Students' critical ability of mathematics based on cognitive styles

Ardi Dwi Susandi1,2,*, Cholis Sa’dijah1, Abdur Rahman As’ari1, and Susiswo1

1State University of Malang, Indonesia
2Universitas Nahdlatul Ulama Cirebon, Indonesia

*Email: ardi.dwi.1603119@students.um.ac.id

Abstract: The strategies used in solving problems can be influenced by cognitive style. This research is a qualitative descriptive study. The purpose of this study was to describe the mathematical critical thinking skills of junior high school students based on the cognitive style of Dependent Field and cognitive style Field Independent in solving SPLDV problems. The subject of this study consisted of 1 student who had the field-dependent cognitive style and 1 student who had the field-independent cognitive style chosen by purposive sampling. Data collection techniques were carried out by administering the cognitive style test of the Embedded Figure Test Group, mathematical problem-solving tests, interview guidelines, and documentation. Data were analyzed based on FRISCO critical thinking category indicators (Focus, Reason, Inference, Situation, Clarity, and Overview) in each step of problem-solving, namely understanding problems, arranging plans, implementing plans, and checking again. Data analysis is done by reducing data, presenting data, and drawing conclusions. The results showed that students who had the cognitive style of field-dependent and students who had the cognitive style FI had good critical thinking skills in each step of problem-solving according to Polya.

1. Introduction

Critical thinking skills are needed in the 21st century [1, 2]. Critical thinking can make someone make rational and valid decisions [3, 4, 5]. Critical thinking will also involve someone in the process of analyzing, making judgments, and evaluating what has happened to solve the problem at hand [6,7]. A person can use cognitive skills to produce the desired goals through critical thinking skills [5, 8]. Therefore, critical thinking skills need to be developed so that a person is flexible and open-minded towards the assessment of knowledge about the world [9].

Based on the above facts, critical thinking skills need to be developed in everyday life. Critical thinking skills are sought to develop through the mathematics education curriculum throughout the world [10, 11]. In addition, the curriculum in Indonesia is based on the Ministry of Education and Culture [12] each student's learning activities must have critical thinking skills as competencies that support daily activities and success in the future. Furthermore, based on Minister of Education and Culture Regulation No. 20 of 2016, there are six thoughts that must be achieved by students in the competency standards of primary and secondary education graduates, one of which is the ability to think critically in mathematics. Furthermore, someone can be said to have good critical thinking skills if they fulfill six indicators, namely: focus, reason, inference, situation, clarity, and overview [13]. Therefore, the six indicators are used as a reference to describe critical thinking skills in solving mathematical problems.

In solving mathematical problems that are being faced, a person needs critical thinking skills [14, 15]. Therefore, the ability to think critically and solve problems goes together. A person who has the
ability to think critically, then he will be able to solve a problem or make a decision. This is because problem-solving involves identifying problems, exploring alternative solutions, applying selected alternatives or solutions, and bringing results as conclusions [16, 17, 18, 19]. Therefore, critical thinking skills can be measured through a person's steps in solving problems. Regarding problem-solving, suggests four steps in solving problems, namely (1) Understanding the problem, (2) Developing a plan, (3) Implementing a plan, and (4) Re-checking [19 - 23].

Someone has a different strategy when preparing what is seen, remembered, and thought about in solving mathematical problems. The strategies used by students in solving problems are influenced by cognitive styles [24]. This is because cognitive style is the habit of individuals in managing and processing information through activities of understanding, thinking, problem-solving, and remembering so that they can determine behavior in learning [25, 26]. Students with different cognitive styles will solve mathematical problem solving using different strategies. Many kinds of cognitive styles have been discussed, but in this study, the cognitive styles to be used are cognitive field dependent (FD) and cognitive field independent (FI) styles. This is because FD cognitive style and FI cognitive style have wide applications in educational problems [27]. The characters of students who have a cognitive style FD experience difficulties in separating information from the contextual environment while students who have an FI cognitive style have fewer difficulties in completing contextual tasks [28, 29, 30].

