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Profiles of Problem-Solving Strategies in Kinematics: A Comparison Between High, Average, and Low Achieving Undergraduates

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Abstract
Problem solving is an essential competency in physics learning, particularly in the topic of kinematics, which requires mastery of concepts, analytical skills, and effective thinking strategies. Understanding the profiles of students' problem-solving strategies across different achievement levels can provide detailed insights into the variety of strategies employed and the areas that require instructional intervention. This study aims to describe and compare the problem-solving strategies of Physics Education undergraduate students with high, medium, and low achievement in solving kinematics problems. A qualitative method was employed, involving six participants representing the three achievement categories. The primary data were collected through the think-aloud technique, supported by observations, retrospective interviews, and answer sheet analysis. The comparison of profiles revealed differences in strategic tendencies and completeness of problem-solving stages among the three student groups. These findings offer strategic insights for developing adaptive teaching methods to enhance problem-solving skills across various levels of academic achievement.
Keyword: *Problem-solving strategies, Kinematics, Achievement Levels*

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1. Introduction

Problem solving is considered a basic element in learning physics and frequently viewed as the foundation of students' conceptual understanding [1]–[3]. Through problem solving, students apply concepts in practical contexts, which strengthens comprehension and evaluating their knowledge [4]. In physics learning, becoming a proficient problem solver is undeniably one of the ultimate goals, as it reflects both conceptual understanding and the ability to apply knowledge to novel situations [5], [6]. Despite the recognized importance of problem solving in physics, challenges persist as research shows that students' problem-solving skills remain consistently low in physics learning [7]–[9]. One significant factor contributing to low problem-solving skills in physics is students' inability to effectively apply appropriate strategies throughout the problem-solving process [10], [11].

Successful problem solving in physics depends not only on students' conceptual understanding but also on their ability to effectively apply strategies throughout the problem-solving process [10], [12]. The problem-solving process involves multiple steps to reach a solution; however, the sequence in which these steps are executed is often overlooked in assessments, potentially missing critical insights into students' thinking processes and affecting their problem-solving outcomes [13].

These strategies also vary among students, including those with different levels of academic performance, while some approach problems with structured reasoning and clear conceptual understanding, others may rely on superficial cues or rote memorization [11], [13]. Understanding the problem-solving strategies of students with varying levels of academic performance can provide valuable guidance for targeted feedback and instructional interventions, enabling learners to refine their strategies and achieve improved outcomes [14], [15].

Previous studies have explored problem-solving strategies and approaches, with some focusing only on describing the strategies or approaches used by learners, while others compared novices with experts or successful with less successful problem solvers. These studies, conducted not only in physics but also in other fields, aim to provide insights into the cognitive processes involved in problem solving. According to Gök and Silay [16], the problem-solving process involves four strategies: understanding the problem, planning the action, constructing a solution, and checking the result, and teaching these strategies in cooperative groups enhances students' performance. Hartviksen and Haavold [17] comparing top-grade students in an advanced mathematics course with participants of a Norwegian problem-solving contest found that the contest participants demonstrated superior problem-solving performance. Burkholder [18] examines the problem-solving strategies of 'transitioning novices'—students who have completed an introductory physics course but are still far from expert-like reasoning. The results show they mainly rely on intermediate strategies, such as unit analysis for interpreting mathematical expressions, while only a few uses advanced approaches like limit checking, which requires mentally simulating system behavior under changing variables. Tóthová and Rusek [19] conducted comparative study of first year chemistry teacher students and postdoctoral experts in chemistry education revealed distinct differences in problem-solving approaches: experts concentrated directly on relevant aspects of the task, whereas novices distributed their attention across less essential parts and tended to employ limiting strategies that were absent in the expert group.

