MATHE*dunesa*
Homepage: https://ejournal.unesa.ac.id/index.php/mathedunesa/index
Email: mathedunesa@unesa.ac.id
p-ISSN: 2301-9085; e-ISSN: 2685-7855
Vol. 15 No. 2 Tahun 2026
Halaman 400-410

Students' Critical Thinking in Solving Mathematics Problems Based on Field-Independent and Field-Dependent Cognitive Styles

Roisatun Nisa'[1,2*], Siti Khabibah[1], Dwi Juniati[1]

[1]Mathematics Education, State University of Surabaya, Surabaya, Indonesia
[2]Mathematics Education, Qomaruddin University, Gresik, Indonesia

DOI: https://doi.org/10.26740/mathedunesa.v15n2.p400-410

Article History:
Received: 13 December 2025
Revised: 6 January 2026
Accepted: 6 January 2026
Published: 19 May 2026

Keywords:
Critical Thinking, Problem Solving, Cognitive Style, Field Independent-Dependent

***Corresponding author:**
25030936003@mhs.unesa.ac.id

Abstract: The purpose of this study was to describe the critical thinking process of students with Field-Independent (FI) and Field-Dependent (FD) cognitive styles when they solved the Two-Variable Linear Equation System (SPLDV) problem, which is based on the Polya step and the Facione critical thinking indicator. This research is qualitative descriptive. The instruments in this study are the GEFT Test, the SPLDV problem-solving test and the interview guidelines are the research instruments. The results of the study show that FI students are able to understand and analyze data independently and systematically, use logical inference to choose a solution strategy, and provide a thorough procedural explanation. They are also capable of self-verification, which shows strong self-control. In contrast, FD students face difficulties in selecting important information, making preparations that rely on the teacher's example, and performing inconsistent completion steps. Since the evaluation stage of FD students still depends on external justification, they also show a lack of self-regulation. These results confirm that cognitive style affects the activation of critical thinking indicators at each stage of problem-solving. In addition, cognitive style also provides implications for the importance of adaptive learning based on students' cognitive characteristics.

INTRODUCTION

One of the important competencies in the Pancasila Student Profile is critical thinking, which is necessary to face increasingly complex challenges around the world. The independent curriculum shows that students who have critical thinking skills can assess information objectively, make evidence-based decisions, and solve problems independently. This ability is an important indicator of the profile of 21st-century students.(Henriksen et al., 2020). According to (Facione, 2020), Critical thinking is a reflective and directed reasoning process used to make decisions based on interpretation, analysis, evaluation, inference, and self-regulation. According to (Ennis, 2011) Critical thinking is defined as "*reasonable reflective thinking focused on deciding what to believe or do*". Other studies show that the reinforcement of critical thinking since primary education is directly related to students' ability to adjust to the changing social and academic environment. (Tiruneh et al., 2018).

Critical thinking in mathematics is not just about finding answers, but also understanding problems, creating solution strategies, checking the correctness of results, and drawing logical and accountable conclusions, as shown in the Two-Variable Linear

Equation System (SPLDV) material.(Rufaidah & Ismail, 2021; Suryanti & Masduki, 2024). According to (Polya, 1977), Problem solving is a thought process that requires understanding, planning, implementing strategies, and re-checking; It's more than just applying formulas. Polya also emphasized that problem-solving is an intellectual activity that requires logic, sharpness of thought, and creativity. Previous studies have shown that individual variables such as cognitive style greatly affect students' ability to read, compose, and solve problems. Therefore, cognitive style is an important factor in research on critical thinking learning.(Salsabila & Surya, 2025; Tiruneh et al., 2018).

Cognitive styles, especially Field-Independent (FI) and Field-Dependent (FD), describe the way students process information and organize their thoughts while solving problems. Students with the FI style tend to be analytical, independent, and able to distinguish important details from intrusive contexts. Students with the FD style often have a hard time distinguishing important information from irrelevant.(Hardiansyah et al., 2024; Sihotang & Huda, 2024). This difference is clearly seen in the students' thought processes when they complete math assignments, including SPLDV; Successful completion of a task depends on a clear interpretation of the problem. (Muis et al., 2021).

