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UNDERSTANDING STUDENT PROBLEM-SOLVING PROCESSES IN PHYSICS: FOCUS ON GLOBAL WARMING TOPICS

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ABSTRAK

This study aims to analyze students' problem-solving abilities in physics related to global warming materials. The research employed a mixed-method approach combining quantitative test analysis and qualitative interviews. A total of 60 students from class X at a public high school in Samarinda city were selected using purposive sampling, considering their representativeness of the school's academic characteristics. The instrument used was a written test consisting of 10 multiple-choice questions and 5 essay questions, which had previously been validated by two physics education. The results showed that most students' problem-solving abilities were categorized as low to moderate. Specifically, 5 students were in the very low category, 7 in the low category, 7 in the sufficient category, and 7 in the moderate category. The average test score was 63.9, with a minimum score of 53.3 and a maximum score of 75.3. Furthermore, interviews with six selected students representing each ability level revealed that students in the low category had difficulty connecting physics concepts with real-world environmental issues, while students in the moderate category were able to identify problems but struggled to develop structured problem-solving strategies. The findings indicate that physics learning still requires improvement, especially in developing students' higher-order thinking skills (HOTS). Therefore, physics instruction should be directed towards more applicable and contextual learning strategies, such as problem-based learning (PBL) and inquiry-based approaches, to help students meaningfully connect physics concepts with real environmental phenomena like global warming.

A. BACKGROUND

Education is something that is always a very important aspect in the progress of a country. (Rahman & Nasryah, 2020) argue that education has a very important role in increasing a person's knowledge to be higher and is important in expanding a person's ability to understand themselves. If someone has the ability, then that ability will lead him to higher or better skills and attitudes. Physics learning is basically not only aimed at memorizing concepts and formulas, but also to equip students with scientific thinking skills and skills in solving contextual problems related to real life. One topic that is closely related to everyday life and global issues is global warming. This material not only contains cognitive aspects but also demands conceptual understanding and critical thinking skills in studying complex natural phenomena (D. Wulandari et al., 2021). Physics is a branch of science that discusses a lot about the phenomena around us or in everyday life that can occur. Science can be interpreted as a field of science in which we can studying the phenomena that occur in nature and the phenomenon that we often see and occur in everyday life. Physics can also be said to be part of science education that can educate people's lives (Annam et al., 2020).

In the context of physics learning, one concept that is highly relevant to global issues is global warming. Understanding this material requires the interconnection of several physics concepts, including: heat transfer (conduction, convection, radiation), the greenhouse effect as an application of the law of energy radiation (Stefan-Boltzmann Law), and the concept of Earth's energy balance. For example, shortwave radiation from the sun is absorbed by the earth, then re-emitted as longwave radiation, some of which is trapped by greenhouse gases. Students often struggle to understand this process because learning still focuses on mathematical formulas, rather than on their application to real-world environmental phenomena (Azhari et al., 2022)(Wang et al., 2022). Therefore, integrating physics concepts such as heat and energy into global warming learning not only helps students understand environmental phenomena but also trains problem-solving and critical thinking skills in connecting physics theory to current contextual global issues. This aligns with the results of the (Astuti et al., 2024), which stated that learning global warming can support the development of students' critical thinking and problem-solving skills, as well as research on critical thinking skills on global warming issues, which found that a socio-scientific issue-based approach effectively improves problem-solving abilities in the context of global warming (Pauzi & Windiaryani, 2021).

In physics, many children say that physics is a difficult or hard thing to learn and understand. However, in fact, many children of the nation are able to compete and excel in physics olympiads abroad and nationally. However, the reality in the field is sometimes different from what we have heard so far regarding the chaos about differences of opinion that say science is difficult to understand.

Based on observations at SMAN 16 Samarinda, it was found that the physics learning process was still ineffective and was still dominated by conventional learning methods, so that around 50% of students had to take remedial classes because they did not reach the Minimum Competency (KKM). This condition is in line with the findings of (N. O. Wulandari et al., 2024),who reported that student learning outcomes using teacher-centered models tended to be lower than those in classes using project-based learning.