Although previous studies have addressed this issue, much of the research has focused on contrasting professional physicists or advanced students with novices, leaving limited understanding of how problem-solving strategies differ within the general student population particularly across different achievement levels in a kinematics context. Moreover, many studies consider only high- and low-achieving students, overlooking the middle group of average performers. This study aims to examine and compare the problem-solving strategies employed by high, medium, and low achieving undergraduates while solving kinematics problems. Kinematics was chosen for this study because it is usually one of the first topics in introductory physics courses. Its basic concepts such as units, position, velocity, and acceleration are essential and appear in many areas of physics. Strong problem-solving skills in kinematics are important, as difficulties in this topic can affect students' overall success in learning physics. By analyzing differences in how these groups understand problems, plan and monitor their steps, and execute solutions, this study seeks to provide insights that are vital for developing personalized instructional strategies, supporting struggling students, and guiding all learners to enhance their problem-solving skills.

2. Method

This study employed descriptive qualitative research to analyze the problem-solving strategies of students with low, medium, and high achievement in solving one-dimensional kinematics problems. The study involved six first-year students from the Physics Education Department at Universitas Syiah Kuala who had completed the Basic Physics I course, which includes kinematics material. The six participants consisted of two students with low achievement, two with medium achievement, and two with high achievement in the Basic Physics I course.

The participants were selected using purposive sampling. They were categorized into three achievement groups—high, medium, and low—based on their scores on a kinematics problem-solving test in a basic physics class, complemented by the lecturer's evaluation of their problem-solving ability. High achievers were defined as students scoring in the top range (≥ 75), medium achievers as those scoring in the middle range (45–74), and low achievers as those scoring in the bottom range (≤ 44) All participants provided their consent to take part in the study and signed informed consent documents.

Data were collected through four techniques: think-aloud as the primary method, supported by retrospective interviews, observations, and analysis of written responses to ensure the data were well validated and to strengthen the credibility of the findings. The think aloud sessions were conducted separately for each participant at different times. During these sessions, participants were instructed to verbalize their reasoning while solving the problems. At the same time, the researcher conducted non-participant observations to monitor participants' actions and engagement without direct interference. Field notes were taken during the observations to assist in formulating interview questions, particularly to clarify ambiguous expressions used by students during the think-aloud process, such as "this" or "that," which cannot be fully interpreted through verbal data alone. Once participants had completed all the problems, retrospective interviews were conducted. In these interviews, participants were asked about their reasoning and strategies for example, "*Why did you choose a particular method to solve it or to clarify their actions for example ?*", "*Why did you look back at what you had written earlier in the process*?" The interview complemented the think-aloud data and provided deeper insights into students' thought processes during problem-solving. Participants' written responses were also analyzed alongside the think-aloud recordings to further trace and understand their problem-solving approaches.

Five kinematics problems were used in this research. Prior to the main research, the problems were piloted with 12 undergraduate students who had completed introductory physics courses covering kinematics. These students were not included in the main research, were selected to represent a range of abilities, and were asked not only to solve the test items but also to provide feedback on their clarity, wording, and level of difficulty. The five problems were adapted from university physics book [20]–[22]. The problems are shown in Table 1 listed in the order they were used.

The data analysis followed Miles et al.'s framework [23] of data reduction, data display, and conclusion drawing. In the reduction stage, think-aloud sessions, retrospective interviews, and field notes were transcribed, then coded using gerunds to capture observable problem-solving strategies used by participants. Vague or overlapping codes were refined (e.g., distinguishing "Reading" from "Rereading"), and unclear statements were clarified by cross-checking with observation notes, interview data, and participants' written answers. In the display stage, codes were organized into tables, grouped into broader categories of problem-solving strategies, and compared across low, medium, and high achievers to highlight differences and similarities. Finally, in the conclusion drawing stage, the analysis focused on interpreting how each achievement group approached problem solving and identified key strategies distinguishing low, medium, and high achievers.

