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# Diagnosing students' difficulties and strategies to overcome them in physics learning

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**ABSTRACT**

Diagnosing students' abilities in learning physics is crucial so that learning designs can be tailored to students' actual learning conditions. This study aims to diagnose students' abilities in physics and identify appropriate learning strategies used by physics teachers according to students' needs. The study employed a mixed-methods approach, involving 163 students and five physics teachers from five high schools in Indonesia. The research instruments consisted of a two-tier, 15-item multiple-choice test administered via Microsoft Forms and a semi-structured interview guide for physics teachers. Quantitative data were analyzed descriptively using statistical categorization, while qualitative data were thematically analyzed to identify relevant learning strategies. The diagnostic results indicated that students' abilities in critical thinking, problem-solving, and scientific literacy were in the moderate category, while their conceptual understanding and numerical abilities were in the low category. Furthermore, most students experienced false-negative errors, indicating that they understood physics material conceptually but had difficulty applying those concepts to solve contextual problems. These findings suggest that students' learning difficulties stem from challenges in transferring conceptual knowledge into problem-solving situations. Therefore, teachers are encouraged to implement problem-based learning strategies that guide students in constructing their knowledge through scientific inquiry to find solutions based on accurate physics concepts.



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## INTRODUCTION

Physics is an essential part of the progress of science and technology. It can be defined as scientific thinking in investigating scientific facts that exist in the universe, based on the interaction of science and social life (Krumphals & Haagen-Schutzenhofer, 2021). Physics subjects need to be given to all students to equip them with the ability to think logically, analytically, systematically, critically, and creatively, as well as work collaboratively (Ekici, 2016). The characteristics of physics as a subject include critical thinking (Abidin et al., 2019; Walsh et al., 2019), conceptual understanding (Bawaneh & Moumene, 2020; Dandare, 2018), problem-solving (Haladyna, 2004; Mumthas & Abdulla, 2019), numerical ability (Faber et al., 2018; Scotti di Uccio et al., 2019), and scientific literacy (Dandare, 2018; Munfaridah et al., 2021).

Studies show that most students consider physics to be one of the most challenging subjects at the high school level (Beck & Perkins, 2016; Spatz & Goldhorn, 2021). This is because physics contains abstract material that requires both scientific procedures and mathematical reasoning to understand fundamental concepts (Odden et al., 2019; Sarabi & Gafoor, 2018). Among the target competencies of physics learning, many students show low

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interest in the subject (Ekici, 2016). They face various learning difficulties, while teachers encounter constraints in teaching physics effectively. These learning difficulties have persisted for a long time (Coletta, 2017), and the existing solutions have not yet succeeded in making physics easier to understand or more engaging for students, particularly in Indonesia.

Students' learning difficulties in physics are generally categorized into three main areas: (1) numeracy difficulties related to computational ability, (2) weak mastery of material concepts and limited ability to relate one concept to another, and (3) difficulty interpreting symbols and converting units, which requires an understanding of physical quantities (Chang et al., 2007; Habibi et al., 2019; Spatz & Goldhorn, 2021). Most of these difficulties are usually identified only at the end of instruction, as shown by formative or summative test results (Asriadi AM & Hadi, 2021; Asriadi & Hadi, 2021). Several studies have shown that diagnostic assessment can help teachers identify students' conceptual weaknesses and learning difficulties at an early stage, enabling more targeted interventions (Fan et al., 2021; Tang & Zhan, 2021). Diagnostic tests have been widely applied in science education internationally, but their use in Indonesian physics classrooms remains limited (Abidin et al., 2019). One effective way to address students' learning difficulties is by identifying their initial abilities. Early diagnosis of students' abilities can help teachers design instruction that matches students' characteristics (Kärner et al., 2021; Munfaridah et al., 2021). However, only a small number of teachers apply this approach. Therefore, it is necessary to identify both students' strengths and weaknesses in physics learning.

The diagnostic test is a tool that can be used to detect and identify students' learning abilities. It aims to identify students' weaknesses and the competencies that need to be developed so that instructional design can be adapted to students' learning conditions (Fan et al., 2021). Diagnostic tests are used to track how far the difficulty of students in understanding learning material (Isbell, 2021). Diagnostic tests are also used to diagnose the weaknesses and strengths of students in learning, so that teachers can provide input and solutions to learning problems (Tang & Zhan, 2021). The diagnostic test is a tool that can be used to detect and identify students' learning abilities. It aims to identify students' weaknesses and the competencies that need to be developed so that instructional design can be adapted to students' learning conditions (Walsh et al., 2019).

