

# Investigation of student self-assessment in understanding physics problem-solving: the Dunning-Kruger effect in mechanics concept

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Problem-solving skills are fundamental to physics learning. However, many students in Indonesia still exhibit low Performance in this area, which is exacerbated by biased cognitive of their self-competence. Previous studies have typically focused on general academic cognitive without systematically measuring the accuracy of self-assessment in the context of physics problem-solving. This study addresses this gap by exploring the Dunning-Kruger effect in physics problem-solving, particularly in the area of mechanics, using a mixed-methods approach. This study aims to evaluate the accuracy of students' self-assessment of their problem-solving skills and to identify patterns of emerging cognitive biases. A total of 10 high school students in East Java were selected through purposive sampling. Quantitative data were collected via problem-solving tests and rubric-based self-assessment and then analyzed using descriptive statistics. Qualitative data were obtained from in-depth interviews and analyzed using thematic analysis methods. The results indicated that the majority of students overestimated their abilities, especially in the Useful Description and Mathematical Procedure aspects, which are strong indicators of the Dunning-Kruger effect. Students with higher skills demonstrated better underestimation bias and self-reflection skills. This study revealed that self-cognitive bias is negatively correlated with student's actual abilities: the lower the problem-solving skills, the higher the level of overestimation. The contribution of this study lies in providing a self-assessment-based framework to enhance students' reflection and problem-solving skills. These findings emphasize the urgency of implementing structured and continuous self-assessment practices in physics learning to reduce cognitive bias and strengthen students' metacognitive development.

*Keywords:* Physics problem solving; self-assessment; Dunning-Kruger effect; mechanics.

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## 1. Introduction

In physics learning, problem-solving skills are a fundamental element that cannot be separated from the learning process itself. Problem-solving has been recognized as an integral part of the experiential learning process involving four main stages: experiencing, reflecting, thinking, and acting [1]. The primary goal of physics learning is to build deep conceptual understanding alongside additional objectives, such as developing students' abilities to connect various ideas and concepts, apply this understanding in diverse situations, and enhance problem-solving skills [2]. Problem-solving serves not only as a pedagogical strategy to deliver material but also as an evaluative tool to measure students' level of understanding [3], as well as an instrument to assess the effectiveness of the learning process [4]. Thus, the active involvement of students in the problem-solving process is essential to creating a more effective and meaningful learning experience [5]. In the context of physics learning in Indonesia, the suboptimal problem-solving abilities of students highlight the need for learning strategies that not only deliver material but also foster reflective awareness of self-competence. If the bias in cognitive of this ability is not addressed systematically, conceptual and problematizing learning will continue to face significant obstacles.

However, many students in the context of physics learning are still classified as novice problem solvers [6]. Begin-

ners generally have fragmented knowledge structures and can only apply concepts in familiar contexts [7]. They tend to rely on memorization-based strategies, focusing on mathematical procedures without adequate conceptual understanding [7], and immediately look for physics equations based on available variables. In contrast, expert problem solvers prioritize conceptual analysis and the visualization of solution strategies before using mathematical expressions [8]. Beginners often also face difficulties in developing advanced strategies and tend to be less able to monitor and evaluate the solution process metacognitively [8].

Various studies have identified several factors that influence success in problem-solving, including mastery of conceptual knowledge, cognitive strategies, self-confidence [9], and metacognitive, motivational, and cognitive aspects [10]. Metacognitive processes, in particular, have proven effective in developing problem-solving skills [11]. Moreover, problem-solving transfer abilities significantly contribute to the effectiveness of problem-solving [12]. Therefore, strategies for improving problem-solving skills should focus on developing students from beginner to expert levels [13] with a deep understanding of how they learn and solve problems [14]. Performance improvement can be optimized through a process that considers students' academic and personal characteristics [15,16]. Within the framework of constructivism theory, students act as active participants in the learning process [17]. Therefore, continuous evaluation is essential to as-

sess the effectiveness of learning strategies and determine the necessary follow-up [18]. Problem-solving-based learning and assessment strategies have proven effective in increasing student engagement and independence. When students can evaluate their work independently, reliance on external feedback can be reduced, thereby enhancing learning effectiveness [19]. One pertinent process is the application of self-assessment, which refers to the self-evaluation process carried out by students regarding their learning process and results [20].

Self-assessment is a pedagogical strategy that plays an important role in increasing students' responsibility for their learning process [20]. This practice includes reflective activities that encourage students to consciously evaluate their academic development [21,22] and contributes to long-term professional development and lifelong learning [23]. Several studies have shown that the implementation of self-assessment can increase students' learning interest, intrinsic motivation, and academic achievement [24]. Furthermore, self-assessment is considered highly beneficial for students with low academic achievement because it provides actionable feedback to improve their academic Performance [25]. In the context of physics learning, self-assessment allows novice students to verify and revise their answers independently and facilitates the development of better problem-solving skills [26].