Table 1. Kinematics Problem Used in Think-Aloud Session

No	Problems
1	Submarine & Sonar To avoid detection by an enemy vessel, a submarine must stay deeper than 3000 m. The vessel uses sonar, which sends a sound pulse into the water and records the echo. If the echo is received back in 3.6 seconds, will the submarine be detected? (Speed of sound in water = 1500 m/s)

2 Emergency Plane Landing
A passenger airplane is flying at 80 m/s when the pilot begins to land on a runway. The braking system provides a constant deceleration of −4.0 m/s². (a) How much time will it take for the plane to come to rest? (b) Can the plane safely land on a runway of length 1200 m?

3 Relay Race
In a 4 × 200 m relay the runners have these average speeds:

- Bima: 10 m/s
- Rudi: 8 m/s
- Tika: 5 m/s

The school record for 4 × 200 m is 111 s. If Maya runs last, what minimum average speed (in m/s) must Maya maintain so the team beats the record by at least 1.0 s?

4 Two Vehicles Approaching
A bus travels east at 25 m/s, while a car starts 600 m away heading west at 20 m/s. When they are at this distance, both drivers suddenly notice an obstacle and begin braking. The bus decelerates at −2.0 m/s², while the car decelerates at −4.0 m/s². Will they collide, or can they both stop before reaching each other?

5 Choosing Between Escalator and Stairs
Rina wants to reach her classroom on the 10th floor.

- Stairs: She can run at 4 m/s for the first 5 s, then slows down with a deceleration of 0.2 m/s².
- Escalator: It moves upward at 1 floor per 2 s. Each floor has a height of 4 m. She must wait 8 s for the escalator to arrive.

Which option will get Rina to the classroom faster?

3. Results and Discussion

The findings revealed thirty distinct strategies observed across participants' problem-solving sessions. These strategies were then organized into six strategy categories based on their functions and roles, providing a clearer view of the strategies used by high, medium, and low achievers. The identified six categories of problem-solving strategies are understanding, planning, executing, monitoring, checking, and concluding. Understanding strategies reflect students' efforts to grasp the problem context before attempting a solution. They read and reread the statements, underlined or listed key information, representing the problem using symbols, sketches, or diagrams to make sense of it and sometimes rephrased the problem in their own word or recalling relevant concepts of the problem. The typical utterances transcribed were *"The question actually ask …" or "So the object starts from rest…"* Planning captures how students emphasized the problem goal, selected formulas, considering alternatives, making assumptions how to solve the problem, outlined possible steps and creating sub-goals. Some carried out this stage confidently, while others made tentative or trial-and-error plans. The example utterances were *"Oh, I need to find the velocity first" or "Maybe I can use that formula here."* Executing strategies encompass the actual implementation of plans through calculations, applying formula, constructing equation, algebraic manipulations, or unit conversions to generate results. The example utterances were *"Four times ten is forty, so the distance is 40 meters" or "Then substitute the values into the formula."*

Monitoring strategies highlight students' awareness of their ongoing problem-solving process, such as reflecting on progress, comparing alternatives, reconsidering variables, reasoning obtained results, recognizing mistakes, making self-correction, and adjusting strategies during the process.

The participants showed the ability to pause during the process and reflect on their work, occasionally murmuring, '*Is this right*?'. Checking encompasses strategy where students looked back at their work to verify accuracy and consistency. This included validating steps, evaluating formulas, verifying the calculation, evaluating intermediate actions or judging the reasonableness of the result. The typical utterance transcribed was *"Let me check this ...."* Finally, Concluding represents students' strategy in stating or communicating the answer. The majority of participants stated the answer by directly mentioning the numerical result, while a few participants explained their answer by relating it back to the original question, or interpreting the meaning of the answer. The problem-solving strategies used by low, medium and high achievers presented in Table 2.