Such student physics learning outcomes are thought to occur due to a lack of understanding of the concepts possessed by students. The lack of conceptual mastery can be caused by students' physics problem-solving abilities which are still underdeveloped. In the learning process, students are also not given sufficient opportunities to comprehensively develop their thinking skills. This condition is supported by the primary data obtained in this study, where the average score of students' problem-solving tests on global warming material was only 63.9, with the lowest score being 53.3 and the highest 75.3. Based on the classification, as many as 5 students (8.3%) were in the very low category, 7 students (11.7%) in the low category, and 7 students (11.7%) in the medium category, while only a limited number of students reached the good category. These findings quantitatively confirm that most students still experience difficulties in applying physics concepts to contextual problems. After considering the researcher's explanation, it is necessary to design learning behaviors and strategies that can awaken students' problem-solving abilities, such as providing opportunities for students to actively engage in the learning process and increasing their motivation. Several possible factors can influence problem-solving abilities, namely external factors such as the learning model used, and internal factors such as the scientific attitude and curiosity of the students, which significantly affect learning outcomes.

Various previous studies have highlighted the importance of problem-based and contextual physics learning in improving students' thinking skills (Meliyanti et al., 2024)(Skills, 2025)(Nurlita et al., 2025) .However, most of these studies focused more on improving learning outcomes or creativity aspects, and have not detailed the processes and categories of students' problem-solving abilities, particularly the difficulties they face in connecting physics concepts with real-world environmental phenomena. Therefore, this study seeks to fill this gap by quantitatively and qualitatively analyzing students' problem-solving abilities on global warming at SMAN 16 Samarinda.

B. RESEARCH METHODS

This study employed a mixed-methods descriptive approach, integrating quantitative test results with qualitative interview data to gain a more comprehensive picture of students' problem-solving abilities in the context of global warming. Quantitative scores were used to classify performance levels, while qualitative insights were gained from students' explanations and reasoning patterns. A similar approach was noted by (Zhang, 2022), who emphasized that combining numerical results with in-depth narratives provides a richer perspective on student learning, and by (Rosen & Kelly, 2023), who highlighted the power of mixed methods in capturing measurable outcomes and underlying processes in physics education research.

The research was conducted at SMAN 16 Samarinda, with the research subjects being 60 students in grades X5 and X6. The selection of subjects was carried out using purposive sampling, namely the selection of samples based on certain objectives and criteria, in this case students who had taken the physics problem-solving ability test on global warming material.

The written test consisted of 10 multiple-choice questions and 5 essay questions designed to measure students' physics problem-solving abilities according to the indicators: problem identification, problem representation, strategy formulation, and outcome evaluation (Heller et al., 1992). Prior to being administered, the test instrument was validated through expert judgment by two physics education lecturers and one experienced physics teacher, focusing on aspects of content validity, construct validity, and language clarity**.** Revisions were made according to the experts' feedback to ensure that the test items aligned with the problem-solving indicators and the global warming context. Furthermore, a trial test was conducted with a group of students outside the research sample to check reliability using Cronbach's Alpha, which yielded a coefficient of 0.82**,** indicating that the instrument had high internal consistency and was reliable for use in this study (Sugiyono, 2020).

The analysis was carried out on test results and interview data in an integrated manner. Data reduction was carried out by filtering student answers and interview transcripts to focus on aspects of problem solving. Data presentation was carried out in the form of tables, graphs, and interview quotes. Conclusions were drawn based on patterns that emerged in students' thinking processes and differences between ability categories.

C. RESULTS AND DISCUSSION

In this discussion, data will be described regarding the independent variables, namely students' physics problem-solving abilities, and the dependent variables, namely students' learning outcomes on global warming material. Data collection was carried out using a written test that aims to measure students' mastery of physics concepts. Test scores for each variable were tabulated, analyzed quantitatively, then presented in the form of a bar chart to support visual data interpretation. Recent educational research supports that written tests, when designed to be valid and reliable, remain robust instruments for assessing students' cognitive achievement and problem-solving skills in science domains (Erlinawati & Muslimah, 2021). Visualizing test data through graphical means such as diagrams facilitates clearer communication of student performance trends and supports evidence-based instructional decision-making (Llaha & Aliu, 2023).