A lot of research has been done about krith's thinking ability. Research conducted by [31], concluded that the critical thinking skills of prospective teachers are at a very low level. The research conducted by Alwadai [32], concluded that students found the biggest obstacle factor in improving students' critical thinking skills derived from students' own abilities. Kumar & James [33], concluded that the level of critical thinking skills in terms of gender and majors in different courses was based on the indicators of critical thinking skills of the Watson-Glaser model which consisted of five variables, namely inference, assumption, deduction, interpretation, and argumentation. Research conducted by [25], concluded that the level of critical thinking skills was identified as follows: non-critical thinkers, emergent critical thinkers, and developing critical thinkers. Prospective mathematics teachers are still at a low level, namely non-critical thinkers. The research conducted by [34], concluded that the use of problem situations could develop better critical thinking in problem-solving among students.

Based on the research that has been done about critical thinking, no one has researched about describing critical thinking skills based on students' cognitive styles. Therefore, the aim to be achieved in this research is to describe the ability of critical thinking in mathematics in solving system problems with two-variable linear equations (SPLD) based on the students' positive style.

2. Method
The type of research used is qualitative descriptive research. Qualitative descriptive research seeks to explain data that comes from the research subject clearly. The researcher used a qualitative approach to understand the context of the participants in a study discussing the problem in question. Subject collection using purposive sampling technique. Subjects were grouped into cognitive style Field Independent (FI) and cognitive style of Field Dependent (FD) using the cognitive style test of the Group Embedded Figure Test (GEFT). Then one student was selected with the cognitive style of the Field Independent (FI) and one student with the cognitive style of the Field Dependent (FD) who was able to communicate the ideas well in writing and verbally. The selection of subjects according to these criteria was obtained from mathematics teacher information at the school.

In this study, the data collection tools used included tests, interviews, and triangulation. There are two types of instruments used, namely the main and additional instruments. The main instrument in this study was the researchers themselves who acted as planners, data collectors, data analysis, and concluded the results of the study. The tools used in this study were GEFT tests, mathematical problem-solving tests, interview guidelines, and documentation. The category of critical thinking by Ennis [13] which consists of focus, Reason, Inference, Situation, Clarity, and Overview can be related to the problem-solving phase by Polya by pairing each indicator in each Ennis critical thinking category at each stage of Polya problem solving [19].
3. Result and Discussion
This section will discuss the results of the research that has been done. The following are the results of the analysis of answers and interviews of students selected as subjects. The results of students’ answers are cognitive style FD can be seen in Figure 1.

![Figure 1: Results of Student Answers in Cognitive Style FD and FI](image)

Based on the data analysis conducted, it was obtained about the critical thinking process of junior high school students in the cognitive style of the Dependent Field (FD) and junior high school students in cognitive style Independent Field (FI) in solving mathematical problems.

3.1 Critical Thinking of Students in Middle School with Cognitive Style of Field Dependent on Solving Mathematical Problems
The following describes the mathematical critical thinking skills of junior high school students with the cognitive style of the Dependent Field (FD) at each stage of the Polya completion steps.

At the step of understanding the problem, the critical thinking skills of junior high school students with the cognitive style of FD on Focus indicators were able to fulfill all the sub-indicators present in this study. Students with cognitive style FD are able to analyze problems by writing down everything that is known in the problem. Based on the results of the answer sheet, students in cognitive style FD write down what is known by using appropriate sentences in the question in verbal form. Students in cognitive style FD write what is known in the problem as follows: in the Delicious Store, Lia buys 2 pukis + 3 moon cakes = 14,000 and 2 plates + 4 paintings = 8,000. Then at TokoManis, Lia buys 3 moonlight + 6 plates = 10,000 and 6 moonlight + 9 months = 42,000. When interviewed about the reasons for writing what is known to use sentences rather than symbols, students in cognitive style FD reason that it is easier to use sentences than to use symbols. Students in cognitive style FD are familiar with sentences. If using symbols, students in the FD cognitive style feel confused, so they find it difficult to solve the questions given. This is reinforced by the opinion of [35], that students in cognitive style FD have better memories in memorizing verbal information. Based on interviews also, students in the cognitive FD style were able to give reasons that information about buying 2 pieces of cake and 4 pieces of cake for Rp. 8,000.00 and buying 3 pieces of moon cake and 6 cake cakes at a price of Rp. 10,000 were actually not needed in solving the problem. This is considered by students to be cognitive style FD only as a trap in the problem. But students in cognitive style reasoned FD write all that is known in...
the problem in order to be able to distinguish which information is used in the question and which information is not used in the problem.