A common form of diagnosis in physics involves identifying misconceptions. Misconceptions refer to students' incorrect understanding of physics concepts that are scientifically accurate in theory (Soeharto, 2021). These misconceptions may arise from a lack of conceptual understanding, misinterpretation of information or experiences, or incorrect reasoning. For example, when asked which object will fall first from the same height, many students intuitively assume that heavier objects fall faster. However, according to physics principles, free-fall motion depends only on height (h), time (t), and gravitational acceleration (g), and not on mass or weight. Such misconceptions negatively affect students' conceptual understanding and their ability to apply physics concepts in real-life or academic contexts (Kaniawati et al., 2019). Therefore, identifying and addressing misconceptions is essential to achieving accurate conceptual understanding. Diagnostic tests designed to identify misconceptions have proven effective in this regard (Istiyono, 2022). Once misconceptions are identified, students can deepen their understanding through structured materials, problem-solving practice, and collaborative discussions (Sesli & Kara, 2012). Based on this, diagnostic tests are very necessary to be carried out as an effort to identify weaknesses, difficulties and competencies possessed by each student, then provide solutions so that learning can adapt to the conditions of each student and learning objectives can be achieved.

Previous studies, however, have rarely analyzed how students' learning difficulties relate to specific types of errors revealed through diagnostic tests. Understanding this relationship is important since each type of error, such as false positives, false negatives, and misconceptions, represents distinct cognitive barriers that need different instructional responses. Unfortunately, many teachers in Indonesia have not yet performed diagnostic tests (Widyaningsih et al., 2021).


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Teachers generally conduct assessments during or after instruction, which often prevents students from achieving the expected competencies. This study, thus, contributes by linking diagnostic results to types of student errors and by identifying learning strategies that physics teachers can apply to address these specific learning difficulties. This research is expected to provide valuable insights into students' physics ability levels and to offer recommendations for appropriate learning strategies that align with students' abilities. The findings are expected to benefit teachers, students, and schools by improving the effectiveness and attractiveness of physics learning. Therefore, this study is important to diagnose students' ability levels in physics and determine appropriate instructional strategies used by physics teachers.

## RESEARCH METHOD

### Research Method

This study employed a mixed-methods approach with an Explanatory Sequential Design (Johnson & Christensen, 2017). The study aimed to diagnose students' abilities in physics and determine appropriate learning strategies used by physics teachers. In the first phase (quantitative), 163 high school students completed a two-tier multiple-choice diagnostic test designed to measure five aspects of physics learning ability: conceptual understanding, problem-solving, critical thinking, numerical ability, and scientific literacy. The students' responses were analyzed descriptively to identify common patterns of difficulty and types of errors. In the second phase (qualitative), semi-structured interviews were conducted with five physics teachers who taught the participating students. The purpose of these interviews was to explain and interpret the diagnostic results, particularly the types of learning difficulties identified from students' errors, and to explore the teaching strategies that teachers used or could use to address those difficulties. The sequential integration of both phases allowed the qualitative findings to provide deeper insights into the quantitative results, consistent with the explanatory nature of this design.

### Research Sample

The research sample was determined by using a convenience sampling technique (Fraenkel & Wallen, 2009) because this technique is relatively inexpensive, does not take much time, and is simple. It is relevant to the purpose of this study so that the samples obtained represent the characteristics of students from various regions in Indonesia. The sample obtained consisted of five physics teachers and 163 grade 11 students from five high schools in Indonesia representing five main islands: Java with 37 students, 35 students from Sumatra, 36 students from Kalimantan, 30 students from Sulawesi, and 25 students from Papua. Of the 163, there were 98 men and 65 women. In addition, the criteria for selecting five physics teachers as respondents were those who had taught for at least two years in grade 11 and had an educator certificate. The selected schools already represent schools with high, medium, and low reputations, so that bias in sampling can be avoided.

### Research Instruments

The research instrument used was a two-tier multiple-choice questionnaire comprising 15 items. The cognitive levels measured range from Level 1: Memorizing/Remembering (C1) and Understanding (C2), Level 2: Implement (C3), and Level 3: Analysis (C4). This diagnostic test was developed based on Haladyna (2004) and Larner (2015). There are several reasons why the diagnostic tests developed based on Haladyna (2004) and Larner (2015) were chosen as the basis

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for developing diagnostic tests in physics learning. First, the three researchers have a good reputation in developing assessment instruments in the field of education and have published their research results in leading academic journals. Second, the three diagnostic tests developed by Haladyna and Larner have been tested and validated using a large and diverse sample of students. This shows that the test is reliable and valid in identifying students' misconceptions about certain physics concepts. Third, the three diagnostic tests have proven to be effective in assisting teachers in designing appropriate and effective learning strategies in helping students overcome difficulties encountered in understanding physics concepts. Therefore, the use of a diagnostic test developed based on Haladyna (2004) and Larner (2015) is expected to increase the effectiveness of learning physics and help students understand physics concepts better. Diagnostic tests are designed to measure students' understanding of physics concepts that have been taught in class and identify misconceptions about physics concepts that often become difficult for students, especially related to motion. There are five aspects that are the focus of the diagnosis. This test was designed using a two-tier multiple-choice question format and was tested using a sample of students from various grade levels.

