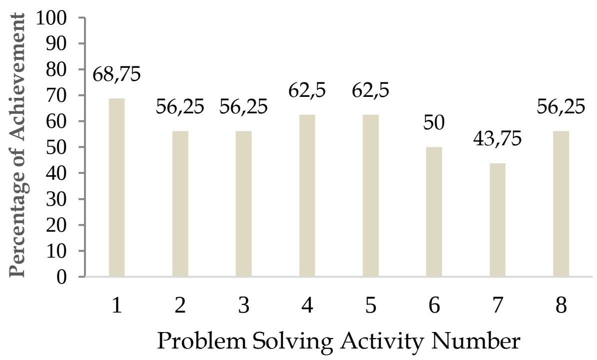

Figure 3. Percentage of Problem-Solving Activities

Learning that involves metacognition is reflected in how students solve problems given by a teacher, which is commonly known as problem-solving. Metacognition and problem-solving are closely related. They are like perpendicular lines; if metacognition is strong, then the problem-solving skills of the students are also strong, and vice versa (Kazemi et al., 2010). Metacognition assists students in seeking the necessary information and applying it to solve problems. Problem-solving is the effort to find a solution to a difficulty (Tachie, 2019). According to Figure 3, the problem-solving activity with a result below 50% is interpreting the solution obtained, with a percentage of 43.75%. This is because interpreting solutions requires strong thinking processes to solve a problem. Problem-solving can stimulate students' thinking abilities by training them to think critically (Yazar Soyadı, 2015). Students are encouraged to engage in thinking activities to resolve or find solutions to the problems they face using the knowledge or skills they have previously acquired (Sarwari & Kakar, 2023).

In Figure 3, the problem-solving activity with the highest percentage is understanding the problem/question, with a percentage of 68.75%. This is because understanding the problem is the first step in starting the problem-solving process. To solve a problem, students need to identify what is known, what is given, the quantities, relationships, and values involved, as well as what they are looking for. Some suggestions that can help students in understanding complex problems include: asking questions about what is known and what is being sought, explaining the problem in their own words, relating it to similar problems, focusing on the critical parts of the problem, developing models, and drawing diagrams.

Student Responses to Problem Solving

This section discusses students' responses to problem-solving learning, measured using a response questionnaire with 15 statement items. The results of the response questionnaire related to problem-solving learning can be seen in Figure 4.

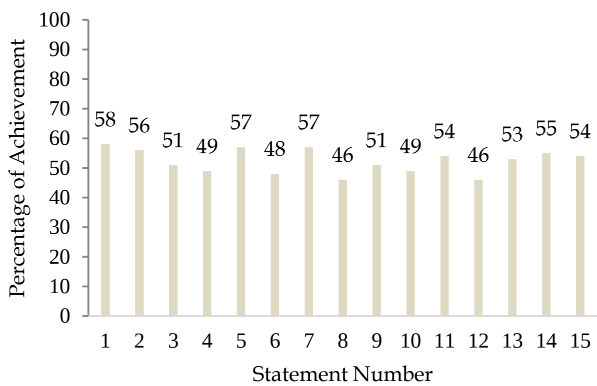

Figure 4. Percentage of Student Responses to Problem-Solving Learning

Problem-solving is a method that fosters understanding by stimulating students to pay attention, examine, and think about a problem, and then analyze it as an effort to solve it (Albay, 2019). Problem-solving is a strategy that teaches problem resolution by emphasizing reasoning to solve a problem (Galate, 2023). According to Figure 4, there are 15 statements with a response percentage below 50%, including: statement number 4 regarding the problem-solving model broadening thinking perspectives with a percentage of 49%, statement number 6 about the problem-solving model helping to solve problems in basic physics material with a percentage of 48%, statement number 8 regarding the problem-solving model encouraging systematic thinking in solving problems with a percentage of 46%, statement number 10 about the problem-solving model enabling direct contribution in presenting arguments with a percentage of 49%, and statement number 12 concerning the problem-solving model guiding thinking to draw conclusions based on the material covered that day with a percentage of 46%. The application of the problem-solving model in Physics learning is carried out through four stages: understanding the problem, planning the solution, solving the problem according to the plan, and reviewing the solution. In the understanding phase, the researcher presents problems in the form of questions and relates them to everyday life. The researcher attempts to explain so that students can understand the problems based on their everyday experiences within their groups. The benefits of applying the problem-solving strategy in understanding problems have been proven to assist students in comprehending the issues and enhancing their academic performance.

Students' epistemological beliefs are centered on their learning and knowledge. These beliefs play a crucial role in how one approaches problem-solving in physics. Findings reveal that students' understanding of physics structure is a weak combination of fragmented information rather than physics connected within a coherent structural framework. Through this process, it becomes possible to classify students' problem-solving strategies into two categories: those with an expert-like view and those with a novice-like view (Reddy, 2020). Thus, it can be said that novices focus on surface features and rely on memorization when attempting to solve problems, while expert-like problem solvers conduct a quantitative analysis of the problem they need to solve. Various techniques are used to assess beliefs, including questionnaires, interviews, reflections, and observations (Ozturk & Guven, 2016). Using questionnaires may have some drawbacks compared to other techniques, as they can overlook information such as changes in beliefs, emotions, behaviors, and feelings as students engage in problem-solving in physics. In this study, interviews, along with observations and reflections, will be chosen because they can provide insights into how students think and understand physics (Redish & Steinberg, 1999). This is valuable as it allows students to describe and explain their thoughts while trying to solve problems in physics.

Problem-Solving according to Batlolona et al. (2018), requires individuals to build knowledge to overcome difficulties and may involve using several strategies to eliminate undesirable situations. Problem-solving skills and conceptual understanding complement each other. Therefore, problem-solving skills refer to students' ability to apply the concepts they have learned in physics to solve problems in the subject. This means that, for students to solve physics problems, they are expected to have a solid understanding of the concepts (Ersoy, 2018). It should be noted that the problem-solving performance of high school students differs after they use problem-solving strategies in cooperative groups in physics class. The problem-solving approach used by physics students is very different due to its individual nature. They believe they have complete knowledge when they are still at the high school level, where they still require guidance (Antwi, 2023).

Conclusion

Based on the analysis of the research data, three conclusions can be drawn: 1) Metacognitive skills in the Basic Physics 1 course indicate that students are reasonably capable in the indicators of planning, monitoring, and evaluating. This is evident from the metacognitive skills achievement rate of 57.58%, which falls into the "fairly good" category. 2) The average percentage of problem-solving activities is 57%, also categorized as "fairly good," indicating that students are moderately capable of carrying out problem-solving tasks. 3) Student responses to learning using the problem-solving model are "fairly good," with an average percentage of 52.27%. The suggestion that the author offers is that this research should be considered by various parties for further study or teaching so that students become more accustomed to practicing metacognitive skills.

Acknowledgments
Thanks to the Dean of the Faculty of Teaching and Education, University of Pattimura, Prof. Dr. I. H. Wenno, S.Pd. M.Pd. who has funded this activity with SK No. 1277/UN13/SK/2022 chaired by Heppy Sapulette, S.Pd., M.Pd.

Author Contributions
All authors were directly involved in this research, which started from the preparation of the proposal to publication in the journal.

Funding
This research was funded by the Research Faculty of Teaching and Education Sciences for the 2022 Budget with SK Number No. 1277/UN13/SK/2023 chaired by Heppy Sapulette, S.Pd., M.Pd. with research members Fryan Sopacua, Venty Sopacua

Conflicts of Interest
The author declares there is no conflict of interest with anyone

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