Students in cognitive style FD can write down what is asked in the questions they are working on by defining key words related to the problem. Students write down what was asked in the question as a keyword, what is the price of 1 piece of cake and the price of 1 moon cake? When interviewed, students in the cognitive style of FD explained that to write down what was asked in the question by reading the question then determine the key question in the question. After students can determine what is known and who is asked in the question, students style cognitive FD determine the strategy that will be used in the problem. Based on the results of the interview, students in the cognitive style FD can mention what strategies should be used in the questions worked on. Students with cognitive style FD mention that the question can be done using the method of elimination, substitution method, and graph method. When asked about these methods, students in cognitive FD style were able to explain methods of resolution using their own sentences. Students in the FD cognitive style also associate problems with mathematical material with other mathematical material. This is evidenced when interviewed, students in cognitive style FD are able to mention elimination, substitution, and integer operations can be used in solving mathematical problems given. Students in cognitive style FD associates a mathematical material depending on the material given by the teacher. This is in accordance with the opinion of [37], that students style cognitive FD; most of the understanding of the material provided is influenced by their environment.

In the step of making a plan, the critical thinking skills of junior high school students with the cognitive style of the Dependent Field (FD) in the Reason indicator were able to fulfill all the sub indicators in this study. Based on further interviews, before completing the question, students are in cognitive style, FD can make hypotheses and test hypotheses with the right reasons. Students with cognitive style FD explain that the question has more than one answer. When asked further, students have cognitive style FD capable of explaining why the question has more than one answer. Students in the FD cognitive style explained by looking at the two equations of 2 months + 3 months light = 14,000 and 6 months light + 9 paintings = 42,000 which are the same equation .. Another explanation, when done using the elimination method between the right and left segments, produces the same is 0. Then if done using the graph method, it produces a graph that is coincidental. According to mathematical concepts, students in the cognitive style of FD argue that the system of linear equations has two sets of solutions. Based on this, students in the cognitive style of FD tend to see a problem globally. This is reinforced by the opinion of [38], that students in cognitive style FD only see a problem globally, so it is difficult to provide information structures that are considered unclear. Based on the interview, when students were asked about how to make a decision using the methods in solving the problem, students in cognitive style FD answered by looking for the evidence in the question. Then students give valid reasons in order to answer the questions in the question correctly. students in the cognitive style FD are able to provide reasons why they can form a system of two-variable linear equations (SPLDV) and also be able to provide a reason why to use the substitution method and elimination in solving the problem. Students are cognitive style FD capable of making good decisions based on information obtained. Students are cognitive style FD only uses information that matches the questions in the question, while information that is not used in solving the problem is ignored.

At the step of implementing the plan, the critical thinking skills of junior high school students with cognitive styles of the Dependent Field (FD) on the Inference, Situation, and Clarity indicators were able to fulfill all sub-indicators present in this study. Students in cognitive style FD are able to think rationally well. When interviewed, students in cognitive style FD are able to make conclusions logically and correctly. The conclusions given by students are in the cognitive style of FD, namely ”so I agree with the answer because 1 piece of painting is priced at 1000 and I for a bright moon cake with a price of 4000”.

When conducting interviews, students have cognitive style FD can give reasons for conclusions made. Students with cognitive style FD give reasons by stating that because the statement of the first equation and the statement of the second equation produce the correct answer, then the conclusion is ”so I agree with the answer because 1 painting price of 1000 and I of bright moon cake price of 4000” is the conclusion right. Based on this, it can be said that students style cognitive FDs longer in making
conclusions because they are accustomed to using verbal language. This is reinforced by the opinion of [34], that students in cognitive style FD tend to spend more time in solving a mathematical problem because they use verbal language.