The test was distributed to physics teachers at each school through Microsoft Forms. The time limit for respondents to complete the test questions was 90 minutes. The test process was monitored directly by the teachers and researchers through Google Meet or Zoom applications, to ensure that the test was taken seriously and appropriately. Respondents were only allowed to complete the diagnostic test once. Respondents could complete the survey on their laptop or smartphone. The assessment rubric and student response data were analyzed by scoring 0-3.

This diagnostic test instrument underwent several stages, including validation, reliability estimation, and item quality analysis. The validation process aimed to establish both content and construct validity. For content validity, the instrument was reviewed by four expert validators, consisting of specialists in educational measurement and physics education. The experts evaluated each item for relevance, clarity, and representativeness. The data from these expert assessments were analyzed using the Content Validity Ratio (CVR) and Content Validity Index (CVI) techniques. To assess construct validity, the instrument was administered to 134 students with characteristics similar to those of the actual research participants. The test results were analyzed using Exploratory Factor Analysis (EFA) to confirm the underlying factor structure. The instrument's reliability was estimated using Cronbach's Alpha based on students' responses from the pilot test. Finally, the item quality was examined using the Partial Credit Model (PCM) method to assess the suitability and discrimination power of each item. Table 1 presents the instrument specification grid.

**Table 1.** Diagnostic Test Matrix

| Diagnostic Aspect | Item Number | Cognitive Level | Physics Material |
|---|---|---|---|
| Critical thinking | 1 | C3 | SRM |
| | 2 | C4 | SRM |
| Concept Understanding | 3 | C1 | PM |
| | 4 | C2 | RM |
| | 5 | C3 | RM |
| | 6 | C4 | PD |
| Problem Solving | 7 | C1 | PD |
| | 8 | C2 | PD |
| | 9 | C4 | WE |
| Numerical Ability | 10 | C1 | MC |
| | 11 | C2 | MC |
| | 12 | C4 | RD |
| Science Literacy | 13 | C1 | SBM |
| | 14 | C2 | SBM |
| | 15 | C3 | SBM |

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The physics materials that are summarized as part of the diagnostic test are SRM (Straight and Regular Motion) two items, PM (Parabolic Motion) one item, RM (Rotational Motion) two items, PD (Particle Dynamics) three items, WE (Work and Energy) one item, MC (Momentum and Collisions) two items, RD (Rotational Dynamics) one item, and SBM (Strong Body Equilibrium) three items. The test results of the diagnostic test instrument met the validity criteria, with a CVR of 0.99 for each item. Meanwhile, the CVI value of the test instrument obtained a value of 0.99, belonging to an excellent category. The results of the EFA analysis shows that there are five factors formed from the 15 items and have a loading factor value above 0.5. The Total Variance Explained showed a percentage of 64.582%. The five factors are: Critical Thinking: this factor includes students' ability to critically analyze the information and problems provided, question the assumptions that underlie a concept, and produce systematic and structured thinking in making decisions. Conceptual Understanding: this factor includes students' ability to fully and deeply understand physics concepts, and to be able to relate these concepts to real-world phenomena. Problem Solving: this factor includes students' ability to identify physics problems, design problem-solving strategies, and evaluate and modify the solutions that have been produced. Numerical Ability: this factor includes students' ability to understand and use mathematical concepts related to learning physics, as well as being able to interpret and produce quantitative data. Scientific Literacy: this factor includes students' ability to understand and use scientific language and symbols, as well as being able to identify and use appropriate sources of scientific information in studying and solving physics problems.

From the results of the estimation of the reliability of the instrument with Cronbach's Alpha, a reliability coefficient of 0.777 was obtained, indicating a reliable category. The results of the analysis of the quality of the items using the PCM method showed that the items were able to measure test takers with low abilities with a theta limit of -1.7 and test takers with high abilities with a theta limit of 2.3.

Interviews with the five physics teachers were also conducted for data collection to sharpen and complement the results of the diagnostic tests and at the same time to allow triangulation. A semi-structured protocol was used with an average duration of 45 minutes for each respondent. The topics addressed were related to the learning methods applied by the teachers, the forms of assessment instruments, the description of the learning situation in the classroom, the obstacles experienced by the teacher in teaching physics material, and the areas of the student's weaknesses or difficulties in the learnt physics materials.

## Data Analysis

To analyze the levels of students' ability in learning physics, descriptive statistics in the form of categorization was applied. Determination of the levels were based on the ideal mean and ideal standard deviation with the help of R Studio software. The highest score = 3 and lowest = 0 of the research variables was used to calculate the ideal average score (Mi) = 1.5 and the ideal standard deviation score (SDi) = 0.5. Classification of students' ability level (θ) has a range obtained through the analysis of the Partial Credit Model (PCM). The student ability categories (θ) are shown in Table 2.