However, while self-assessment has great potential for improving students' competence, inaccuracies in self-assessment remain a significant challenge. Research shows that students with high competence tend to underestimate their abilities, whereas students with low competence often overestimate their skills. This phenomenon is known as the Dunning-Kruger effect [27] and can be recognized by analyzing the difference between subjective assessments and objective results in evaluation activities [28,29]. This effect can also be identified by estimating the correlation between self-rated ability minus objective scores and actual objective ability [30,31]. Interestingly, cross-national studies indicate that the manifestation of the Dunning-Kruger effect can vary, suggesting differences in cognitive mechanisms and socio-cultural factors that influence the calibration between self-confidence and actual competence [32].

To assess the accuracy of self-assessment, a comparison can be made between the results of self-assessment and external assessments, such as those from teachers, peers, or parents, or with objective test results [33]. When students have a more realistic cognitive of their abilities, they tend to develop a more accurate understanding and significantly improve their problem-solving skills [34]. In the context of physics learning, further exploration of the congruence between self-assessment and instructor assessment can occur through the use of knowledge-based, competency-based, and self-cognitive tests [35]. This study aims not only to evaluate the consistency between self-assessment and instructor assessment but also to classify the level of students' self-assessment skills in solving physics problems. The findings

of this study are expected to contribute to the development of more effective learning strategies for improving students' physics problem-solving skills. Therefore, structured and ongoing self-assessment practices need to be maintained and developed to minimize cognitive bias and optimize students' learning potential.

Although the Dunning-Kruger effect has been widely studied in various disciplines, research specifically exploring this phenomenon in the context of physics learning, especially regarding mechanics, remains very limited. Furthermore, previous studies tend to focus on general cognitive of academic ability without thoroughly examining the relationship between students' self-assessments and their actual Performance in solving physics problems. Additionally, the processes used to identify the Dunning-Kruger effect in the context of learning are often descriptive and qualitative, while more systematic and quantitative measurements-such as the differences between subjective and objective scores-have not been explicitly applied. Although several studies have discussed self-assessment in the context of learning, few have explicitly measured the level of self-assessment accuracy using a structured mixed-methods approach, particularly in solving physics-based problems within the topic of mechanics. Moreover, there is no adequate framework for classifying and analyzing students' perceptual biases in this context.

On the other hand, few studies directly link self-assessment accuracy with problem-solving ability, even though this relationship is crucial for supporting the development of students' metacognitive skills in learning physics. This study presents a novel approach by analyzing the Dunning-Kruger effect in the context of physics problem-solving, especially in mechanics material, which has not been extensively addressed by previous studies, particularly within the Indonesian learning environment. Utilizing a mixed-methods approach, this study compares students' self-assessment scores and objective results to measure the accuracy of their cognitive competencies. By identifying differences between the two, this study contributes to a deeper understanding of how students calibrate their competencies and the impact this calibration has on learning Performance.

Therefore, this study aims to explore students' physics problem-solving skills in depth through self-assessment mechanisms, focusing particularly on identifying the presence of biased cognitive of their abilities, as explained in the Dunning-Kruger effect phenomenon. By comparing students' subjective assessments with objective results of their Performance in solving physics problems related to mechanics, this study seeks to reveal how self-cognitive discrepancies can influence the learning process and outcomes. This study presents a unique approach by combining quantitative and qualitative analysis (mixed methods) to evaluate the accuracy of self-assessment in mechanics learning systematically. Additionally, this study is expected to formulate a practical self-assessment-based intervention framework that physics teachers can use to enhance students' reflective and

problem-solving skills. The findings of this study are anticipated to significantly contribute to the development of self-reflection based learning strategies, particularly through designing a self-assessment intervention model aimed at improving the accuracy of independent competency evaluation. RQ: What are the physics problem-solving abilities of students in the field of mechanics? How accurately do they assess their skills, and in what manner does the Dunning-Kruger effect influence their cognitive bias?

## 2. Method

This study is a mixed-method study with an explanatory-sequential design. This design was chosen because it allows researchers to obtain a quantitative picture of students' self-assessment discrepancies, which are then enhanced by in-depth understanding through qualitative exploration of students' experiences and difficulties during the problem-solving process [36]. This design tends to emphasize strong quantitative data. The process begins with the collection and analysis of quantitative data, followed by the gathering and analysis of qualitative data in the second stage, which builds on the results from the initial phase. This design is fully represented in Fig. 1.

This study employs a mixed-method design with an explanatory sequential approach, as explained by [36]. In this design, the research process begins with the collection and analysis of quantitative data to understand the phenomenon being studied. The results of the quantitative stage are then enriched through qualitative data collection to gain a more comprehensive understanding. The complete flow of this research process is illustrated in Fig. 2.

This study involved 10 students from a private high school in East Java, Indonesia. Students were selected using purposive sampling techniques based on their availability, willingness to participate in the entire series of research activities, and representation of varying levels of academic ability. Inclusion criteria consisted of students who had taken mechanical material and had report card scores above the KKM (Minimum Completion Criteria). Additionally, this study also involved one physics teacher and one doctoral student learning physics as instructors. In the initial stage of the study, the participating students were asked to complete a 40-minute physics problem-solving test. The physics problem-solving test instrument comprises 5 test items modified from a physics and engineering book developed [37]. The instrument underwent a content validation process by two expert lecturers in the field of physics education and one high school physics teacher. A readability test was conducted on two students outside the research sample. The assessment rubric



FIGURE 1. Explanatory sequential design.