Differences in critical thinking skills between FI and FD students are found in a number of empirical studies on cognitive style and mathematical problem-solving. Research results (Nugraha et al., 2025; Witkin et al., 1977) found that students with the FD style had difficulty absorbing information and understanding the problem thoroughly, so they often neglected the process of verifying results independently. Students with FI styles, on the other hand, tend to be more systematic when thinking critically. (Ismaimuza & Lefrida, 2024)

In several studies, a relationship has been found between FI/FD cognitive style and mathematical problem-solving ability. However, many studies focus only on solving common problems or aspects of knowledge without examining critical thinking indicators such as interpretation, analysis, evaluation, inferences, explanations, and self-regulation in an SPLDV environment. In addition, most current research uses both quantitative and aggregate designs, so they cannot clearly describe how students think individually when solving complex problems.(Suryanti & Masduki, 2024)

Taking this background into account, this study aims to thoroughly study how students with Field-Independent and Field-Dependent cognitive styles use their critical thinking skills to solve SPLDV problems. The purpose of this study is to explain the differences in thinking patterns that emerge, as well as the learning implications that can improve the quality of students' critical thinking.

METHODS

This study uses a qualitative descriptive approach. The research was carried out at Junior High School in the odd semester of the 2025–2026 school year. The research subjects consisted of two students, namely one student with a Field-Independent (FI) cognitive style, and one student with a Field-Dependent (FD) cognitive style. Given the limited number of participants, this study is positioned as an in-depth qualitative case study. The

methodological aim is to obtain a deeper understanding of students' critical-thinking processes at each stage of solving SPLDV problems, rather than to generate generalizable findings.

The research instruments consisted of the GEFT, which was used to identify FI and FD cognitive styles; a problem-solving test on SPLDV; and an interview guide. Source triangulation, which involved comparing and cross-checking data from the problem-solving test and interviews during the solution process, ensured the validity of the data. This procedure was carried out to guarantee the consistency of the results and to minimize interpretive bias on the part of the researcher.

Data analysis uses qualitative text analysis techniques which are reduced to three basic forms of interpretation as developed by Mayring (2010a, 2010b), namely: Summary (text reduction), Explicating and Structuring (Grouping data based on indicators of critical thinking and problem solving). The data analysis technique is carried out based on the indicators listed in table 1.

Table 1. Indicators of Critical Thinking Criteria in Problem-Solving Steps

Polya Steps	Facione Indicator	Explanation
Understanding the Problem	Interpretation and Analysis	• In the Interpretation stage, students understand the meaning of information, read symbols/terms. (IT.1) • In the Analysis stage, students find important and unimportant facts, and connect data between sections. (AN.1)
Devising a Plan	Inference and Evaluation	• In the Inference stage, students draw logical conjectures and choose a method (e.g. elimination/substitution). (IF.1) • In the Evaluation stage, students assess whether the strategy is appropriate, efficient, and in accordance with the context of the question. (EV.1)
Carrying Out the Plan	Explanation	• In the Explanation stage, students explain the reason for each step, write down the procedure in sequence, and show an understanding of why a certain operation is performed. (EP.1)
Looking Back	Evaluation and Self-Regulation	• The Evaluation stage appears again when students assess whether the results are correct. (EV.2) • In the Self-Regulation stage, students monitor the thought process, find and correct mistakes, and ensure that answers are reasonable without relying on outside help. (SR.1)

RESULTS AND DISCUSSION

Critical thinking Students with Field Independent (FI) cognitive style

The Figure 1 is presented the answers of FI subjects in solving SPLDV problem solving problems.