**Table 2.** The interval of Values at the Ability Level

| Ability Interval | Category |
|---|---|
| $\theta \geq 2.25$ | Very high |
| $1.75 \leq \theta < 2.25$ | High |
| $1.25 \leq \theta < 1.75$ | Medium |
| $0.75 \leq \theta < 1.25$ | Low |
| $\theta < 0.75$ | Very low |


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The types of error experienced by students were based on the score. The technique of determining the score from the answers and reasons used was the conversion of binary number scores to hexadecimal numbers. If the answer is correct and the reason is correct, it is scored 3. If the answer is correct and the reason is wrong, the score is 2. If the answer is wrong and the reason is correct, the score is 1; if the answer is wrong and the reason is wrong, it is scored 0 (Bansal & Mehtre, 2019; Roy & Bhunia, 2015). The criteria for determining the type of error score can be seen in Table 3.

**Table 3.** Criteria for Determining the Type of Error

| Answer | Reason | Decision | Score |
|---|---|---|---|
| Right (1) | Right (1) | Scientific Conception | 3 |
| Right (1) | Wrong (0) | False Positive | 2 |
| Wrong (0) | Right (1) | False Negative | 1 |
| Wrong (0) | Wrong (0) | Misconception | 0 |

Scientific conception means that students can solve physics problems using the correct physics concepts. A false positive indicates that students understand the context of the problem in the problem but do not understand the concept of the material. A false negative is a condition where students understand the concept of the material but cannot adjust the concept of the material to the problem in the problem. Misconception is the inability of students to relate physics concepts to solving problems (Ketabi et al., 2021).

The model suggested by Bogdan and Biklen (2007) was employed to analyze the interview data, aiming at identifying the relationships between themes and producing a detailed understanding. The qualitative analysis consisted of three stages. The first stage involved transcribing the interview results, coding, classifying the codes, and connecting the meaning of each code based on relevant themes. The second stage consisted of data reduction, data display, and conclusion drawing. After the data were reduced to a simplified form, they were grouped according to similar aspects and themes. The third stage involved identifying the interrelationships among these themes to obtain a deeper understanding. The results of the analysis were then used to draw conclusions about students' areas of weakness in learning physics and to determine appropriate learning methods or strategies based on students' characteristics.

To ensure the trustworthiness of the qualitative analysis, several strategies were applied. Credibility was maintained through triangulation between diagnostic test results and interview data, as well as by conducting member checks with the participating teachers to verify the accuracy of the interpretations. Transferability was supported by providing detailed descriptions of the research context, participants, and procedures, allowing other researchers to apply the findings to similar contexts. Dependability was ensured by maintaining a systematic audit trail of the analysis process, including coding decisions and theme development. Confirmability was strengthened by documenting all analytical steps and interpretations, enabling external review and minimizing researcher bias.

## FINDINGS AND DISCUSSION

### Findings

#### *Diagnostic Results of Students' Ability in Physics Subjects*

The results of the diagnostic test of students' abilities in learning physics for each aspect can be seen in Table 4.

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**Table 4.** Diagnostic Results of Physics Ability

| Diagnostic Results | Mean (*SD*) Logit Score (θ) | Converted Score (0–100) | Category |
|---|---|---|---|
| Summary of Physics Abilities | 1.36 (0.55) | 72 | Medium |
| Aspects of Critical Thinking | 1.50 (1.04) | 75 | Medium |
| Aspects of Concept Understanding | 1.22 (0.69) | 68 | Low |
| Aspect of Problem Solving | 1.60 (0.78) | 76 | Medium |
| Aspects of Numerical Ability | 1.23 (0.67) | 69 | Low |
| Aspects of Scientific Literacy | 1.35 (0.91) | 72 | Medium |

Table 4 indicates that students' abilities in critical thinking, problem solving, and scientific literacy are in the medium category. Critical thinking is a complex skill that enables a person to effectively obtain information, collect data, and evaluate findings. In this aspect, the physics material being tested is the material of uniformly changing rectilinear motion. There are two questions with moderate difficulty. Problem-solving is a planned process that needs to be implemented to obtain a certain solution to a problem that may not be obtained immediately. In this aspect, the physics material being tested is particle dynamics material and work and energy material. There are three questions, with difficulty levels ranging from easy to medium. Scientific literacy is an individual's scientific ability to apply their knowledge in the process of identifying problems, obtaining new knowledge, explaining scientific phenomena, and drawing conclusions based on evidence related to scientific issues. In this indicator, the physics material being tested is the material for the equilibrium of rigid bodies. There are three questions with the difficulty of the questions at the easy and medium levels. These results indicate that students' abilities in these three aspects are quite good, but still need to be improved.

Table 4 also shows that understanding concepts and numerical abilities are in the low category. The aspect of understanding the concept is the ability to capture meanings, such as being able to express a material that is presented in a form that is more understandable, able to provide interpretation, and to apply it. In this aspect, the physics materials tested are parabolic motion, circular motion, and particle dynamics. There are four questions, with the difficulty levels of being easy, medium, and demanding. In numerical ability, an individual can formulate, use, and interpret mathematics in various contexts, including reasoning mathematically and using mathematical concepts, procedures, facts, and tools to explain and predict events. In this indicator, the physics material tested is momentum, impulse, and rotational dynamics material. There are three questions, with difficulty levels ranging from easy to medium. These results indicate that the student's ability in these two aspects is still not good. Physics teachers still need to provide special treatment so students can master these two aspects.