Data on students' physics problem-solving abilities were obtained from a written test consisting of 15 questions, 10 multiple-choice questions and 5 essay questions distributed to all students of class X5 and X6 SMAN16 Samarinda, so that the total was 60 students as a research sample. And stated through the pie chart below shows the distribution of students' problem-solving abilities which are categorized as Very Low, Low, Sufficient, Average, and Good. Good (56.7%): More than half of the students showed strong problem-solving skills, which is a positive indicator of effective learning. Average, Sufficient, and Low (11.7% each): Most students fall into this middle-level category, indicating the need for targeted instruction to help them reach higher levels. Very Low (8.3%): A small number of students have significant difficulties and may require additional support or intervention.

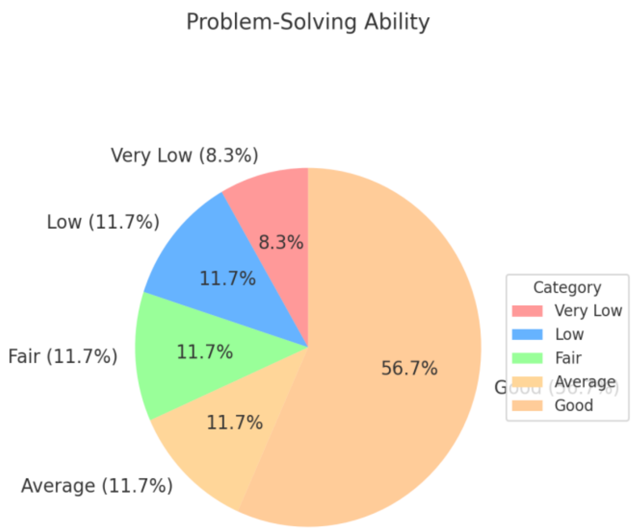

Fig 1. Student ability test results

Figure 1 illustrates the results of the students' problem-solving ability test.The data show that the majority of students (56.7%) are in the good category, indicating that more than half of the participants demonstrate relatively strong problem-solving skills. However, a significant proportion of students remain in the average, fair, and low categories (11.7% each), suggesting that a considerable number of learners still struggle to consistently apply physics concepts in solving contextual problems. Meanwhile, 8.3% of students fall into the very low category, which highlights a critical group that requires special attention and targeted instructional support. Overall, this distribution emphasizes that although the majority are categorized as good, the presence of students in the lower categories reflects the need for more varied and contextual learning strategies to ensure all students can achieve optimal problem-solving skills.

The findings of this study indicate that most students are still in the low to moderate category in their problem-solving abilities on global warming material. This aligns with the problem-solving framework, which emphasizes that difficulties often arise at the stages of problem understanding and rechecking (Sinaga et al., 2023). Students' understanding of problem-solving steps, including rechecking answers, is strongly related to academic achievement. Meanwhile, the Mathematical Problem-solving Model Within the Polya (Nico Pradana, 2024) exemplifies that although students can complete some of the steps, many of them have difficulty connecting concepts and concluding results systematically.

In terms of strategy formulation, only a limited number of students could design logical problem-solving plans. Consistent with these findings, (Gousopoulos, 2023) reported that even when students possess sufficient content knowledge, they tend to rely on heuristic or intuitive approaches rather than systematic analytical reasoning, which further explains the weak problem-solving strategies identified in this research.

Table 1. Data on Problem Solving Ability Test Results for Global Warming Material

No	Data	Value
1	Average test score	63.9
2	Maximum test score	75.3
3	Minimun test score	53.3

Based on Table 1, the average score of students' problem-solving ability on global warming material was 63.9, with the highest score of 75.3 and the lowest score of 53.3. These results indicate that although some students have reached relatively high performance, the overall achievement remains below the expected standard.

Table 2. Grouping of Criteria Based on Test Results

No	Value	Criteria	Number of Student
1	0-40	Very Low	5
2	41-50	Low	7
3	51-60	Medium	7

Table 2, the categorization of student scores, shows that 5 students (8.3%) are in the very low category, 7 students (11.7%) are in the low category, and 7 students (11.7%) are in the medium category, the criteria of learning outcome grouping adapted from (Dawana & Dwikoranto, 2024). The distribution of learning scores shows that most students are still in the low and medium categories, indicating difficulties in connecting physics concepts to real-world contexts such as global warming. Similar findings were reported by the Profile of Students' Physics Problem-Solving Skills and Problem-Based Learning Implementation Supported by Website on Gas Kinetic Theory (Pristianti & Prahani, 2022), which showed that the majority of students are in the low category for physics problem-solving skills and their use is still limited.