When students style, cognitive FDs are told to prove answers using the graph method and elimination method, students in the FD cognitive style feel confused. But students in cognitive style FD know that the SPLDV produces a graph that coincides if it is worked on with the graph method. Students with cognitive style FD also know that when done using the elimination method, between the right and left segments produce the same value, which is 0. Therefore, students in the cognitive style FD state that the SPLDV has many sets of solutions. This proves that students in cognitive style FD are not accustomed to learning mathematics, but cognitive style students FD tend to get used to learning about social problems [39, 40, 41].

Based on the interviews conducted, students in the style of cognitive FD were able to provide other answers to the problem. The description of other answers from FD students is: students in cognitive style FD find the price of (pukis, moonlight) = \{1,090,3,940\}. So if done using a substitution method, then input (pukis, moonlight) = \{1,090,3,940\} togetherness (1), obtained:

\[
\begin{align*}
&2 \text{ pukis} + 3 \text{ moonlight} = 14,000 \\
&= 2 \times (1,090) + 3 \times (3,940) \\
&= 2.180 + 11,820 \\
&= 14,000 \text{ (correct)}
\end{align*}
\]

And enter (pukis, moonlight) = \{1,090,3,940\} togetherness (2), obtained:

\[
\begin{align*}
&6 \text{ months} + 9 \text{ months of painting} = 42,000 \\
&= 6 \times (1,090) + 9 \times (3,940) \\
&= 6,540 + 35,460 \\
&= 42,000 \text{ (correct)}
\end{align*}
\]

In the step of checking again, the critical thinking skills of junior high school students with cognitive styles of the Dependent Field (FD) on the Overview indicator were able to fulfill all sub-indicators present in this study. Students in the cognitive style of FD are able to believe the truth of the answers that have been obtained. When conducting interviews, students have the style of cognitive FD self-confidence that the answers obtained are the correct answers. Students with cognitive style FD can convince researchers by answering each question given. Students in cognitive style FD also checks the answers that have been made. Student cognitive style reasoned FD that checks it to avoid mistakes in every step of the problem. Students in cognitive style FD check the answer sheet starting from the first step to the final step.

3.2 Critical Thinking of Students in Middle School Cognitive Field Independent (FI) in Solving Mathematical Problems

The following is explained the mathematical critical thinking skills of junior high school students with cognitive style Field Independent (FI) at each stage of the Polya completion steps. At the step of understanding the problem, the critical thinking ability of junior high school students with cognitive style Field Independent (FI) on Focus indicators was able to fulfill all sub-indicators present in this study. Students in the FI cognitive style are able to analyze problems by reading the questions write down all that is known in the problem. Cognitive-style students FI defines key words related to problems faced by using mathematical symbols. This is in accordance with the opinion of [42, 43] when students have a cognitive FI style given a problem, they will tend to have a higher ability to determine the main ideas implied and aimed at using keywords that are considered important. Students in the cognitive style FI also write what is known in accordance with the sentence in the problem and then change into mathematical symbols. Students in the FI cognitive style write down what is known in the problem as follows: in the Delicious Store, Lia buys 2 pukis + 3 moon light cakes = 14,000 and 3 plates + 4 paintings = 8,000. Then students in cognitive style FI changed the two equations into mathematical symbols, namely \(2p + 3t = 14000\) and \(2l + 4p = 8000\). Then at TokoManis, Lia buys 3 moonlight + 6 plates = 10,000 and 6 moonlight + 9 months = 42,000. Students with cognitive style FI also change the two equations into mathematical symbols, namely \(3t + 6l = 10000\) and \(6p + 9t = 42000\). When interviewed about the reasons for writing down what was known by changing into mathematical symbols, students
style cognitive FI reasons that it is easier to work on mathematical problems using mathematical symbols. Students with cognitive style FI are used to using mathematical symbols. This is reinforced by the results of research from [44], that students in the cognitive FI style can change algebraic ideas from narrative questions to mathematical symbols and variables.