Furthermore, the five aspects measured are related. Aspects of Critical Thinking and Problem Solving are interrelated in solving complex physics problems, students need to critically analyze the information provided, question the underlying assumptions of a concept, and produce systematic and structured thinking in making decisions. Aspects of Understanding Concepts and Numerical Ability have relevance in understanding physics concepts thoroughly and in depth, students need to understand and use mathematical concepts related to learning physics and be able to interpret and produce quantitative data. Aspects of Problem Solving and Scientific Literacy are related to solving physics problems, students need to identify and use appropriate sources of scientific information in studying and solving physics problems. Aspects of Critical Thinking and Scientific Literacy are related in carrying out critical analysis of the information and problems provided, students need to understand and use appropriate scientific language and symbols. Aspects of Understanding Concepts and Scientific Literacy are related to understanding physics concepts thoroughly and deeply, students need to understand and use appropriate scientific language and symbols and be able to identify and use appropriate sources of scientific information in studying and solving problems, in this case, physics problems.


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In addition to providing quantitative results in the form of determining student abilities, scoring activities must also be able to record the type of error in the student's response. Students with the same score, for example, 0 (meaning the response is wrong), do not necessarily have the same type of error. Therefore, identifying the cause of the error is much more meaningful than determining how many mistakes they made or the total score they achieved. Table 5 summarises the scores for each aspect.

**Table 5.** Recapitulation of Scores on Each Aspect

| Diagnostic Aspects of Student Abilities | Number of Respondents Who Got A Score | | | | Total |
|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | |
| Critical thinking | 28 (17.2%) | 42 (25.8%) | 49 (30.1%) | 44 (27%) | 163 (100%) |
| Concept Understanding | 17 (10.4%) | 73 (44.8%) | 65 (39.9%) | 8 (4.9) | 163 (100%) |
| Problem Solving | 18 (11%) | 57 (35%) | 72 (44.2%) | 16 (9.8%) | 163 (100%) |
| Numerical Ability | 25 (15.3%) | 79 (48.5%) | 54 (33.1%) | 5 (3.1%) | 163 (100%) |
| Science Literacy | 39 (23.9%) | 59 (36.2%) | 40 (24.6) | 25 (15.3%) | 163 (100%) |

Table 5 shows that students experienced all types of errors. This is because all respondents have different difficulties or weaknesses in learning physics. However, in critical thinking, a score of 2 is dominant, meaning that the students can answer the question correctly but give incorrect reasons for the answer. Thus, it can be interpreted that most students in this aspect have a false positive type of error. Students can solve problems correctly but do not master the correct physics concepts. In the aspects of critical thinking and problem solving, score of 2 is also dominant. This means that most students in this aspect have a false positive error type. Aspects of understanding concepts, numerical skills, and scientific literacy get a score of 1 as dominant. This means that students are not able to answer the questions correctly but are able to answer correctly on the reasons for the answers. Most students in this aspect have a false negative error type. Students are not able to solve problems correctly but have mastered the correct physics concepts.

### *Learning Strategies According to Student Characteristics*

In this section, the findings are divided into two parts. The first part presents the results of interviews related to the difficulties experienced by students in learning physics from the teachers' perspectives (Table 6). The second part presents the results of interviews related to solutions in the form of appropriate learning strategies (Table 7). These strategies were developed based on the results of the diagnostic test, specifically the levels of students' abilities and types of errors, as well as the teachers' professional experiences in teaching physics.

The difficulties experienced by students in learning physics, as illustrated in Table 6, are mainly in mastering the basic concepts of mathematics and physics. In addition, limited analytical thinking skills reduce their interest and motivation to learn physics. Therefore, solutions in the form of suitable learning strategies are needed to address these difficulties.

The various learning strategies described in Table 7 align with the difficulties experienced by students. Some teachers have already implemented these strategies in their classrooms. In general, the main solution to overcome students' difficulties in physics is simplifying learning outcomes and contextualizing materials so they are relatable to students' lives. Teachers should emphasize basic mathematical operations and physics concepts mastery through experimental and problem-based methods. Implementing these strategies consistently is expected to make physics learning more effective and engaging while addressing students' conceptual weaknesses.