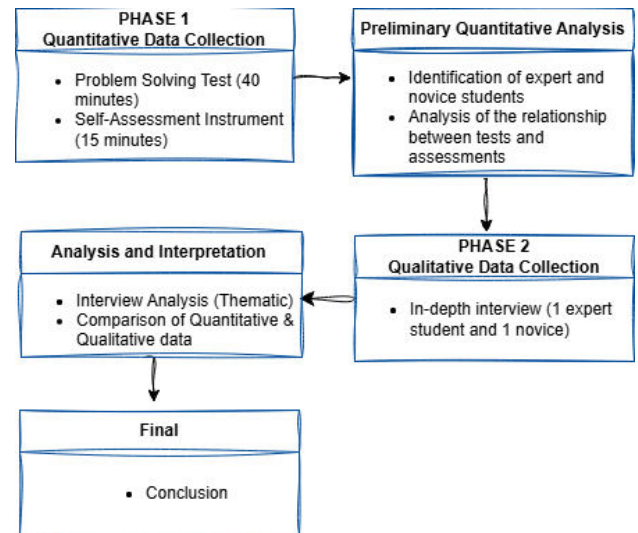


FIGURE 2. Research design activity.

TABLE I. Distribution of mechanics problem-solving questions.

Items	Questions
Item 1	The elevator accelerates upward in the opposite direction of its motion.
Item 2	A block of mass is at rest and, when pushed, the block continues to remain at rest.
Item 3	Two blocks are linked by a pulley, with one block positioned on a smooth flat surface and the other block hanging from a rope.
Item 4	Two blocks are linked by a pulley: one block sits on a rough flat surface while the other hangs from a rope.
Item 5	A rope connects two blocks and is hung on a pulley.

refers to the Docktor (2016) [3] rubric, which has been tested for reliability in previous studies. The test addresses mechanical problems related to flat planes, inclined planes, and pulleys. The distribution of mechanical problem-solving questions is presented in full in Table I.

The next stage in the learning activity is the implementation of self-assessment by students, allowing for a time allocation of 15 minutes. At this stage, students are asked to evaluate their work results using the problem-solving rubric provided by the instructor. The assessment rubric is designed based on the criteria developed by Docktor (2016) [3] and consists of several indicators that are scored on a range from 0 (very low) to 5 (very high). In addition, this rubric includes two additional categories: “NA (Problem)” and “NA (Problem Solver)”. The NA (Problem) score is assigned if a problem does not assess a particular category because it does not require decision-making in that aspect. Meanwhile, the NA (Problem Solver) score is applied if, based on the overall solution, it is assumed that a series of decisions may have been made by the problem solver but are not explicitly stated in

TABLE II. Description of the physics problem discussion framework.

Aspects	Description of Activity
Useful Description (UD)	Understanding the issue or representing it within a problem-solving framework.
Physics Approach (PA)	Selecting relevant physics principles that may apply to a situation before implementing them in the specific context of a problem and outlining a solution.
Specific Application of Physics (SAP)	Separating the identification of precise principles and concepts in physics from the actual application of those principles to specific problem conditions.
Mathematical Procedures	Selecting the appropriate mathematical procedure and adhering to mathematical rules to achieve the target quantity
Logical Regression (LP)	Checking whether the overall problem solution progresses consistently towards the correct goal, with support for each step being evident, though not necessarily stated explicitly

in the solution. This rubric is specifically designed for application in the field of physics, particularly in introductory physics courses at the University level, especially concerning the topic of mechanics. The aspects measured through this rubric include: (1) Useful Description, (2) Physics Approach, (3) Specific Application of Physics Concepts, (4) Mathematical Procedures, and (5) Logical regression. A complete description of each aspect is presented in Table II.

The next stage involves students answering several questions from the teacher on the self-assessment sheet. These questions explore students' problem-solving skills, their difficulties in the problem-solving process, and their evaluation and reflection on further problem-solving. Students are given 15 minutes to complete the self-assessment activity, during which instructors accompany them. They are allowed to ask the instructor about anything they do not understand. The results produced are quantitative data in the form of problem-solving scores and student self-assessment scores. The test results were analyzed using descriptive statistical analysis. This analysis includes calculating the mean, standard deviation, skewness, and kurtosis to evaluate the distribution of the data. Additionally, a correlation analysis was carried out between the student self-assessment scores and the teacher's assessment to identify the level of bias. The self-assessment

results were compared to the teacher's assessment outcomes. This comparison provides insight into the validity of the student self-assessment. The analysis of the students' physics problem-solving test also produced a categorization of the students' physics problem-solving skills. These identification results became the basis for the in-depth interview stage conducted by the instructor. Interviews were held with one student who achieved the maximum score and one student with the minimum score, aiming to explore the students' physics problem-solving skills in greater depth. The interview results were analyzed using thematic analysis. The thematic analysis process followed the stages outlined by [38]: data familiarization, initial coding, theme search, theme review, and reporting. Coding was performed manually by two researchers to enhance trustworthiness, and agreement between the researchers was achieved through reflective discussions. This study received permission from the school where it was conducted and was approved by the Ethics Committee of the Faculty of Mathematics and Natural Sciences, State University of Malang. Written consent was obtained from all participants, along with letters of parental permission for the involvement of students in the study.