Table 2. Problem-Solving Strategies Used by Low, Medium and High Achievers

Categories of strategies	Codes of strategies	Low achievers	Medium achievers	High achievers
Understanding	Reading the problem	√*	√	√
	Rereading the problem	~**	~	√
	Extracting given information	√	√	√
	Representing the problem (symbols, sketchs, etc.)	~	√	√
	Rephrasing the problem in own words	x***	~	~
	Recalling relevant concept	~	~	√
Planning	Setting the goal	~	√	√
	Making assumptions	x	x	√
	Selecting the appropriate formula	~	√	√
	Considering alternatives	x	~	~
	Creating sub-plan	x	~	√
	Outlining next step	~	√	√
Executing	Applying formula	√	√	√
	Constructing equation	√	√	√
	Mathematical Execution	√	√	√
	Unit conversion	~	~	√
Checking	Validating steps	x	~	√
	Evaluating formulas	~	~	√
	Verifying the calculation	x	~	√
	Evaluating intermediate actions	x	x	~
	Checking with alternative method	x	x	~
	Reasoning the result	x	~	~
Monitoring	Reflecting on progress	x	~	√
	Comparing alternatives	x	x	~
	Reconsidering variables	x	~	√
	Adjusting strategies	x	x	√
	Realizing mistake	x	~	√
	Self-correction	x	~	√
Concluding	Stating the answer (number)	√	√	√
	Explaining answer in words	x	x	~

*√ : consistently demonstrated by participants; **~ : demonstrated but inconsistently or with mistakes; ***x : not demonstrated by participants

The findings reveal distinct profiles of students' problem-solving strategies across low, medium, and high achievers. Low achievers primarily relied on basic procedures such as reading the problem, extracting given information, and performing straightforward calculations. However, they rarely engaged in deeper analysis such as rephrased or represented the problem effectively, and almost never checked or validated their solutions. Their lack of monitoring and reflection often led them to overlook mistakes, resulting in incorrect answers or incomplete solutions. Medium achievers demonstrated a wider range of strategies. They were able to organize problem information into physics symbols, occasionally represent the problem with sketches, select formulas more deliberately, and or creating sub-plans. They also engaged in checking and monitoring, reconsideration of variables, and self-correction, though inconsistently. This partial monitoring allowed them to reach correct solutions in simpler cases, but their inconsistent checking and evaluation, often led them to rely on trial-and-error approaches when confronted with more complex tasks.

High achievers employed more systematic and flexible strategies that combined understanding, planning, executing, monitoring, and concluding strategies. They systematically set goals, selected and applied formulas, constructed equations, and checked units. Importantly, they frequently monitored their progress by recognizing mistakes, adjusting strategies, and verifying results. Although some minor inconsistencies appeared, their frequent reflection and adaptive use of strategies allowed them to identify and correct errors more effectively than the other groups. Overall, the comparison indicates that low achievers tended to rely on surface-level procedures, medium achievers showed emerging strategic awareness but inconsistent checking monitoring strategies, and high achievers demonstrated integrated and adaptive strategies that enhanced the effectiveness of their problem solving in kinematics. The comparisons are summarized in Table 3.

Table 3. Comparative Summary of Problem-Solving Strategies Across Achievement Groups

Problem-solving strategy	Low achievers	Medium achievers	High achievers
Understanding	Read the problem literally, extract given numbers, but rarely rephrase or represent the problem	Read and record information, sometimes represent with symbols or sketches, but inconsistently	Reading carefully, often reread, rephrasing, representing with symbols/diagrams, and recalling relevant concepts
Planning	Minimal planning; often jump straight to formula without setting goals	Some planning by identifying goals and selecting formulas, but sometimes trial-and-error	More structured planning with goals, formula selection, sub-plans, and outlining steps
Executing	Apply formulas mechanically; rely on memorization; errors often uncorrected	Carry out calculations carefully, sometimes with hesitation; partial unit conversion	Perform stepwise calculations; construct equations; include unit checks
Checking	Almost no checking or validation; ignore inconsistencies	Occasional checking of results or formulas, but not systematic	Consistent checking of formulas, units, results, and alignment with the problem goal