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**Table 6.** Difficulties Experienced by Students in Learning Physics

| Theme of Student Difficulties in Learning Physics | Interrelations among the Themes | Representative Teacher Statements |
|---|---|---|
| Inability to relate a problem to an appropriate solution | Students are weak in mastering the basic concepts of physics and mathematical operations, which causes them to be unable to provide appropriate solutions to complex problems. | "*Many students can recall formulas but don't know when to use them.*" (T1) |
| Lack of mastery of basic science concepts and physics formulas | Conceptual weaknesses lead to low confidence when solving problems. | "*Students often memorize rather than understand. When the question changes slightly, they get confused.*" (T2) |
| Weak basic mathematical operation skills | Difficulties in mathematical manipulation affect physics problem-solving ability. | "*Even simple calculations like ratios or conversions cause mistakes.*" (T3) |
| Difficulty solving complex problems | Students find it difficult to connect between known information and what is asked. | "*They know the topic but struggle to link different concepts into one complete solution.*" (T4) |

**Table 7.** Physics Learning Strategy

| Aspect of Student Ability | Physics Learning Strategy Theme | Interrelations among the Themes | Representative Teacher Statements |
|---|---|---|---|
| Critical Thinking | Provide problem-based learning | Teachers guide students to construct knowledge through scientific inquiry to solve real-world problems based on core physics and mathematics concepts. | "*When students are faced with real situations, they start thinking logically instead of memorizing.*" (T5) |
| Concept Understanding | Train students with various types of questions | Exposure to diverse question types enhances flexibility in applying concepts. | "*We need to vary question formats so they can connect theory to application.*" (T1) |
| Problem Solving | Give contextual problems | Contextual questions encourage the use of daily-life reasoning. | "*If the examples are from their surroundings, students are more motivated to solve them.*" (T2) |
| Numerical Ability | Strengthen basic mathematical understanding | Emphasize the mastery of simple operations and unit conversions before solving complex problems. | "*Mathematical basics must be drilled first—otherwise, students can't progress.*" (T3) |
| Scientific Literacy | Train students to think and act systematically | Develop habits of analysis and reflection through experiments and discussions. | "*Hands-on activities make them realize that physics is about observing and reasoning.*" (T4) |

## Discussions

### *Students' Ability in Physics Subjects*

Diagnostic testing allows service providers, in this case, teachers or schools to diagnose, monitor, and treat conditions or anticipate changes in student behavior and abilities during the learning process. According to research results Gurel et al. (2015), diagnostic tests based on indicators and maps of learning difficulties are used to diagnose students' learning difficulties. In practice, diagnostic tests in the classroom have two objectives, namely: (1) to identify learning targets that students have not mastered; and (2) to find the causes or reasons that make students unable to master the learning targets (Frey, 1991; Kaltakci-Gurel et al., 2017). The diagnostic test result shows that students' physics abilities are in the moderate category. Most students experience this type of false negative error. So far, the teacher has only focused on teaching one form of the problems in the book. Teachers rarely provide advanced forms of questions based on physics problems that exist in everyday life. As a result, students who are less intelligent and a bit lazy will be confused if they find different question forms even though the context is the same (Asriadi & Istiyono, 2020).


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Implementing learning in the classroom is also generally carried out by looking at students as individuals with average abilities. Students who have high abilities and students who have medium or low abilities are considered to have the same mastery of the materials. The burden of learning achievement is considered quite heavy for students and teachers. In addition, the difficulties and weaknesses experienced by students in learning physics are related to mastery of a collection of knowledge in the form of facts, concepts, or principles based on the discovery process. Students sometimes do not understand the aims and objectives explained in physics questions. This is usually influenced by a lack of understanding of terms, concepts, physics symbols, and the use of units of measurement that are not commonly known by students (Asriadi AM & Istiyono, 2022), so that students give wrong answers to questions given by the teacher. This incident often occurs and always recurs, so that through this diagnostic test, the teacher should first have to teach the correct physics concepts from the aspect of terms, formula symbols, and international units in physics lessons.

There are interesting findings that show that students' average understanding of physics concepts is in the low category, even though their ability to think critically and solve problems is in the medium category. This contradicts previous studies by Istiqomah et al. (2019) and Wulandari (2018) that, if students have a low understanding of concepts, then their ability to think critically and solve problems will also be low. This, of course, raises the question of why this can happen primarily in physics learning. Based on a deeper search, the researchers together with the physics teachers found the fact that students were indeed quite weak in understanding the concepts of physics material. This is because, so far, physics has only been taught based on theories and formulas without ever telling the meanings and functions of these physical theories and formulas in everyday life. As a result, students only know physics concepts (terms, formulas, symbols) without understanding their meaning and function.

Then why is the ability to think critically and solve problems in the medium category? This is because students, when giving answers to questions, tend to think of solutions outside of physics concepts or those that have been taught by the teachers. They do their own reasoning and imagination in solving problems. Their way of thinking or reasoning is sometimes not always in accordance with existing physical theories. This finding is interesting to be used as a reflection for teachers to make improvements in teaching physics. Physics must be taught by first inviting students to know physics holistically, along with its benefits and functions for their lives. After they are interested in physics, then the teachers might introduce basic concepts and simple physics formulas and their functions. After they understand the basic concepts, the teacher then gives a problem encountered in everyday life to find a solution based on the theoretical concepts and formulas that have been studied. This cycle is repeated by adding more complex concepts or formulas. Thus, students will be able to achieve all the competencies expected in learning physics. This is because students, when giving answers to questions tend to think of solutions outside of physics concepts or those that have been taught by the teachers. They do their own reasoning and imagination in solving problems. Their way of thinking or reasoning is sometimes not always in accordance with existing physical theories. This finding is interesting and can serve as a reflection for teachers to improve their teaching of physics. Physics must be taught by first inviting students to know physics holistically, along with its benefits and functions for their lives. After they are interested in physics, then the teachers might introduce basic concepts and simple physics formulas and their functions. After they understand the basic concepts, the teacher then gives a problem encountered in everyday life to find a solution based on the theoretical concepts and formulas that have been studied. This cycle is repeated by adding more complex concepts or formulas. Thus, students will be able to achieve all the competencies expected in learning physics.