### 3. Results

#### 3.1. Physics problem-solving test assessment results

Physics problem-solving skills are reflected in students' test results, which are analyzed using descriptive statistics. The descriptive analysis reveals a substantial score distribution [Mean = 49.60; Max = 70; Min = 40; SD = 9.442]. This analysis indicates that students' problem-solving scores range from 40 to 70, with an average of 49.60. Furthermore, the data exhibits a significant spread, as indicated by the standard deviation value. The skewness ratio score suggests that the data is skewed to the right, implying that some students achieved notably high scores compared to the majority. Meanwhile, the kurtosis indicates a flatter distribution, suggesting there is not a high concentration of values around the Mean. After completing the physics problem-solving test, students conduct self-assessments using rubric. The results of these self-assessments are compared with the teacher's assessment to evaluate the accuracy of the students' self-evaluations. The findings from this comparison are fully illustrated in Fig. 3.

The comparison of student and teacher assessments in Fig. 3 shows that nearly all students experience bias. Assessment bias is indicated by the average score of each student's self-assessment being higher than the score given by the teacher. There are significant differences between self-assessment and teacher assessment among some students. Students S1, S2, and S3 exhibit notable discrepancies between their self-assessments and the teacher's evaluations, rating themselves significantly higher than the teacher does. Student S9 has the highest self-assessment among all students, reflecting a considerable gap compared to the teacher's

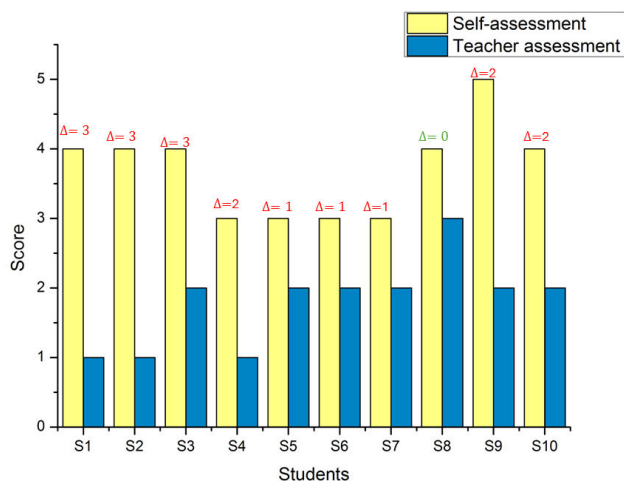


FIGURE 3. Comparison of student assessment (SA) and teacher assessment (TA) on the Problem-Solving skills aspect.

assessment. This scenario could suggest high self-confidence and a lack of objectivity in self-evaluation. Student S8 demonstrates a high self-assessment, but the teacher’s score is also relatively high compared to those of other students. This indicates that this student possesses a more accurate self-cognitive. Students S5, S6, and S7 show a smaller gap between self-assessment and teacher assessment than their peers. Since most students assign themselves higher marks than the teacher’s evaluation, this may indicate an optimism bias. Optimism bias results from students tending to evaluate their abilities more favorably than reality warrants. Conversely, students who rate themselves lower than the teacher’s assessment may indicate underestimation or a lack of self-confidence. The differences between student and teacher assessments across various aspects of physics problem-solving skills are outlined in Table III.

TABLE III. Difference in score between student and teacher assessments ( $\delta = SA - TA$ ).

Students	Useful Description ( $\delta$ )	Physics Approach ( $\delta$ )	Specific Application of Physics ( $\delta$ )	Mathematical Procedures ( $\delta$ )	Logical Progression ( $\delta$ )
S1	2	3	3	2	1
S2	3	3	3	2	1
S3	3	2	3	1	2
S4	0	2	3	1	2
S5	1	-1	-1	2	-3
S6	0	0	0	2	-2
S7	2	-1	-1	2	-3
S8	-1	-2	0	2	-2
S9	4	0	2	2	0
S10	2	2	2	2	0

Information: TA (teacher assessment); SA (student assessment)

It was found that there was a difference between negative and positive assessments. The conditions of these assessments revealed the direction of bias. The results of positive assessments indicated an overestimation, while the results of negative assessments showed an underestimation of the student’s Performance. The analysis results in the table categorize students into several groups: the group that overestimates themselves (overestimation-Dunning-Kruger effect), the group that underestimates themselves (underestimation), and the group with accurate assessments. The majority of students fall into the overestimation group, as evidenced by the positive difference in assessment results. This group tends to rate themselves higher than the teacher. It was found that S1, S2, and S3 students experienced overestimation across all aspects of problem-solving. Meanwhile, S4, S9, and S10 students made accurate assessments in one aspect of problem-solving while overestimating in the other four aspects. The aspect of problem-solving skills that nearly all students experienced overestimation were Mathematical Procedures and Useful Description. The Mathematical Procedures and Useful Description aspects that were most frequently overesti-

mated by students were likely due to their more visible and concrete nature compared to other aspects. Students tend to believe that success in performing calculations or drawing diagrams is sufficient to represent overall success in problem-solving, while conceptual aspects such as SAP and LP are more crucial for demonstrating a deeper understanding.