Understanding the Problem (Interpretation and Analysis)

The following are the results of interviews with FI subjects on the Interpretation and Analysis indicators.

P1 : Can you explain what information you know from the question?
S-FI : You say that on Monday there are 4 premium pencils and 2 gel pens that cost Rp20,000. Then on Tuesday there are 3 premium pencils and 3 gel pens that cost Rp21,000.
P2 : What are the important things about that information?
S-FI : The number of pencils and pens and the total price are important, because that's what makes the equation.

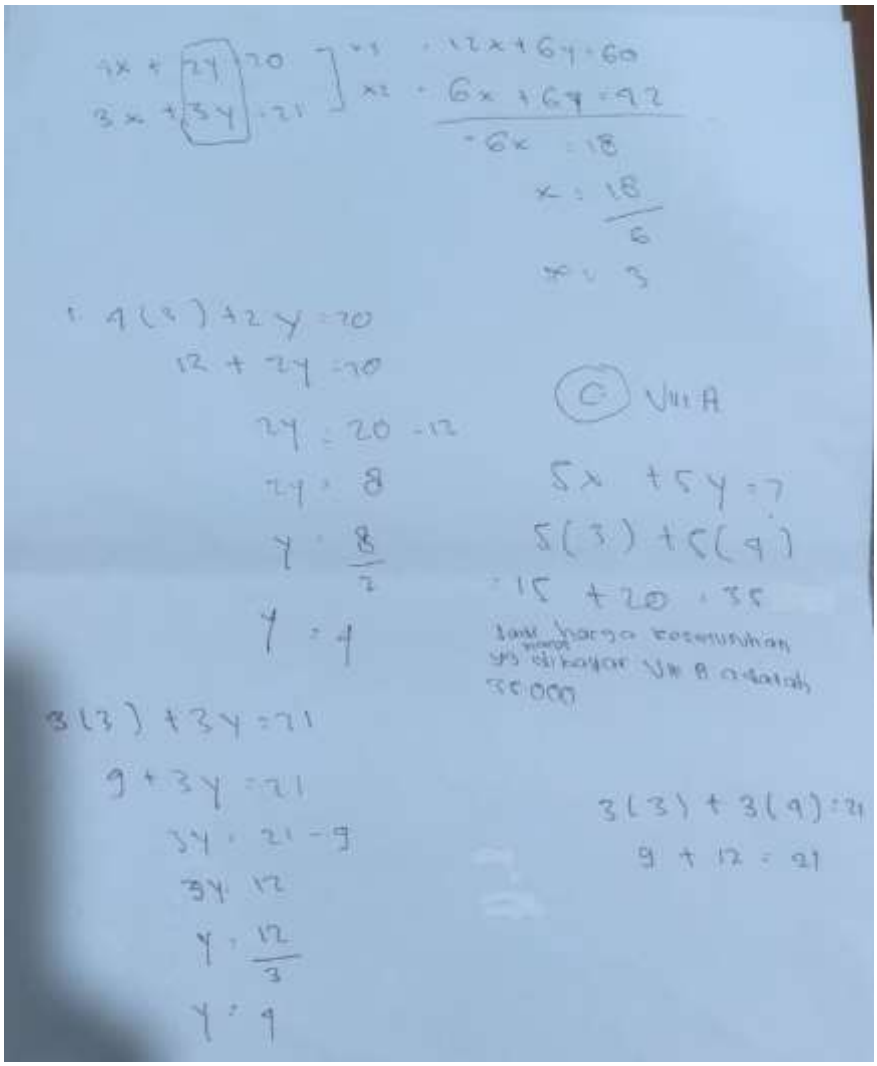

Figure 1. FI Subject Answers

P3 : Is there anything that is not important from the information in the question?
S-FI : Yes, the price of the eraser is Rp2,500. The cooperative recorded 203 transactions this week.
P4 : Why is that information not important?
S-FI : Because it is not used to solve problems.