Monitoring	No reflect or adjust; no awareness of mistakes	Occasionally reflect, reconsider variables, and attempt self-correction, though inconsistently	Frequently monitor progress, realize mistakes, adjust strategies, and self-correct
Concluding	State final number without explanation	Often state final number only; rarely explain in words	State answer and sometimes explain meaning or relate back to problem
Overall strategies	Procedural execution with little reflection or evaluation	Demonstrate partial mastery with some strategic awareness but inconsistently.	Exhibit adaptive and flexible problem-solving strategies

The problem-solving strategies understanding, planning, executing, monitoring, checking and concluding observed in this study provide a comprehensive picture of how students navigate kinematics problem solving. The problem-solving strategies observed align with established models of problem solving such as Polya's [24], Schoenfeld's [25] and previous studies examined problem-solving strategies [2], [16], [18], [26]. The problem-solving strategies might suggest a linear progress, but the actual processes observed in students' sessions were dynamic and recursive, with frequent backtracking, revisions, and shifts between strategies depending on the challenges encountered. The findings indicate that high achievers frequently revisited earlier steps when encountering difficulties, suggesting that flexibility is an essential feature of effective problem solving. This observation aligns with the studies of Rahayuningsih et al., [27] and Hacatrjana [28] study which propose that the flexibility to modify a solution strategy contributes to successful problem solving. These results suggest that teaching instruction should explicitly model and scaffold problem solving strategies, not only content knowledge, to help students improve their problem-solving performance.

Understanding were the most consistent strategy observed across all levels of achievement. This aligns with Eryilmaz-Toksoy's findings [29], which show that the most frequently used problem-solving strategy among students is understanding, and that the understanding phase significantly influences both the solution process and the time needed to reach a solution. The difference lies in the duration and variety of understanding strategies used by high, medium, and low achievers: high and medium achievers employed a wider range of strategies, while low achievers primarily focused on reading the problem and extracting the given information to understand the problem. This finding aligns with prior research by Larkin and Reif [30] which emphasized that experts tend to use more strategies during the understanding stage of problem solving, such as organizing detailed physical descriptions or retrieving relevant information to guide their solutions.

In the planning category, clear differences emerged among high, medium, and low achieving participants. Low achievers frequently jumped directly to execution without engaging in planning, whereas medium achievers demonstrated some planning, though inconsistently. High achievers, in contrast, exhibited a broader range of planning strategies, which enabled them to reach correct solutions more effectively than the other two groups. This finding underscores the importance of planning, consistent with Eichmann et al., [31] who reported that engaging in a planning phase at the beginning of the problem-solving process leads to higher performance.

The findings suggest that all participants engaged in understanding, executing, and concluding strategies, whereas planning, checking, and monitoring strategies were primarily observed among high achievers.

This reinforces prior research showing that successful problem solvers possess metacognitive regulation planning, monitoring, and evaluating their learning processes, such as reflecting on progress and verifying solutions which are key indicators of expertise [25], [32]–[35]. Izzati and Mahmudi [35] reported that metacognition is essential for successful problem solving, which involves analyzing the problem, planning a strategy, executing the plan, checking the correctness of each step, and monitoring progress; students with higher metacognitive skills tend to perform better in problem solving. High achiever participants demonstrated an ability to pause during execution, reflect on whether their approach was making sense, and adjust their strategies accordingly. Medium achievers exhibited some monitoring but did so sporadically, while low achievers showed little evidence of this behaviour. This uneven distribution suggests that metacognitive monitoring is a distinguishing feature of higher-level problem solvers. Schoenfeld [25] argued that expert problem solvers constantly regulate their progress by asking themselves whether their current actions are moving them closer to the solution. Instructional approaches such as think-aloud model, metacognitive prompts, and reflective questioning can help foster these skills in novice learners. Checking and monitoring strategies are critical for ensuring the validity of solutions and for detecting errors. The absence of these strategies among low and medium achievers often led to incorrect solutions. This echoes findings from previous research showing that novices frequently terminate problem solving once an answer—any answer—is obtained [36], [37]. Promoting a learning culture that emphasizes verification and reflection may encourage students to view checking and monitoring as an integral part of the problem-solving process