In other groups of students, negative scores were found, indicating that these students experienced underestimation. This group tended to rate themselves lower than the teacher’s assessment. It was observed that students S5, S6, S7, and S8 experienced underestimation, although not in all aspects of problem-solving. For example, students in S5 rated themselves lower in the areas of physics approach, specific application of physics, and logical progression, but students also rated themselves too high in the aspects of useful description and mathematical procedures. The areas of physics approach, specific application of physics, and logical progression are known to be the most biased underestimates experienced by students. Finally, a minority of students had a score difference of zero or close to zero, indicating that their assessments were accurate and aligned with the instructor’s evaluations.

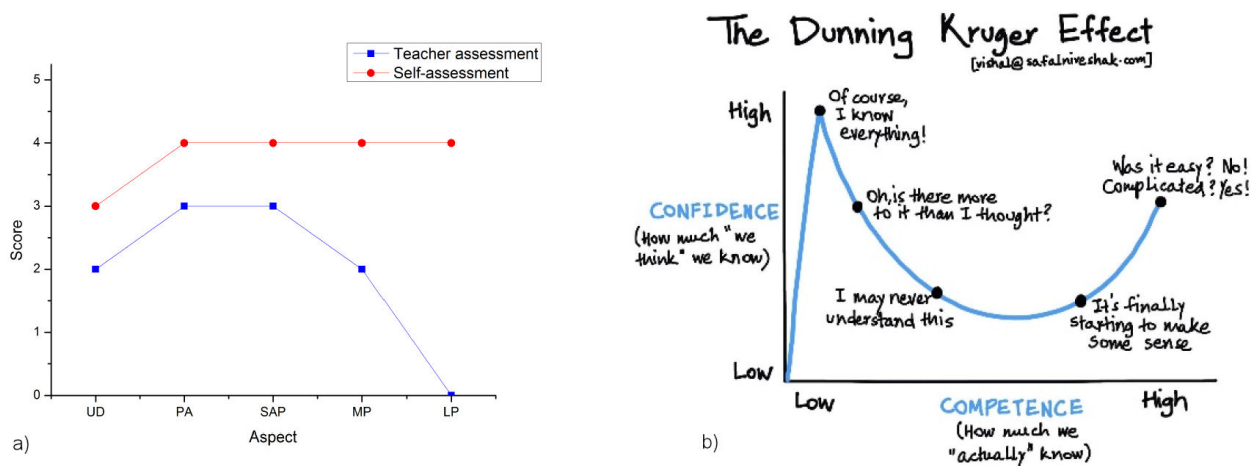


FIGURE 4. Relationship between student (SA) and teacher (TA) assessment results and the Dunning-Kruger effect graph.

Students S4, S6, S8, S9, and S10 were identified as having accurate assessments. Accurate student assessments were found in several aspects of problem-solving. For example, student S6 made accurate assessments in the areas of useful description, physics approach, and specific application of physics. However, in other aspects, namely mathematical procedures, students experienced overestimation, and in the aspect of logical progression, students experienced underestimation. Overall, most students' self-assessments showed higher scores than their teachers' assessments, although not directly in every aspect. Therefore, this condition indicates that most students experienced the Dunning-Kruger effect. To further explore the Dunning-Kruger effect phenomenon experienced by students, the assessment results were compared with the Dunning-Kruger effect graph in Fig. 4.

The differences in the assessment of test results by teachers and students are illustrated visually in Fig. 4. The blue line represents the results of teacher assessments of student worksheets, indicating an increase from the UD aspect to the SAP aspect. This increase in teacher assessments is possible due to a growing understanding among students. However, teacher assessments decreased from the MP aspect to the LP aspect, likely because students face difficulties in both areas. Meanwhile, the assessment by students, indicated by the orange line, shows a trend that is generally high and stable. Students consistently rate themselves with nearly the same value, suggesting they feel confident about their physics problem-solving skills, even as teachers start to give lower assessments. The results shown in Fig. 4 relate to the Dunning-Kruger effect. Initially, from the UD aspect to the SAP aspect, students may believe they understand the material well, while teachers provide increasing assessments, marking the peak of the Dunning-Kruger effect. This finding also highlights the disparity between students' self-confidence and their actual abilities, which poses a barrier to developing metacognitive skills. It emphasizes the importance of systematic self-reflection training to help students objectively recognize their limitations. As the aspects be-

come more challenging, specifically from the MP aspect to the LP aspect, teachers lower their assessments, yet students continue to maintain high self-assessments. This situation reflects the Dunning-Kruger effect, wherein students remain unaware of their limitations. In the LP aspect, a significant gap exists between teacher and student assessments, indicating that students may be less aware of the limitations in their understanding. The results of the analysis reveal that students tend to overestimate their abilities while teachers provide a more realistic assessment. An in-depth exploration of the Dunning-Kruger effect phenomenon experienced by students was conducted. Further analysis involved comparing the biases experienced by students with the assessments provided by teachers. The distribution of teacher assessments and the extent of bias experienced by students are depicted in Fig. 5.