FI students can precisely and systematically find important information. Students note the number of pencils, the number of pens, and the total cost as important elements that should be modeled in the P1–P2 transcript. It demonstrates strong interpretive abilities (IT.1). In addition, students have the ability to relate information into logical equations and provide reasons for information that is not important, as shown by the analysis (AN.1). In FI students, this corresponds to their characteristics, i.e. the ability to break down information independently and in a structured manner.

Devising a Plan (Inference and Evaluation)

The following are the results of interviews with FI subjects on the Inference and Evaluation indicator.

P5 : What are your plans to solve this problem?
S-FI : I did the math first. I suppose x is for the price of 1 premium pencil, y for the price of 1 gel pen. Then I made two equations. (by pointing to the equation).
P6 : How many ways are there to solve SPLDV?

S-FI : Graph, Elimination, Substitution, Mix (Elimination-substitution).
P7 : Which method do you use?
S-FI : Mix (Elimination-Substitution), The initial step I used elimination first.
P8 : Why did you choose elimination to solve the equation system?
S-FI : Because it's faster. If I equal the coefficient and subtract it, x or y disappears immediately.

By selecting the elimination-substitution method (P5–P8), FI students showed good inference (IF.1) and were able to assess the reasons for choosing a "faster and more efficient" strategy, which indicates evaluation (EV.1). This is consistent with the nature of FI students, who tend to choose strategies independently based on logical considerations without relying on external scaffolding.

Carrying Out the Plan (Explanation)

The following are the results of interviews on FI subjects on the Explanation indicator.

P9 : Explain your solution steps.
S-FI : I multiply the first and second equations so that the coefficient y is the same. Then I subtract the two equations. After subtracting, we find x = 3. Then I substitute it to another equation and get y = 4.
P10 : What does x = 3 and y = 4 mean?
S-FI : The price of 1 premium pencil is IDR 3,000 and the price of 1 gel pen is IDR 4,000.
P11 : How do you calculate the cost for 5 premium pencils and 5 gel pens?
S-FI : I directly substituted one of the equations: 5(3) + 5(4) = 15 + 20 = 35.
P12 : What does that mean?
S-FI : Price for 5 premium pencils and 5 gel pens is IDR 35,000.

FI students explain the steps of completion in a series of P9–P12. These steps include multiplying equations, eliminating variables, substituting, and calculating results. This shows a strong explanation (EP.1). This systematic explanation shows FI's tendency to do in-depth and analytical work on symbol manipulation and procedures.

Looking Back (Evaluation and Self-Regulation)

The following are the results of interviews with FI subjects on the Evaluation and Self-Regulation indicator.

P13 : How do you make sure your answer is correct?
S-FI : I checked again at the initial equation. I put the values x and y into both equations, and the result is equal to the total price in the problem. (by pointing to the result of the answer)
P14 : Is there a part that makes you doubt?
S-FI : Not really, because after checking the results are just right.

By re-entering the values of x and y into the initial equation (P13), the student performs a self-check and shows the Evaluation (EV.2) at the verification stage. In addition, he stated that checking convinced him that the answer was correct, which showed the ability to control oneself (SR.1). It corresponds to FI's self-contained character and can be changed on its own without much help.

Critical thinking Students with Field Dependent (FD) cognitive style

The following is presented the answers of FD subjects in solving SPLDV problem solving problems.