In summary, the findings indicate that while students at all achievement levels are capable of understanding and executing problem-solving steps, only high achievers engage consistently in systematic planning, monitoring, and checking. This imbalance between lower-order strategies (understanding and executing) and higher-order strategies (planning, monitoring, and checking) likely contributes to the persistent differences in problem-solving performance among high, medium, and low achievers. These results underscore the importance of fostering higher-order strategies in instruction and suggest that explicitly teaching planning, monitoring, and checking may help students across all achievement levels develop more effective and adaptive problem-solving skills.

4. Conclusion

This study examined students' problem-solving strategies in kinematics and identified thirty distinct strategies, which were grouped into six categories: understanding, planning, executing, checking, monitoring and concluding. The findings indicate that while most students are capable of understanding and executing, fewer engage in systematic planning, monitoring, and checking. The imbalance between lower-order strategies (understanding and executing) and higher-order strategies (planning, monitoring, checking) may explain the persistent gap in problem-solving performance between high, medium and low achievers. Importantly, the recursive nature of the problem-solving process observed in this study reinforces that effective problem solving is not a straightforward, step-by-step procedure but a flexible and adaptive process. High achievers demonstrated this adaptability by moving back and forth between categories as needed, while lower achievers often proceeded linearly and rigidly, leaving them unable to recover when errors occurred. The study contributes to physics education research by providing a clearer framework for categorizing students' strategies across achievement level. This framework can guide explicit instructional design by modelling expert-like behaviours, encouraging multiple representations, scaffolding planning processes, and embedding metacognitive prompts- monitoring and checking-into problem-solving tasks. Future research is recommended to investigate how targeted instructional interventions can foster the use of these problem-solving strategies across different physics topics and learning contexts.

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References

[1] K. Bariyyah, "Problem solving skills: esssential skills challenges for the 21st century graduates," *J. Educ. J. Pendidik. Indones.*, vol. 7, no. 1, p. 71, 2021. doi:10.29210/120212843

[2] C. Riantoni, Rusdi, Maison, and U. Yelianti, "Analysis of Student Problem Solving Processes in Physics," *Int. J. Educ. Teach. Zo.*, vol. 2, no. 1, pp. 1–12, 2023. doi: 10.57092/ijetz.v2i1.107

[3] S. Sutarno, D. H. Putri, E. Risdianto, M. Satriawan, and A. Malik, "The students' Physics Problem Solving Skills in basic physics course," *J. Phys. Conf. Ser.*, vol. 1731, no. 1, 2021. doi: 10.1088/1742-6596/1731/1/012078

[4] T. Tong, F. Pi, S. Zheng, Y. Zhong, X. Lin, and Y. Wei, "Exploring the Effect of Mathematics Skills on Student Performance in Physics Problem-Solving: A Structural Equation Modeling Analysis," *Res. Sci. Educ.*, vol. 55, no. 3, pp. 489–509, 2025. doi: 10.1007/s11165-024-10201-5

[5] L. Shakhman and M. Barak, "The physics problem-solving taxonomy (PPST): Development and application for evaluating student learning," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 15, no. 11, 2019. doi: 10.29333/ejmste/109266

[6] M. H. Nasir and H. Kuswanto, "Problem Solving Skill in Physics Learning: Systematic Literature Review," *J. Penelit. Pendidik. IPA*, vol. 11, no. 4, pp. 34–40, 2025. doi: 10.29303/jppipa.v11i4.9579

[7] S. K. Jua, Sarwanto, and Sukarmin, "The profile of students' problem-solving skill in physics across interest program in the secondary school," *J. Phys. Conf. Ser.*, vol. 1022, no. 1, 2018. doi: 10.1088/1742-6596/1022/1/012027