Table 3. Subject Selection Results

No	Crteria	Student Grade	Student Code
1	Very Low	14	TGA
2	Very Low	25	BJE
3	Low	30	TAK
4	Low	32	GSA
5	Medium	50	PTR
6	Medium	57	OKW

This study was conducted on 60 students of grades X5 and X6 of SMAN 16 Samarinda. Data were collected through a written test consisting of 10 multiple-choice questions and 5 essay questions. The test results showed an average student score of 63.9 with a maximum score of 75.3 and a minimum score of 53.3. Several students were then selected to be interviewed based on the categorization of their test results. As presented in Table 3, two students represented the very low category (TGA and BJE), two students came from the low category (TAK and GSA), and two students came from the medium category (PTR and OKW).

The interview instrument was semi-structured with open-ended questions that revealed students' thinking about conceptual physics problems. Students were asked to explain their problem-solving steps verbally and in detail, such as how they understood the problem, developed a strategy, implemented the solution, and reviewed their answers (Park, 2020). The use of open-ended questions was intended to encourage students to express their reasoning process, misconceptions, and difficulties more freely. The selection of these subjects was intended to represent various levels of problem-solving abilities, so that the interviews could reveal various learning difficulties and strategies in understanding the concepts of global warming in physics.

Table 4 below used to measure problem solving related to global warming.

No	Problem Solvings Indicator	Description/Sub-Indicators
1	Identification of problems	Students are able to identify specific global warming issues (for example: rising temperatures, greenhouse effect, rising sea levels) and formulate research questions (A Suryansyah et al., 2021)
2	Identifying relevant physics concepts	Students connect the phenomenon of global warming with physics concepts (thermodynamics, heat transfer, radiation, greenhouse effect) (DrShivaraj Gadigeppa Gurikar, 2016)
3	Designing alternative solutions	Students propose various physical/technical solution options (e.g. increased energy efficiency, carbon capture, renewable energy technologies) (A Suryansyah et al., 2021)
4	Determine the best solution / priority	From the proposed alternatives, students choose the most feasible, effective and realistic solution, taking into account the physics & resource aspects. (A Suryansyah et al., 2021)
5	Execute or model actions/simulations	Students implement solutions in simple models (e.g. radiation simulations, energy flow models) or describe the implementation stages.
6	Evaluation of results and reflection	Students evaluate the advantages/disadvantages of proposed solutions, revise assumptions, or review alternative solutions.
7	Data analysis physical argumentation	In the problem-solving process, students use quantitative analysis (formulas, graphs, calculations) and physical reasoning to support the solution (A Suryansyah et al., 2021).

In general, the proportion of students who fall into the low to very low category indicates significant challenges in contextual physics learning. This indicates that most students still have difficulty in applying physics knowledge to solve problems related to real phenomena such as global warming. This finding is in line with the results of the study by (Ruslan et al., 2024)(Lestari et al., 2024) which stated that students' low problem-solving abilities are influenced activities and a lack of understanding of basic physics concepts.

Selected subjects were then analyzed through a series of questions related to problem-solving skills on global warming, as well as their responses on completed test answer sheets. To accurately assess students' problem-solving abilities, specific indicators or steps must be examined. The first stage is problem understanding, as reflected in questions 1, 2, 3, 4, 9, and 10, as well as essay questions 1 and 2. The analysis showed that out of 60 students, 60%

were able to answer question 1 correctly, indicating a moderate level of understanding at this initial stage.This finding aligns with research on physics problem-solving profiles, where the problem understanding stage is seen as a crucial foundation for successful problem-solving, and the implementation of problem-based learning has been shown to help strengthen students' problem-solving indicators (Pristianti & Prahani, 2022).