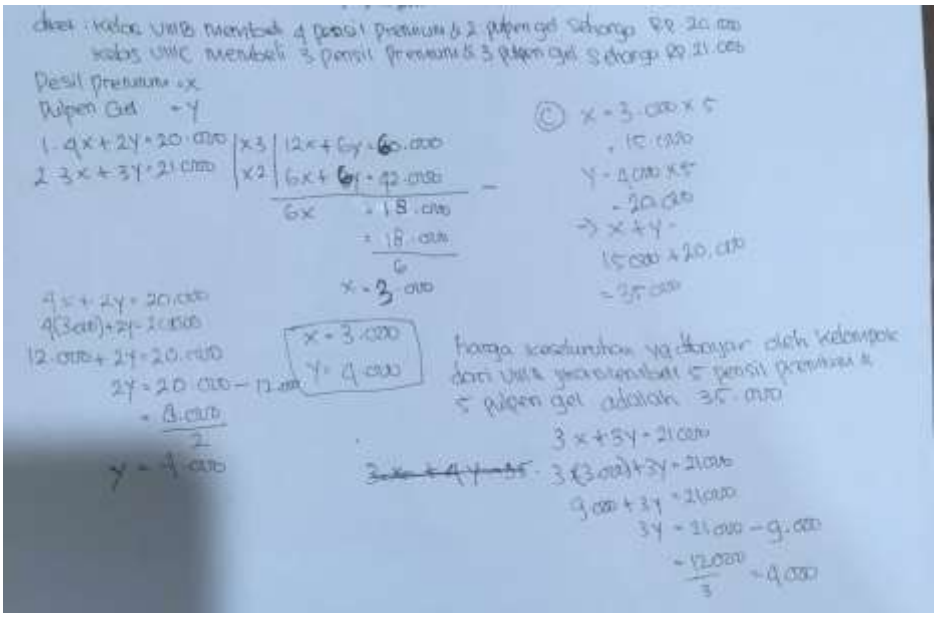

Figure 2. FD Subject Answers

Understanding the Problem (Interpretation and Analysis)

The following are the results of interviews with FD subjects on the Interpretation and Analysis indicators.

P1 : Try to tell us what you understand from this question. What information do you see?
S-FD : In that matter there is the purchase of premium pencils and gel pens by two classes. Then there is the total price as well... but I am a bit confused to distinguish between Monday and Tuesday. What I remember, class VIII-B bought 4 pencils and 2 pens, then class VIII-C bought 3 pencils and 3 pens, and then there was the price.
P2 : Of all that information, which one do you think is important to solve the problem?
S-FD : Hmm... yes... The number of pencils and pens is important. But I'm not sure if the additional information like the eraser is used or not.
P3 : Why not convinced?
S-FD : Because it is inserted in the question.

At the interpretation stage, FD students showed a tendency to be less able to sort out information, as shown by their statement that they were "confused about distinguishing important and non-important information" (IT.1), and they chose to copy all the information without doing the analysis (AN.1). This corresponds to the nature of FD which is difficult to find the core of the problem and is heavily influenced by the external context.

Devising a Plan (Inference and Evaluation)

The following are the results of interviews with FD subjects on the Inference and Evaluation indicator.

P4 : After reading the question, what is your plan to solve it?
S-FD : I usually rewrite the numbers first. I keep trying to make equations, but sometimes I am confused about where to start. So, I try to follow the example that the teacher has given.
P5 : Have you ever been taught how to solve problems like this?
S-FD : A lot, but I think it's just elimination-substitutions.
P6 : What method do you use?
S-FD : How to eliminate.
P7 : Why do you use the elimination method?
S-FD : Because... That's a way that is often used in class. So, I just went along. I think that's the safest way to avoid making mistakes.

FD students' planning follows a pattern that has been taught by teachers, not by themselves. In accordance with the FD profile that is less independent in determining the settlement strategy (EV.1), the selection of the elimination method is not a decision of the results of the analysis; instead, it shows weak inference (IF.1) and a great reliance on external guidance.

Carrying Out the Plan (Explanation)

The following are the results of interviews on FD subjects on the Explanation indicator.