The graph shows a positive bias ( $SA - TA > 0$ ), indicating that most students overestimate their abilities compared to teacher assessments. No data points appear near zero, suggesting no students assessed themselves accurately. Students with lower instructor-assessed scores ( $TA < 2.0$ ) exhibit

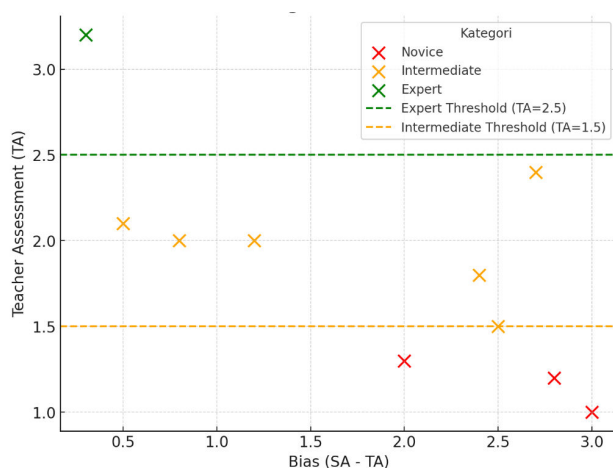


FIGURE 5. Distribution plot of assessment bias with teacher assessment (TA) scores.

higher positive bias, consistent with the Dunning-Kruger effect. Specifically, six students in this group rated themselves significantly higher than the instructor did. In contrast, students with higher TA scores ( $> 2.5$ ) show minimal or negative bias, indicating more accurate or even underestimated self-assessments. A negative relationship between bias and TA is evident: as TA increases, bias decreases. Further analysis by problem-solving category reveals that novice students ( $TA < 1.5$ , red dots) consistently overestimate their abilities, aligning with the Dunning-Kruger effect. Intermediate students ( $1.5 \leq TA < 2.5$ , orange dots) show more varied bias levels. Expert students ( $TA \geq 2.5$ , green dots) display low or negative bias, suggesting realistic or modest self-assessments. This pattern highlights how self-perception improves with actual competence. In general, there is a tendency for lower problem-solving (TA) skills to correlate with a higher positive bias. This condition supports the finding that students with low skills face challenges not only in problem-solving but also in objectively assessing their abilities. In contrast, more competent students (expert category) exhibit a smaller bias. This condition indicates that expert students possess better metacognition, allowing them to evaluate their abilities more accurately. Further exploration related to the category of physics problem solving, particularly for expert and novice students, is conducted through qualitative interviews and survey results.

### 3.2. The assessment results of students' physics problem-solving skills with maximum scores

The analysis of the test results demonstrates the quality of students' physics problem-solving skills. It was found that students with the highest scores exhibited better problem-solving abilities than their peers. One of the students' worksheets with maximum problem-solving scores is fully presented in Fig. 6.

Students with maximum scores demonstrated better problem-solving skills compared to their peers. This condition is reflected in the quality of the problem-solving aspects, which are quite good. In each test item, students were able to present at least three of the five aspects of physics problem-solving. However, the Logical Progression (LP) aspect was absent from the students' answer sheets. Meanwhile, the Useful Description (UD) and Physics Approach (PA) aspects consistently appeared in students' answers to each test item. The UD aspect is generally presented in the form of free-body diagrams (FBDs). However, the quality of the FBDs produced remains less than optimal. This can be observed from the difficulty students faced in determining the direction of the forces acting on each object in the system being analyzed. To explore the problem-solving process further, interviews were conducted with students who earned the highest scores in the problem-solving aspect. The results of the interviews are presented in Table IV.

TABLE IV. Results of interviews with students who achieved the highest scores.

Teacher	What are the difficulties in solving the problem?
Student	The difficulty is determining the formula approach, and the physics concepts used (SAP).
Teacher	What is a general formula or formula elaboration?
Student	Formula elaboration. "When I solve the problem, I think that one force is greater than the other. However, I still don't know for sure whether it is a greater thrust or a greater friction force" (SAP).
Teacher	Is the use of a general formula not a problem? (PA).
Student	No.
Teacher	Then, are there any difficulties with mathematical procedures, such as many mathematical numbers or others?
Student	If it is about mathematical numbers, no. For example, in question 1 the force only goes up and down in one direction. We can still imagine it. The following problem has many directions. For example, there are some with angles, and the forces acting on the object are many, so it is confusing to formulate the forces acting on the object.
Teacher	Which question number is the most difficult for you?
Student	Except for question 1.
Teacher	Is question 2 difficult? The one about friction.
Student	The use of the formula is not difficult, but it does not have much imagination. I found it using Newton's first law and the amount of friction. However, I am confused about the relationship between the two concepts when combining them (SAP).
Teacher	Which step do you feel more proficient in?
Student	"Description of strengths" (UD).
Teacher	What are the following learning needs based on the difficulties encountered.
Student	Repeat the material, study and do more problems, find similar problems for better understanding.
Teacher	What kind of help is needed to facilitate getting better at solving problems.
Student	Problems similar to those modeled by the teacher and answer keys to make the exercises more.

Note: UD: Useful Description; PA: Physics Approach; SAP: Specific Application of Physics; MP: Mathematical Procedures; LP: Logical progression.