The analysis of physics students' problem-solving abilities in the context of global warming shows significant variation in ability levels. For the problem identification indicator (questions 1–4), students in the very low category (BJE and TGA) were only able to answer within the range of 0–25%. The errors that occurred were caused by misconceptions about the material, lack of self-confidence, and inaccurate reading of the questions. Meanwhile, students in the low category (TAK and GSA), with a percentage of 26–50%, began to demonstrate understanding of the questions, but still struggled to formulate logical solutions, tending to answer based on intuition or general knowledge, rather than scientific analysis. Meanwhile, students in the moderate category (PTR and OKW), with a percentage of 51–75%, were able to identify problems and formulate solutions effectively, although they remained weak at the calculation and final conclusion stages (Rusilowati et al., 2023). These results are also in line with (Safitri et al., 2022) who found that misconceptions and weaknesses in reading questions contribute to low problem-solving skills, as well as with (Setyarini et al., 2021) who emphasized that students mastered the problem understanding stage more than the calculation and evaluation stages.

Furthermore, in the indicator for developing a plan or strategy (questions 5, 6, 7, 8, and description 3), students in the very low category only achieved 0–25% and appeared unable to develop a correct problem-solving strategy. Students in the low category (26–50%) began to attempt to develop a strategy, but it was not yet logical and lacked a basis in physics principles. Meanwhile, students in the moderate category (51–75%) were able to develop a correct problem-solving strategy, although sometimes their answers were incomplete.

On the indicator for implementing a plan or strategy (descriptions 3–4), students in the very low category only achieved 0–25% and tended to be unable to answer the questions, some even leaving blank answers. Conversely, students in the moderate category achieved 51–75% and were able to apply problem-solving strategies effectively, for example by explaining individual steps and the role of forests in addressing global warming, and provided mostly correct answers.

The final indicator, evaluation or rechecking (question 5), showed varying results. In the very low category (0–25%), students were unable to evaluate the relationship between greenhouse gas emissions and the greenhouse effect. Students in the low category (26–50%) were able to provide partially correct answers, but they were incomplete or even misleading. Meanwhile, students in the moderate category (51–75%) were able to evaluate solutions well, and most of their answers were complete (Wildbichler et al., 2025).

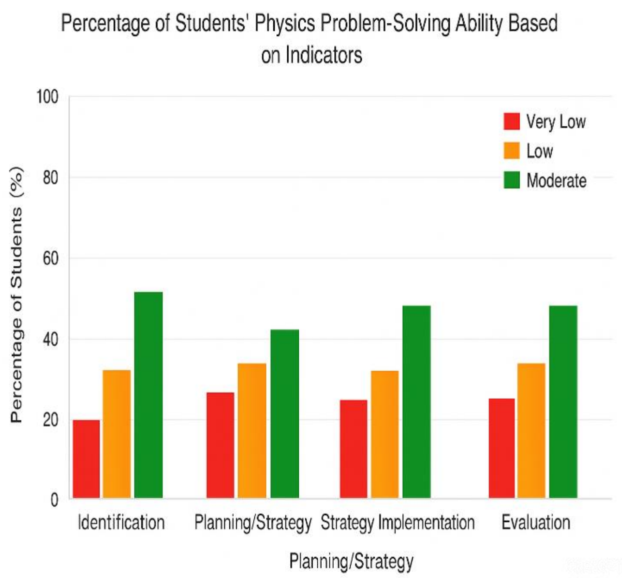

Fig. 2 Percentage of students' physics problem-solving abilities based on indicators

Figure 2 shows the percentage distribution of student abilities. Furthermore, for descriptive question number 1, only students in the moderate category (OKW) were able to answer correctly. Students in the low category (GSA and TAK) were only able to answer partially, while students in the very low category (BJE and TGA) were unable to answer. These errors are generally caused by misconceptions about the material, lack of confidence, and inaccuracy in reading the question.

Students in the low category (TAK and GSA) showed little progress in understanding the questions, but still had difficulty in designing logical solutions and using physics principles correctly. They tended to answer based on intuition or general knowledge, rather than based on scientific analysis. This finding supports the research results by (Nurhasan Ropi'i et al., 2025) which states that the integration of science skills and scientific reasoning abilities is still weak in the curriculum and learning practices in many secondary schools.