[8] M. Syukri, E. S. Putri, M. Musdar, and L. Halim, "Analysis of Solving Physics Problems Using the Minnesota Model for Mechanics Concepts," *JIPF (Jurnal Ilmu Pendidik. Fis.*, vol. 8, no. 3, p. 296, 2023. doi: 10.26737/jipf.v8i3.3995

[9] B. Silaban and J. Nainggolan, "The Mastery of Science Concepts in Solving Physics Problems for Junior High School Students," *JPI (Jurnal Pendidik. Indones.*, vol. 11, no. 4, pp. 618–625, 2022. doi: 10.23887/jpiundiksha.v11i4.54039

[10] N. Balta and M. A. Asikainen, "Introductory students' attitudes and approaches to physics problem solving: Major, achievement level and gender differences," *J. Technol. Sci. Educ.*, vol. 9, no. 3, pp. 378–387, 2019. doi: 10.3926/JOTSE.666

[11] P. N. Iwuanyanwu, "'I think I know it, but I'm not sure': How pre-service teachers blend conceptual physics problems into solution frameworks," *South African J. Educ.*, vol. 45, no. 2, 2025. doi: 10.15700/saje.v45n2a2352

[12] T. Ovadiya, "Training problem-solving skills by building connections: the case of struggling high school students," *Int. J. Math. Educ. Sci. Technol.*, vol. 5211, 2025. doi: 10.1080/0020739X.2025.2512473

[13] P. Tschisgale, M. Kubsch, P. Wulff, S. Petersen, and K. Neumann, "Exploring the sequential structure of students' physics problem-solving approaches using process mining and sequence analysis," *Phys. Rev. Phys. Educ. Res.*, vol. 21, no. 1, p. 10111, 2025. doi: 10.1103/PhysRevPhysEducRes.21.010111

[14] G. Taasoobshirazi and M. Carr, "A review and critique of context-based physics instruction and assessment," *Educ. Res. Rev.*, vol. 3, no. 2, pp. 155–167, 2008. doi: 10.1016/j.edurev.2008.01.002