Several studies have been conducted to overcome this problem. Research by Puspitasari et al. (2021) found that integrating physics learning with applications in everyday life can increase students' understanding of concepts and interest in physics. The results of this study are in line


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with other findings by Santoso et al. (2022), which show that the use of real examples in learning physics can increase the motivation and effectiveness of learning. In other literature, there are several opinions that are in line with this idea. For example, according to Yalçin et al. (2017), the use of real contexts in learning physics can help students build a stronger understanding of physics concepts and develop critical and creative thinking skills. In addition, according to Beck and Perkins (2016), teaching physics through real contexts can also improve students' skills in problem solving, because they must apply physics concepts and principles in real situations. Overall, integrating physics learning with applications in everyday life is a very important approach in increasing students' understanding of concepts and interest in physics. This can help students understand the relevance of physics concepts in their lives and improve their ability to apply physics concepts and principles in real situations.

This finding is supported by the results of research conducted by Frömke et al. (2022) and Homjan et al. (2022) that by using this diagnostic test, teachers can identify student learning deficiencies in addition and subtraction. Therefore, for effective learning in this massive subject, one must examine deficiencies and plan improvements in parallel with teaching (Simion, 2022). In addition, this finding is also reinforced by a number of research studies Burkholder et al. (2021) and Hyland and O'Shea (2022) that the results of diagnostic tests can make students overcome their learning difficulties by focusing particular time on studying material they do not understand.

### *Learning Strategies According to Students' Ability*

The ability of teachers to detect student difficulties and weaknesses is a challenge in physics learning activities to lead students to success in learning (Cornett et al., 2020; Keuning & Van Geel, 2021). Each student in the class has a different characteristic (Hersi & Bal, 2021). Students' differences can be caused by their way of thinking. Therefore, individual differences need to be considered by teachers in learning activities (Xiao et al., 2018). Teachers must pay attention to individual students, and therefore, students' weaknesses and difficulties must be considered. Physics learning currently places more emphasis on the sequence of subject matter, not on the thinking processes and cognitive psychology of students, so in learning, many students experience difficulties and misconceptions (Ginja & Chen, 2020). Because teachers play an essential role in overcoming student difficulties and improving the learning process in the classroom, the results of diagnostic tests will be essential input material in improving physics learners' quality.

Different problems require different strategies. The following is a discussion on the right learning strategy based on each kind of students' difficulties as found in the research. The right learning strategy to overcome students' difficulties in the critical thinking aspect is Problem-Based Learning (PBL). This learning strategy is characterized by the existence of real problems as a context for students to learn to think critically in acquiring new knowledge. Teachers can provide training to students more specifically about the material that students often encounter in everyday life (Ketterlin-Geller et al., 2019).

Inquiry learning is the right learning strategy to overcome students' difficulties in understanding the concept. This learning prepares a situation for students to conduct their experiments; in a broad sense, they want to see what happened, do something, use symbols, and look for answers to their questions, connecting one discovery to another and comparing what was found with what others found. Students can be helped by familiarizing students with looking for similarities by providing an integrated understanding of concepts (Soeharto, 2021; Yuan et al., 2020).

The right learning strategy to overcome student difficulties in problem-solving is Project-Based Learning. This learning uses projects/activities as a medium. Learners conduct exploration, assessment, interpretation, synthesis, and information to produce various learning


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outcomes. Teachers can train students' thinking skills deductively by holding class discussions, giving portfolio assignments, or conducting experiments carried out using the scientific method (Mellroth et al., 2021).

Participative Teaching and Learning is the right learning strategy to overcome students' difficulties in numerical ability. This learning strategy involves students actively planning, implementing, and evaluating learning. In addition, learning requires students' emotional and mental involvement and willingness to contribute to the achievement of goals. Teachers can help students gradually according to their grasping power in understanding number operations, and provide additions to the primary mathematical calculation method (Chu et al., 2021).

The right learning strategy to overcome students' difficulties in the aspect of scientific literacy is the Scientific Learning Strategy. This learning process will guide students in actively constructing concepts, laws, or principles through the stages of observing (to identify or find problems), formulating problems, proposing, or formulating hypotheses, collecting data with various techniques, analyzing data, drawing conclusions, and communicating concepts, found law or principle. Students must be accustomed to working on problems with various solutions based on facts that occur in nature or are experienced in everyday life (Scotti di Uccio et al., 2019).