Second, there is an indicator, namely the stage in making a plan or what is commonly called a strategy. Questions containing this indicator are in questions number 5, 6, 7, 8 and description number 3. The results of the analysis for question number 5 show that 78% of the 60 students can choose the correct answer. In question number 5, 68% of the 60 students can answer the question correctly, but then in question number 7 only a few students, namely 40%, can answer the question correctly. Next to description number 3, the results of the analysis show that only 25% of the total 60 students can answer the question correctly, students who answer the question partially or incompletely but correctly are students who are in the medium category, namely PTR, and there are students in the very low category who cannot even answer the question or in other words, it can be said that the answer sheets collected for answer number 3 are empty. As for students who answer questions from description number 3 but are completely wrong, this is not in the medium, low, or very low categories.

Meanwhile, students categorized as having moderate abilities (PTR and OKW) showed stronger skills in identifying problems and formulating solutions. However, they still showed weaknesses in the calculation process and in drawing final conclusions. "A study found that students with moderate abilities could reach the solution planning stage but often made errors in entering numbers and calculations. This aligns with recent research showing that tailored teaching strategies, especially problem-based learning, can significantly improve students' high-level thinking and problem solving competencies (Cahyaningsih et al., 2023)(Wahyuni et al., 2023).

Third, this indicator is implementing a plan or strategy. The questions containing this indicator are in descriptive question number 3 and descriptive question number 4 which contain about how the real steps of individuals and the role of forests (which can be categorized as solution planning). For the results of the analysis of descriptive question number 3 as the researcher mentioned earlier and for the results of the analysis of descriptive question number 4 there are several students who can answer the question correctly and well, but on the contrary in the very low category such as TGA still cannot answer the question. However, in the analysis results 75% of 60 students can answer the question correctly.

The fourth indicator is the rechecking stage, represented in question number 5, which assesses students' understanding of the relationship between greenhouse gas emissions and the greenhouse effect specifically focusing on cause-and-effect reasoning and evaluating the effectiveness of proposed solutions. Based on the analysis results, 55%of the 60 students answered the question correctly and thoroughly. Some students gave partially correct or incomplete answers, while others gave reverse answers. Interestingly, students who answered in this way were not categorized as very low but fell into the low and even moderate categories, such as students coded OKW and PTR. This finding is consistent with previous studies that emphasize that the ability to re-evaluate and verify solutions is a high-level skill that often appears among students with moderate abilities, especially when engaging with contextual scientific problems (Arnellis et al., 2021)(Collins et al., 2021).

This low physics problem-solving ability can be caused by various factors, such as learning methods that do not involve exploratory activities, the dominance of memorization-based learning, and the lack of challenging practice questions. According to (Ayudha & Setyarsih, 2021), improving students' high-level thinking skills can only be achieved through learning strategies that emphasize active student involvement, such as the Problem-Based Learning (PBL) model or the STEM approach. Meanwhile, according to (Ronzon et al., 2025), the causes of this difficulty at the test stage include students who do not seem to understand the problem well so that students find it quite difficult to carry it out, students are not careful in reading questions and students are less interested in reading long questions.

Overall, the results of this study reinforce previous research (Yamin et al., 2024) that conventional memorization-based learning fails to foster higher-order thinking skills. Students' low problem-solving abilities underscore the need for more contextual and problem-based learning innovations.

In the context of SMAN 16 Samarinda, the results of this study can be the basis for designing learning improvement programs, such as teacher training in implementing problem-based learning models and compiling contextual questions that require analysis. In this way, it is expected that students can be more trained in critical and scientific thinking.

D. CONCLUSIONS AND SUGESTIONS

This study shows that the problem-solving ability of grade X students of SMAN 16 Samarinda on global warming material is still dominated by the low to moderate category, with an average score of 63.9. Of the 60 students, 5 are in the very low category, 7 in the low category, 7 in the sufficient category, and 7 in the moderate category, while only a small proportion reached the good category. The interview results revealed that students in the low category have difficulty in connecting physics concepts with real environmental issues, while students in the moderate category are able to recognize problems but had not been able to develop systematic problem-solving strategies. These findings indicate that physics learning in the classroom still tends to be conventional and has not fully trained students' higher-order thinking skills (HOTS). Therefore, there is a need for more applicable and contextual physics learning innovations, especially through the implementation of problem-based learning (PBL) and inquiry-based strategies, in order to help students meaningfully connect physics concepts with environmental phenomena such as global warming.

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