[15] F. Cahyono, E. Saptono, and S. Sulhadi, "How to Improve Problem Solving Ability in Learning Physics: A Systematic Review," *Int. Conf. on Sci., Edu. and Technology*, pp. 654–666, 2022.
[16] T. Gök and I. Sýlay, "The Effects of Problem Solving Strategies on Students' Achievement, Attitude and Motivation," *Latin-American J. Phys. Educ.*, vol. 4, pp. 7–21, 2010.
[17] E. Stenberg Hartviksen and P. Ø. Haavold, "Differences between experts in mathematical problem solving," *Think. Ski. Creat.*, vol. 58, no. October 2024, 2025. doi: 10.1016/j.tsc.2025.101875
[18] E. Burkholder, L. Blackmon, and C. Wieman, "Characterizing the mathematical problem-solving strategies of transitioning novice physics students," *Phys. Rev. Phys. Educ. Res.*, vol. 16, no. 2, p. 20134, 2020. doi: 10.1103/PhysRevPhysEducRes.16.020134
[19] M. Tóthová and M. Rusek, "'Do you just have to know that?' Novice and experts' procedure when solving science problem tasks," *Front. Educ.*, vol. 7, no. November, pp. 1–14, 2022. doi: 10.3389/feduc.2022.1051098
[20] E. Hecht and F. Bueche, J, *Schaum's Outline of Theory and Problems in College Physics*. The McGraw-Hill Companies, 2006.
[21] H. D. Young and R. A. Freedman, *Sears and zemansky's university physics: with modern physics*. 2012.
[22] D. Halliday, R. Resnick, and G. H. Bowen, *Fundamentals of Physics*. Wiley, 2014.
[23] M. B. Miles, A. M. Hubberman, and J. Saldana, *Qualitative Data Analysis*. SAGE Publications, 2014.
[24] G. Pólya, *How to solve it: a new aspect of mathematical method*. Princeton University Press, 1957.
[25] A. H. Schoenfeld, *Mathematical Problem Solving*. Florida: Academic Press, 1985.
[26] E. W. Burkholder, J. K. Miles, T. J. Layden, K. D. Wang, A. V. Fritz, and C. E. Wieman, "Template for teaching and assessment of problem solving in introductory physics," *Phys. Rev. Phys. Educ. Res.*, vol. 16, no. 1, p. 10123, 2020. doi: 10.1103/PHYSREVPHYSEDUCRES.16.010123
[27] S. Rahayuningsih, S. Sirajuddin, and N. Nasrun, "Cognitive flexibility: exploring students' problem-solving in elementary school mathematics learning," *JRAMathEdu (Journal Res. Adv. Math. Educ.*, vol. 6, no. 1, pp. 59–70, 2020. doi: 10.23917/jramathedu.v6i1.11630
[28] L. Hacatrjana, "Flexibility to Change the Solution: An Indicator of Problem Solving That Predicted 9th Grade Students' Academic Achievement during Distance Learning, in Parallel to Reasoning Abilities and Parental Education," *J. Intell.*, vol. 10, no. 1, 2022. doi: 10.3390/jintelligence10010007
[29] S. Eryilmaz-Toksoy, "Analysis of Strategies Used by Students in Solving Motion Problems According to the Presentation of the Problem," *Kuramsal Eğitimbilim*, vol. 15, no. 2, pp. 327–346, 2022. doi: 10.30831/akukeg.975348
[30] J. H. Larkin and F. Reif, "Education Understanding and Teaching Problem - Solving in Physics," *European Journal of Science and Theology*, vol. 1, no. 2. pp. 191–203, 1979. doi: 10.1080/0140528790010208
[31] B. Eichmann, F. Goldhammer, S. Greiff, L. Pucite, and J. Naumann, "The role of planning in complex problem solving," *Comput. Educ.*, vol. 128, no. July 2018, pp. 1–12, 2019. doi: 10.1016/j.compedu.2018.08.004
[32] I. Ismayati, N. Ratnaningsih, and S. Supratman, "Students' Metacognition and Self-Regulated Learning: An Analysis Through Students' Work in Solving HOTS Problem," *JETL (Journal Educ. Teach. Learn.*, vol. 5, no. 1, p. 21, 2020. doi: 10.26737/jetl.v5i1.1328
[33] Yuberti, I. Kartika, Viyanti, H. Wulandari, and Anillah, "Identification of Students' Metacognitive Levels in Physics Learning Viewed from the Problem-Solving Ability," *J. Phys. Conf. Ser.*, vol. 1467, no. 1, 2020. doi: 10.1088/1742-6596/1467/1/012041
[34] A. Adinda, H. Purnomo, D. Rahmatina, and N. C. Siregar, "Characteristics of Students' Metacognitive Ability in Solving Problems using Awareness, Regulation and Evaluation Components," *J. Didakt. Mat.*, vol. 10, no. 1, pp. 48–62, 2023. doi: 10.24815/jdm.v10i1.29041

[35] L. R. Izzati and A. Mahmudi, "The influence of metacognition in mathematical problem solving," *J. Phys. Conf. Ser.*, vol. 1097, no. 1, 2018. doi: 10.1088/1742-6596/1097/1/012107

[36] A. M. Persky and J. D. Robinson, "Moving from novice to expertise and its implications for instruction," *Am. J. Pharm. Educ.*, vol. 81, no. 9, pp. 72–80, 2017. doi: 10.5688/ajpe6065

[37] F. Eylon, B. S., Reif, "Effects of Knowledge Organization on Task Performance," *Cogn. Instr.*, vol. 1, no. 1, pp. 5–44, 1984. doi: 10.1207/s1532690xci0101_2