P8 : Can you explain your calculation steps?
S-FD : I wrote 4x + 2y = 20,000 and 3x + 3y = 21,000. Then I multiply one of them so that it can be eliminated. But I was confused about which one to equalize, so I wrote several times. After that, I subtracted and got x = Rp 3,000. For y, I tried substitution, but I recalculated it again because I was afraid of making a mistake. So, in the answer there are several scribbles.
P9 : For and how?
S-FD : I substitute the value of x into the first equation. So that the value of y= IDR 4,000.
P10 : How do you calculate the price for 5 pencils and 5 gel pens?
S-FD : I just have to multiply. But I had time to recheck it on paper because I was afraid of miscalculating. Finally, I got 35 thousand.

FD students made inconsistent and scribble steps during the implementation stage, which showed that the calculations were still hesitant. The explanation (EP.1) of the procedure is less clear, and due to uncertainty, the steps may be repeated. This behavior shows the nature of FD that is less systematic and easily confused when faced with choice of steps.

Looking Back (Evaluation and Self-Regulation)

The following are the results of interviews with FD subjects on the Evaluation and Self-Regulation indicator.

P11 : How do you check if your calculation results are correct?
S-FD : I'm not too sure, so I match it again with the notes that the teacher has explained. If the numbers are similar, it means that I consider it correct.
P12 : Is there a part that makes you doubt or confuse?
S-FD : Yes, especially when you have to choose whether you want to eliminate x or y. I was also afraid of copying the wrong numbers from the questions, so I scribble a lot first.

At the evaluation stage, FD students did not conduct an independent examination; instead, they refer to "teacher's notes". This indicates a lack of self-regulation (SR.1) and an inability to evaluate results independently (EV.2). FD students still rely heavily on external justification due to recurring doubts, such as "fear of being wrong", "confused", and "a lot of scribble".

Discussion

The results of the study showed that cognitive style affects the quality of students' critical thinking when they solve SPLDV problems. Although the study involved only two participants, this selection was made deliberately so that the students' thinking could be examined in depth at the process level rather than merely at the level of final outcomes. Consequently, each step of interpretation, analysis, inference, evaluation, explanation, and self-regulation could be modeled more comprehensively as components of the critical-thinking framework(Facione, 2020). In addition, source triangulation strengthened the findings, meaning that the researcher's interpretations did not rely on a single type of data but were validated through the integration of test results and interview evidence.

Students' ability to distinguish important numbers from the context of the story becomes more structured and independent as they learn about Field Independent (FI).(Ismaimuza & Lefrida, 2024). These results support previous research (Xu et al., 2023; Yu & Zin, 2023) which states that students with analytical tendencies perform problem-solving tasks that require deductive reasoning and symbolic representation better. In addition, FI students seemed to activate metacognitive processes such as monitoring and evaluation independently, in line with the findings(Muis et al., 2021; Q. Wang & Abdullah, 2024) that high metacognitive activity is directly correlated with improved quality of critical thinking on tasks that require logical inference.

The planning process also shows the difference between FI and FD. In FI subjects, the elimination method was chosen through considerations of efficiency and accuracy rather than simply following the taught pattern; this indicates the presence of a strong inference ability (IF.1) (Tiruneh et al., 2018). These results support the study's findings (Suryanti & Masduki, 2024) The findings found that FI students had a greater ability to create problem-solving strategies based on problem structure than FD students, who were more likely to follow the teacher's example mechanically. In contrast, FD students rely heavily on outside help, especially when it comes to determining the initial steps or choosing elimination and substitution methods. This pattern is in line with the results (Hardiansyah et al., 2024) which suggests that FD students typically have difficulty in logical inference and that the planning stage requires greater scaffolding.

FI students show more consistent and consistent reasoning during the plan implementation stage. Students can explain why each mathematical operation is performed, and the algebraic steps are performed in a logical order. This process demonstrates a strong explanatory ability (EP.1), as affirmed by (Anggraeni et al., 2023; Xu et al., 2023) The ability to logically explain procedures is a key feature of mathematical critical thinking. Other studies(Ismaimuza & Lefrida, 2024), found that FI students had more stable mental representations when using linear equations. Students with the FD cognitive style, on the other hand, show unsystematic steps, a lot of re-scribbling, and unclear explanations of procedures, a phenomenon that is also reported by(Suryanti & Masduki, 2024) This is a common feature of the FD's cognitive style when dealing with complex mathematical tasks.