Based on interviews, similar to students with cognitive style FD, students in cognitive style FI style were also able to give reasons that information about buying 2 pieces of cake and 4 pieces of painting for Rp. 8,000.00 and buying 3 moon cake and 6 lemper cakes with the price of IDR 10,000.00 is actually not needed in solving the problem. This was considered by students to be a cognitive FI style just as a trap in the problem. But students in the cognitive style FI reasoned to write down all that is known in the problem in order to be able to distinguish which equations are used in which questions and equations are not used in the problem. This is reinforced by [35, 39], that the detail and analytical way of presenting information in the problems faced are very beneficial for students in the FI's cognitive style because students in cognitive style FI tend to be analytical.

Students in the cognitive FI style can write what is asked in the questions they are working on. The student writes what is asked in the question is, "do you agree with the answer lia ?. When interviewed, students in the cognitive style, FI explained that to write down what was asked in the question by reading the questions in the last part of the sentence. As with students with cognitive style FD, students in the cognitive style FI can also state what strategies should be used in the problem being worked on. Students in the cognitive style FI mentioned that the problem could be done using the elimination method, substitution method, and graph method. When asked about these methods, students in the cognitive FI style were able to explain methods of completion using their own sentences. Students with cognitive style FI can also link problems with some other mathematical material. When interviewed, students in the cognitive FI style linked the material to linear variables of two variables, function domains, function graphs, and one-variable linear equation systems. Students in the cognitive style FI are able to use these materials in solving the problem.

In the step of making a plan, the critical thinking skills of junior high school students with cognitive style Field Independent (FI) in the Reason indicator were able to fulfill all sub-indicators present in this study. Based on further interviews, before completing these questions, students are cognitively styled FI can make hypotheses and test hypotheses with the right reasons. Students in the cognitive style FI explained that the question had more than one answer. When asked further, the student has a cognitive FI style capable of explaining why the question has more than one answer. Students with FI cognitive style explained by looking at the two equations 2p + 3t = 14,000 and 6p + 9t = 42,000 which are the same equation. In addition, students can sketch graphs from the system of linear equations of these two variables. Based on the graph sketch obtained that between the lines of the first equation and the second equation produces a line that coincides. Then when done using the elimination method between the right and left segments produce the same value, which is 0. From the three proofs, according to the mathematical concept, students have obtained the cognitive style FI that the two-variable system of linear equations has many sets of solutions.

Based on the interview, when students were asked about how to be able to make a decision using these methods in solving the problem, students in the cognitive style FI answered by looking for the evidence in the problem. Then students give valid reasons in order to answer the questions in the question correctly. Students in the cognitive style FI are able to make decisions on arguments by selecting relevant information that is appropriate to use in solving problems. Students in the FI cognitive style are able to choose the information needed in making decisions so that problem solving can be solved easily.

At the step of implementing, critical thinking skills of junior high school students with cognitive style Field Independent (FI) on the Inference, Situation, and Clarity indicators were able to fulfill all sub-indicators present in this study. Students in cognitive FI style are able to think rationally and reflectively. Cognitive-style students FI can reason by writing conclusions "so I agree with the answer that the price of 1 painting cake is 1000 and the price of 1 pastry cake is 4000. Then students in cognitive FI style can think reflective by giving logical reasons based on the evidence relevant to conclusions that have been made previously. This is in accordance with the opinion of [43] when students have a
cognitive FI style given a problem, then they will tend to have a higher ability to make conclusions accompanied by relevant evidence.

Students in the cognitive FI style are able to provide reasons for conclusions that have been obtained. When interviewed, students in the cognitive FI style can provide reasons for conclusions made. Students with cognitive style FI give reasons by stating that because the statement of the first equation and the statement of the second equation produce the correct answer, then the conclusion is about "so I agree with the answer because 1 painting price of 1000 and I of the bright moon cake for 4000" is the conclusion right.

When students style cognitive FI told to prove answers using the graph method and elimination method, students in the cognitive style FI can explain correctly. Students with cognitive style FI can also explain that when done using the elimination method, between the right and left segments produce the same value, which is 0. Therefore, students in the cognitive style FI state that the SPLDV has many sets of solutions. Based on this explanation, it is said that students in the cognitive style FI tend to be detailed in making excuses. This is evidenced by students' cognitive style FI paying attention to all aspects when making excuses from conclusions that have been made. This is reinforced by the opinion of [45], that students in the FI cognitive style tend to be more focused and disciplined in making the right reasons by being marked by longer attention before making excuses.