Based on the interview results presented in Table IV, it can be concluded that students with high problem-solving scores conducted a more in-depth evaluation of their problem-solving process. Additionally, expert students were able to provide detailed input for future improvements. Students also revealed that the aspects they mastered best were Useful Description (UD) and Mathematical Procedures (MP). This statement aligns with the results of student work, which indicated that both aspects consistently appeared in students' answers, although the quality still needed improvement. However, students had difficulty applying the physics approach to more specific conditions (Specific Application of Physics, SAP). For instance, some students were unable to define the friction force precisely or determine its value. This difficulty likely stems from the complexity of the cases being analyzed. The challenges faced by students in this SAP aspect are explained in more detail in Fig. 6. Furthermore, expert students do not solely depend on the teacher for assistance. Students need learning scaffolding to develop problem-solving skills. In this context, students indicated that work examples emphasizing conceptual aspects, particularly in SAP, are a form of assistance they need.

### 3.3. The assessment results of students' physics problem-solving skills with minimum scores.

The assessment of physics problem-solving skills is a crucial indicator in evaluating students' understanding and critical thinking abilities regarding physics concepts. The analysis of

the problem-solving test results revealed that most students demonstrated a low level of proficiency in solving physics problems. This finding emphasizes the necessity for greater focus on the learning process, particularly in developing students' systematic and analytical thinking skills. To illustrate this more concretely, the following is a sample of a student's answer that received a minimal score on the test, as shown in full in Fig. 7.

The student worksheets presented in Fig.7 illustrate the quality of students' problem-solving. The results of the analysis show that students only completed three of the five test items provided. Additionally, the problem-solving aspects used were incomplete. Useful Description (UD) and Specific Application of Physics (SAP) were aspects that rarely appeared in students' answers, while Logical Progression (LP) was not found at all in the student worksheets. Two aspects that were consistently present were the Physics Approach (PA) and Mathematical Procedures (MP). However, even though these two aspects were always used, their quality remained low. This is evident from the application of the physics approach, which was not entirely correct. One example of inaccuracy in the physics approach can be found in test item 2, which discusses the force on a stationary block. The physics approach that should have been utilized is Newton's First Law, but students did not apply it accurately. Furthermore, interviews were conducted with students who had low problem-solving scores to explore the strategies they applied further. The complete interview results are presented in Table V.

TABLE V. Results of interviews with students who received the lowest scores.

Teacher	What difficulties did you face when working on the problem?
Student	Determine what formula to use. For example, if $F$ is a force, then what force is working is difficult to determine. If you can draw it, it will be easier (PA and SAP).
Teacher	Do you not have difficulty with the steps of the mathematical procedure? (MP)
Student	So far, no.
Teacher	How about understanding the context of the question?
Student	This is not a very disturbing difficulty.
Teacher	Okay, when you worked before, what made you overcome the difficulty
Student	Because of the little help guided by the teacher
Teacher	What is the most difficult problem to solve? And why?
Student	Problem number 3 is complicated because the number is large and understanding and then describing the forces that work is difficult (UD and SAP)
Teacher	What do you suggest to improve it in the future?
Student	Focus more on learning Newton's laws, especially learning concepts
Teacher	How about the mathematical aspect?
Student	So far, mathematics is not a problem (MP)
Teacher	What kind of help do you need to be able to solve problems better?
Student	Teacher assistance and practice questions so that I can understand the concept better

Note: UD: Useful Description; PA: Physics Approach; SAP: Specific Application of Physics; MP: Mathematical Procedures; LP: Logical Progression

The results of interviews with students who have minimum scores indicate that the self-assessment conducted is not thorough. Students encounter difficulties in determining the appropriate physics approach (PA) and applying the process to specific conditions (SAP). This situation is believed to arise from students' inability to draw force diagrams (UD) effectively. These challenges are detailed in full in Table V. The problems presented require students to have the skills to create FBDs (force diagrams) to solve them. Students need support focused on the role of teachers and practice exercises.

#### 4. Discussions

The results of this study indicate that most students fall into the novice and intermediate categories of physics problem-solving skills. One of the main findings is the presence of cognitive bias, characterized by a mismatch between students' self-assessments and teacher assessments. Most students tend to overestimate their abilities, a phenomenon known as the Dunning-Kruger effect [27,32]. This effect hinders students' ability to accurately evaluate their competence, which can lead to erroneous decision-making [29,39]. The study specifically explores the relationship between self-assessment and physics problem-solving ability and provides an in-depth analysis of aspects of students' self-assessments. This enables comprehensive identification of students' difficulties in problem-solving. This finding aligns with results from studies across various fields. In economics, Koc (2021) [35], Sawler (2021) [40], and Xin *et al* (2024) [41] reported similar findings. Likewise, biases were noted in the fields of health [28,42], mathematics [43]. In the context of physics, cognitive biases were found to be more prominent in abstract topics such as quantum mechanics, where novice students exhibited disproportionate confidence compared to expert students (Testa *et al.*, 2020). This discrepancy is due to the lack of connection between students' mental models and everyday experiences. Biases were also found in mechanics [44], electromagnetism [45], and quantum conceptions [46], generally stemming from students' weak conceptual understanding.