When we look back, the difference is most obvious. FI students exhibit strong self-evaluation and self-regulation abilities (EV.2 and SR.1), re-examining by substituting results for the initial equation. According to this pattern, epistemic scrutiny is essential for the precision of critical thinking (M. Wang et al., 2025). In contrast, FD students prefer to use self-paced algebraic checks rather than matching numbers to teachers' notes. This suggests low metacognitive activation, in line with the findings (Hardiansyah et al., 2024) that FD students often rely on external support to organize themselves.

Theoretically, the results of this study reinforce the long-standing understanding of FI/FD cognitive styles(Witkin et al., 1977). They also incorporated the new idea that metacognitive activation serves as an important link between cognitive styles and critical

thinking qualities, in a pattern that FI conducts self-supervision and evaluation, whereas FD does not support modern metacognition frameworks(Muis et al., 2021). In addition, this study provides a theoretical shift to the idea of appropriate strategies, namely that the match between task characteristics and students' cognitive styles seems to affect the effectiveness of certain math strategies. This idea is in line with the recommendations of the research(Q. Wang & Abdullah, 2024) which emphasizes the importance of adaptive learning design.

In addition, these findings suggest that learning interventions should be tailored to students' cognitive traits. To improve the self-evaluation ability of FD students, clear scaffolding is needed at the interpretation stage, selection strategy training, and metacognitive reflection sheets. However, to increase flexibility of thinking, FI students may be assigned exploratory tasks and open-ended problems. This strategy is in line with the recommendation that a different pedagogical approach is needed to build mathematical critical thinking (Sari & Rosyidi, 2025; Xu et al., 2023). Overall, this study not only sheds light on the differences in cognitive behavior between FI and FD, but also offers a theoretical framework that will enrich the conversation about the relationship between cognitive styles, metacognition, and critical thinking in mathematics.

CONCLUSIONS AND SUGGESTIONS

The results and discussion above show that FI students have better critical thinking skills at almost all stages of problem-solving. FI students are able to interpret and analyze data independently at the stage of understanding problems by sorting out important data and making precise mathematical representations. FI students can draw logical conclusions and choose a settlement strategy based on efficiency and precision at the planning stage. At the implementation stage, they explain the procedure in a concise and logical manner. At the re-check stage, they showed good self-regulation through self-evaluation and systematic verification of results.

In contrast, FD students have difficulty from the early stages of problem-solving, especially in distinguishing important information from non-essential information. The inference and evaluation process of FD students tends to be influenced by the teacher's example or instruction, which suggests that they are highly dependent on external support. At the implementation stage, actions are carried out irregularly and full of doubts. FD student evaluation relies on matching with teacher records rather than independent mathematical verification.

Overall, the study says that critical thinking indicators are activated by differences in cognitive style. While FD students need more structured scaffolding, FI students focus more on the analytical and metacognitive aspects. The results of this study support the research of cognitive styles and provide theoretical contributions on concepts that are appropriate to strategies, such as how students' cognitive styles are aligned with the needs of problem-solving strategies in mathematics learning.

Acknowledgments
Thank you to the students who are willing to be the subjects, teachers, supervisors, and all parties involved morally and materially during the process of completing this article.

REFERENCES

Anggraeni, D. M., Prahani, B. K., Suprapto, N., Shofiyah, N., & Jatmiko, B. (2023). Systematic review of problem based learning research in fostering critical thinking skills. *Thinking Skills and Creativity*, *49*, 101334.

Ennis, R. (2011). Critical thinking: Reflection and perspective Part II. *Inquiry: Critical Thinking across the Disciplines*, *26*(2), 5–19.