The theory supports the results of this study. It proposes that students who have learning disabilities caused by inaccuracies in understanding material concepts can be assisted by asking them to analyze the causes of a common phenomenon that exists in nature. This finding is also reinforced by research conducted by Kaniawati et al. (2019) that thinking about solving problems from a scientific concept can be taught by making direct observations through experimental activities. The learning strategies identified in this study, such as problem-based, inquiry-based, project-based, participative, and scientific learning, have strong theoretical and empirical support for improving students' understanding of physics concepts and critical thinking skills. However, the potential effectiveness of these strategies in actual classroom settings depends on various contextual factors such as teacher competence, classroom resources, and students' prior knowledge. Therefore, there is no absolute guarantee that the identified strategies will always produce the same positive outcomes when implemented in different contexts. To ensure their practical applicability and effectiveness, future studies should empirically test these strategies through classroom-based interventions or quasi-experimental designs. The results of such studies would help validate the findings and strengthen the evidence for applying these strategies more broadly in physics education.

Although these strategies are theoretically appropriate for addressing the types of learning difficulties identified in this study, they should be viewed as having potential effectiveness rather than assured impact. Their success is closely tied to the quality of implementation, the readiness of teachers to facilitate student-centered learning, and the suitability of classroom conditions. Without adequate scaffolding, monitoring, and instructional support, the strategies may not lead to meaningful improvements and could even result in student confusion or reduced engagement. Furthermore, several contextual factors such as class size, access to laboratory tools or project materials, students' motivation and prior misconceptions, and institutional constraints may significantly influence outcomes. These factors can enhance or hinder the strategies' effectiveness, indicating that instructional approaches cannot be assumed to work uniformly across all settings. Therefore, implementation should be adapted to the needs and resources of each learning environment. Considering these considerations, future research is needed to examine how these strategies function in real classroom contexts through experimental, quasi-experimental, or action research designs. Such studies would help identify which strategies are most effective for particular types of difficulties, what challenges teachers encounter during implementation, and what forms of professional development or resource support are required. The findings would provide stronger empirical justification for broader application and inform more context-sensitive instructional planning in physics education.

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### *Study Limitations and It's Implications*

This study has several limitations that should be acknowledged. First, the number of participating teachers and schools was limited, involving only five physics teachers and five high schools. Consequently, the diagnostic results and the learning strategies identified may not fully represent the diversity of instructional contexts across Indonesia. Second, the qualitative data were obtained from interviews with teachers only, without direct classroom observations. Therefore, the interpretations of students' difficulties and proposed strategies relied on teachers' perspectives and experiences. Third, the diagnostic test focused on five aspects of physics ability: critical thinking, conceptual understanding, problem-solving, numerical ability, and scientific literacy using a two-tier multiple-choice format. Other important factors, such as affective and metacognitive aspects, were not examined.

Regarding the identified learning strategies, their potential effectiveness is supported by existing theories and prior research on problem-based, project-based, inquiry, participative, and scientific learning approaches. However, this study did not experimentally test the implementation or outcomes of these strategies in classroom settings. As such, there is no empirical guarantee that the strategies will be equally effective when applied in different contexts or with different groups of students. Future studies are needed to validate these strategies through classroom interventions or quasi-experimental designs to evaluate their actual impact on improving students' physics learning outcomes and reducing misconceptions.

Despite these limitations, the findings of this study provide valuable diagnostic insights for teachers and contribute to the development of adaptive instructional strategies in physics education. The diagnostic approach demonstrated here can serve as a model for identifying learning difficulties in other scientific domains, helping teachers design more targeted and student-centered learning experiences.

## CONCLUSION

The results of the diagnostic test show that students' abilities in physics are in the moderate category. In addition, most students experience a false negative error type, which means that students understand the concept of the material but are unable to adapt the concept of the material to the problems in the problem. The results of this study also reveal the level of student weakness in physics subjects, which can also be seen in learning performance in class. Students who really have an interest in learning physics from the start will give a good response and the test instrument will also record good things too. This indicates that the physics learning that has been done so far still needs to be improved. Using a variety of learning strategies can increase students' ability levels. Recommendations for learning strategies that can be used by teachers include problem-based learning. This strategy was chosen because it will stimulate students' curiosity by generating reason and their potential to think scientifically, enabling them to find solutions to problems. Nevertheless, this study still has limitations, namely the sampling technique and the number of samples used. The researchers admit that the more samples used, the more accurately the results can be generalized. This research can be a reference for teachers to take measurements using more varied types of questions, but have different diagnostic goals. In addition, for students, this diagnostic test will be a guide in improving and adapting a better way of learning, especially in physics. For schools, the results of the test can be used as a reference for formulating policies in forming a good learning system.

### Conflict of Interests

The authors declare that they have no conflict of interest to disclose.


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