In this study, overestimation was found to be most dominant in the Useful Description and Mathematical Procedures aspects. Several factors are thought to influence this bias, including dimensions of student narcissism, namely admiration (a tendency to enhance self-image) and rivalry (a tendency to protect oneself) [31]. Admiration is positively associated with the tendency to overestimate oneself [47,48]. However, students with admiration-type narcissism and high intelligence levels actually show stronger academic potential because they possess a positive self-image. Another contributing factor is self-efficacy. Students who exhibit overconfidence tend to underestimate the importance of improving skills and learning motivation [28,35]. Inaccurate self-assessments also result in difficulties in comparing data across students [49] and can hinder adequate allocation of time and effort [5]. Ineffective self-monitoring exacerbates the effects of cognitive biases, while accurate self-

assessments have been shown to improve conceptual understanding and curb over-confidence [34,50]. Inaccurate self-assessments also lead to negative consequences, such as task avoidance and poor learning decisions [51]. Overconfident students tend to quit early, whereas students who assess themselves realistically study longer and achieve deeper understanding [52]. Therefore, a balance between self-confidence and openness to feedback is essential and can be developed through strategies such as self-reflection, formative testing, and rubric-based learning [53].

Interestingly, students with maximum scores also experienced the Dunning-Kruger effect, but in the form of underestimation. Self-assessments of students with maximum scores were found to be lower than teacher assessments in the Useful Description and Physics Approach aspects. It may be due to the cognitive that external assessments are more rigorous than they actually are, along with limited learning time that inhibits deep understanding [46,51]. However, students with high intelligence are less likely to engage in destructive narcissism and instead exhibit more realistic self-confidence [31]. To explore further, this study also employed interviews as an exploratory method. The results of the interviews indicated that students had difficulty describing the forces at work, including force identification and the use of correct FBD notation [54]. In the Physics Approach aspect, challenges were identified in distinguishing the context of moving and stationary systems, which highlights limitations in understanding Newton's Laws and constructing mental models [55]. Students with minimum scores explicitly stated the necessity for an improved understanding of concepts and the role of teachers in guiding the learning process.

Novice students are highly dependent on teacher assistance, both in the problem-solving process and in self-assessment practice. However, when conducting self-assessment, students tend to be less proactive in asking questions that could clarify their understanding. This situation creates a mismatch between cognitive and reality. In contrast, expert students exhibit less reliance on instructors and utilize more internal strategies. They actively employ techniques such as worked examples and tend to be more reflective in their self-assessments. The results of self-assessment through journals demonstrate that repeated practice can enhance students' metacognitive abilities, particularly in comparing their work with ideal answers [56]. If this practice is consistently incorporated into the physics learning curriculum, students can be better trained to become more reflective and realistically independent learners. It is also useful for teachers who need an in-depth understanding of self-evaluation training strategies [33]. In judgment, the application of appropriate, reflective, and repeated self-assessment is essential for reducing the Dunning-Kruger effect and developing in-depth physics problem-solving skills. With this approach, self-assessment not only serves as an evaluation tool but also as an active learning strategy that contributes to students' ongoing metacognitive development.

## 5. Conclusions

This study shows that students' physics problem-solving skills in the topic of mechanics mostly remain in the novice to intermediate category. Students tend to excel in the Useful Description and Mathematical Procedures aspects but encounter significant difficulty in the Physics Approach and Specific Application of Physics aspects, particularly in understanding basic concepts and relating them to problem situations. The accuracy of students' self-assessment of these skills is also still low, with most students showing a tendency to overestimate their abilities compared to the objective assessment of the instructor. Only a few students can make accurate self-assessments, and this tendency for accuracy is more common among students with higher problem-solving abilities. The Dunning-Kruger effect phenomenon was confirmed in this study, revealing that students with lower skills exhibit greater self-cognitive bias. Students with low objective scores tend to be overly confident in their abilities, while students with high abilities are more realistic or even underestimate themselves in their self-assessments. These findings underscore the importance of implementing systematic and ongoing self-assessment practices in physics learning to correct cognitive biases, enhance reflection skills, and optimize the development of students' problem-solving skills.

**Limited research:** This study has several limitations that need to be considered. First, the sample size used is relatively small and restricted to high school students, which limits the generalization of the findings to a broader population. Sec-

ond, the focus of the study is solely on the topic of mechanics in physics learning, so it does not encompass a variety of other subjects that may exhibit different cognitive bias dynamics. Additionally, the intervention process in this study remains short-term and has not evaluated the ongoing impact of self-assessment practices on the development of students' metacognitive skills.

**Future research:** In light of these limitations, future research is recommended to involve a greater number of participants with more diverse academic backgrounds, including at higher learning levels. Further studies should also expand the scope of the material, covering various topics in physics, such as electromagnetism, optics, and modern physics, to gain a more comprehensive understanding of cognitive biases in different learning contexts. Additionally, a sustainable self-assessment intervention model should be developed to longitudinally examine how such practices affect students' self-evaluation accuracy, problem-solving skills, and metacognitive development over the long term.

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## Conflict of Interests

The authors declare no conflict of interest.

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