Based on the interviews conducted, students in the cognitive FI style were able to provide other answers to the problem. The description of other answers from students in the cognitive style of FI, namely: suppose \( (p, t) = \{1,750,3,500\} \). So if done using a substitution method, then input \( (p, t) = \{1,750,3,500\} \) togetherness (1), is obtained:

\[
2p + 3t = 14,000 \\
= 2 (1,750) +3 (3,500) \\
= 3,500 + 10,500 \\
= 14,000 \text{ (correct)}
\]

And enter \( (p, t) = \{1,750,3,500\} \) togetherness (2), obtained:

\[
6p + 9t = 42,000 \\
= 6 (1,750) +9 (3,500) \\
= 10,500 + 31,500 \\
= 42,000 \text{ (correct)}
\]

In the step of checking again, the critical thinking skills of junior high school students with the Field Independent (FI) cognitive style on the Overview indicator were able to fulfill all the sub-indicators in this study. Students in the cognitive FI style are able to believe the truth of the answers that have been obtained. When conducting interviews, students style the cognitive FI sure that the answers obtained are the correct answers. This is evidenced by students' cognitive style FI able to explain based on logical reasons from answers that have been obtained. Students in cognitive style FI also checks the answers that have been obtained. But students in the cognitive FI style only check the final answer. This is because students have reasoned cognitive FI style so as not to waste time. This is because students have cognitive style FI feel confident that the steps that have been done are in accordance with the rules of mathematics. But when students style cognitive FI are told to repeat the steps to work, students can explain it from the initial steps to the steps to find answers. This is in accordance with the results of [46] research, that students with the cognitive style of FI practice metacognition well on the answers that have been obtained.

From the explanation above, even though students are cognitively styled FD and students in cognitive style FI have the same critical thinking skills, but in answering math questions, students have a cognitive FI style more complete answer than students with cognitive style FI. This is reinforced by [43, 47], that students in the cognitive FI style tend to get higher results than students in cognitive FD style in solving mathematical problems. Furthermore, according to [45], found that students in cognitive style FD were more low achievers in basic science and students in cognitive style FI were more interested in mathematics. In compiling the assignment, FI students are more successful in doing tasks deductively while students in cognitive style FD are more successful in doing tasks inductively. This is reinforced by the opinion of [48], that students with the FI cognitive style tend to be more successful in deductive assignments, while students with the FD cognitive style work better on inductive tasks. Based on the
mathematical questions given, it was proven that students in the cognitive FI style were more successful in completing the task. This is because the math assignment is a deductive form task. Therefore, teaching activities and the selection of assignments for students must be clarified because students have different cognitive styles [43, 49]. Furthermore, according to [41], adjusting the problem given will be beneficial for students in the cognitive style of FI and students in cognitive style FD.

4. Conclusion

Based on the data analysis and discussion of the study, it can be concluded that junior high school students who have the cognitive style of Dependent (FD) and junior high school students who have the Field Independent (FI) cognitive style in Polya completion steps have good mathematical critical thinking skills. This is evident in the four steps of Polya settlement both students in cognitive style FD and students in cognitive style FI have been able to meet the six indicators of critical thinking skills namely Focus, Reason, Inference, Situation, Clarity, and Overview. In the step of understanding the problem of sub-indicators that arise from critical thinking skills are students can determine what is known in the problem, students can determine the questions in the question, and students can determine the strategies to be used in the problem. In the step of making a sub-indicator plan that arises from critical thinking skills, students can test hypotheses based on the right reasons, and students can provide reasons based on relevant evidence in making a decision. At the step of implementing the sub-indicator plan that emerges from critical thinking skills is students can make conclusions appropriately, students can provide reasons to reinforce conclusions that have been made, students can choose all the information needed based on the existing situation on the problem at hand, students are able to provide further explanations related to the answers to the questions, and students are able to provide other answers to the answers in the questions. At the step of checking the sub-indicators that arise from critical thinking skills is to check again from each step of the decision that has been taken.

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