Facione, P. A. (2020). Critical thinking: What it is and why it counts. *Insight Assessment*, *1*(1), 1–23.

Hardiansyah, F., Armadi, A., AR, M. M., & Wardi, M. (2024). Analysis of field dependent and field independent cognitive styles in solving science problems in elementary schools. *Journal of Science Education Research*, *10*(3), 1159–1166.

Henriksen, D., Richardson, C., & Shack, K. (2020). Mindfulness and creativity: Implications for thinking and learning. *Thinking Skills and Creativity*, *37*, 100689. https://doi.org/https://doi.org/10.1016/j.tsc.2020.100689

Ismaimuza, D., & Lefrida, R. (2024). Mathematical communication of vocational students with field dependent and independent cognitive styles in solving linear programming problems. *Journal of Hunan University Natural Sciences*, *51*(8).

Muis, K. R., Chevrier, M., Denton, C. A., & Losenno, K. M. (2021). Epistemic emotions and epistemic cognition predict critical thinking about socio-scientific issues. *Frontiers in Education*, *6*, 669908.

Nugraha, A. M., Muslimahayati, M., & Sunarto, S. (2025). Analysis of Mathematics Learning Difficulties in Terms of Students Cognitive Styles at Madrasah Aliyah Laboratory Jambi City. *Journal of Curriculum and Pedagogic Studies (JCPS), 4*(1), 37–44.

Polya, G. (1977). *How to solve it: A new aspect of mathematical method*. Princeton University Press.

Rufaidah, A. S., & Ismail, I. (2021). The profile of students' critical thinking in solving open ended mathematical problems was reviewed from the Dependent-Independent Field cognitive style. *Journal of Mathematics and Science Education Research*, *5*(1), 19–25.

Salsabila, F. K., & Surya, A. (2025). Cognitive Style on Students' Mathematical Problem-Solving Abilities in Elementary School: Systematic Literature Review (SLR). *Social, Humanities, and Educational Studies (SHES): Conference Series*, *8*(3), 2179–2189.

Sari, S. N., & Rosyidi, A. H. (2025). Students' Critical Thinking in Solving Open Contextual Math Problems Reviewed from Reflective and Impulsive Cognitive Styles. *MATHEdunesa*, *14*(1), 175–194.

Sihotang, M. R., & Huda, N. (2024). Metacognition Analysis in Problem Solving of Field Independent and Field Dependent Students. *Riemann: Research of Mathematics and Mathematics Education*, *6*(3), 325–334.

Suryanti, L., & Masduki, M. (2024). Exploration students' computational thinking skills in mathematical problem solving based on field independent and dependent cognitive style. *Decimals: Journal of Mathematics*, *7*(3), 475–488.

Tiruneh, D. T., De Cock, M., & Elen, J. (2018). Designing learning environments for critical thinking: examining effective instructional approaches. *International Journal of Science and Mathematics Education*, *16*(6), 1065–1089.

Wang, M., Mohd Matore, M. E. E., & Rosli, R. (2025). A systematic literature review on analytical thinking development in mathematics education: trends across time and countries. *Frontiers in Psychology*, *16*, 1523836.

Wang, Q., & Abdullah, A. H. (2024). Enhancing students' critical thinking through mathematics in higher education: A systemic review. *SAGE Open*, *14*(3), 21582440241275652.

Witkin, H. A., Moore, C. A., Goodenough, D. R., & Cox, P. W. (1977). Field-dependent and field-independent

cognitive styles and their educational implications. *Review of Educational Research*, *47*(1), 1–64.

Xu, E., Wang, W., & Wang, Q. (2023). The effectiveness of collaborative problem solving in promoting students' critical thinking: A meta-analysis based on empirical literature. *Humanities and Social Sciences Communications*, *10*(1), 1–11.

Yu, L., & Zin, Z. M. (2023). The critical thinking-oriented adaptations of problem-based learning models: a systematic review. *Frontiers in Education*, *8*, 1139987.