Analysis of Students' Errors in Solving Mathematical Problems Based on Field Independent and Field Dependent Cognitive Styles

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Abstrak

Kesalahan siswa dalam menyelesaikan soal matematika masih menjadi permasalahan yang sering dijumpai dalam proses pembelajaran. Faktor gaya kognitif, seperti Field Independent (FI) dan Field Dependent (FD), diduga turut memengaruhi cara siswa memahami dan menyelesaikan masalah matematika. Berdasarkan hal tersebut, penelitian ini bertujuan untuk menganalisis kesalahan yang dilakukan oleh siswa saat mengerjakan soal matematika dengan memperhatikan gaya kognitif mereka, yaitu Field Independent (FI) dan Field Dependent (FD).Penelitian yang dilaksanakan di SMAN 1 Besuk ini menggunakan metode deskriptif kualitatif, dan melibatkan enam siswa yang dipilih berdasarkan hasil tes Group Embedded Figure Test (GEFT) mereka. Data dikumpulkan melalui tes GEFT, tes pemecahan masalah dan wawancara, kemudian dianalisis menggunakan metode Analisis Kesalahan Newman. Temuan penelitian menunjukkan bahwa siswa dengan gaya kognitif FI biasanya melakukan kesalahan dalam keterampilan proses (17,13%) dan dalam menyusun jawaban akhir (20,00%). Sebaliknya, siswa dengan gaya kognitif FD sering melakukan kesalahan dalam transformasi masalah (45,71%), keterampilan proses (57,14%), dan penulisan jawaban akhir (65,71%). Beberapa faktor yang menyebabkan kesalahan ini meliputi kurangnya ketelitian, terburu-buru, salah menafsirkan informasi yang tersirat dalam soal, serta tidak memeriksa kembali jawaban akhir. Kesimpulan dari penelitian ini menunjukkan bahwa gaya kognitif mempengaruhi jenis dan frekuensi kesalahan yang dibuat oleh siswa dalam menyelesaikan soal matematika. Hasil ini memberikan pentingnya bagi pendidik untuk meningkatkan strategi pembelajaran yang lebih sesuai dengan gaya kognitif siswa.

Keyword: kesalahan siswa, pemecahan masalah, gaya kognitif, Field Independen, Field Dependent.

Abstract

Errors made by students in solving mathematical problems remain a common issue encountered in the learning process. Cognitive styles, such as Field Independent (FI) and Field Dependent (FD), are believed to influence how students comprehend and solve mathematical problems. Based on this premise, this study aims to analyze students' errors in solving mathematical problems by taking into account their cognitive styles, namely Field Independent (FI) and Field Dependent (FD). This research was conducted at SMAN 1 Besuk using a qualitative descriptive method and involved six students selected based on the results of the Group Embedded Figures Test (GEFT). Data were collected through the GEFT, problem-solving tests, and interviews, then analyzed using Newman's Error Analysis Procedure. The findings show that students with an FI cognitive style typically made errors in process skills (17.13%) and in constructing final answers (20.00%). In contrast, students with an FD cognitive style frequently made errors in problem transformation (45.71%), process skills (57.14%), and final answers (65.71%). Several factors contributing to these errors include lack of accuracy, rushing through tasks, misinterpreting implicit information in the problems, and failing to recheck final answers. The study concludes that cognitive style influences both the types and frequency of errors students make when solving mathematical problems. These findings highlight the importance for educators to develop instructional strategies that are better aligned with students' cognitive styles to enhance learning effectiveness.

Keyword: student errors, problem solving, cognitive style, Field Independent, Field Dependent.

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INTRODUCTION

Mathematics plays an essential role in shaping students' affective, cognitive, and psychomotor abilities. It serves not only as the foundation for technological advancement but also as a means to develop analytical thinking and practical problem-solving skills. Through numeracy, students learn to interpret information and address real-life problems using mathematical reasoning. These competencies are fundamental for preparing students to meet the demands of the 21st century (Cynthia & Sihotang, 2023; Djeni & Nasikhah, 2022; Lestari et al., 2023, 2024; Pratama et al., 2020)

It is unfortunate that the results of the Programme for International Student Assessment (PISA) in 2022 showed that only around 18% of students in Indonesia were able to achieve level 2 or higher in mathematics (Wardani et al., 2022). This figure is far different from the average of OECD countries which reached 69% (Lestari & Lestari, 2022). The average math score of Indonesian students is 366, a significant difference of 106 points compared to OECD countries which recorded an average of 472. Almost no students from Indonesia managed to reach level 5 or 6, illustrating a lack of ability in modeling and finding solutions to complex problems (Sutama et al., 2020)This less than satisfactory achievement indicates that the mathematics teaching and learning process in Indonesia is still struggling with a number of complex problems, especially in terms of focusing on problem-solving skills (Nabilah & Triyana, 2023).

Various studies indicate that student errors when solving mathematics problems are a crucial factor that influences low learning achievement (Amir and Risnawati in Yolandita, 2021). These errors are not only related to the use of formulas, but also related to understanding the problem, changing information into a mathematical model, and presenting the final answer (Wijaya & Siswono, 2021). According to Moru (Kanata et al., 2022), error evaluation is not only important to improve educators' understanding, but also helps in understanding relevant learning theories.

Students' ability to solve problems is influenced by their cognitive style, as evidenced by various studies indicating that cognitive characteristics shape how individuals process information, interpret problems, and apply strategies in mathematical contexts. Cognitive style refers to the way students organize, manage, and process various information (Mahfiroh et al., 2021). There are two types of cognitive styles that are often used as research subjects, namely Field Independent (FI) and Field Dependent (FD). Students who have an FI style are usually more analytical and independent, while those who have an FD style tend to be more influenced by the surrounding situation (Judrah et al., 2024). These variations in cognitive styles can impact students' understanding, strategies, and final outcomes in solving problems (Khusna & Ulfah, 2021).

Although there has been a lot of research on cognitive styles, research that specifically links FI and FD cognitive styles with error types in solving mathematical problems is still rare (Erviandita et al., 2023; Firestone, 1977). However, a deeper understanding of the relationship between cognitive styles and different types of errors is essential for designing more efficient and differentiated learning processes.

In addition, documentation of student work results shows a tendency for repeated errors, especially in the stages of understanding and transforming information into mathematical models. These initial findings reinforce the importance of research that analyzes student errors based on Field Independent and Field Dependent cognitive styles, so that teachers can understand the differences in student characteristics and adjust learning approaches more effectively.

Based on the preceding information, the researcher aims to carry out a study titled "Analysis of Student Errors in Solving Mathematical Problems Based on Field Independent and Field Dependent Cognitive Styles. " Although earlier research has examined cognitive styles and students' academic performance individually, there remains a deficiency in comprehensive studies that connect specific cognitive styles specifically, Field Independent and Field Dependent with the mistakes made by students in solving math problems. This research intends to address that shortcoming by identifying the types of errors linked to each cognitive style. It is anticipated that the results will aid in crafting more focused and efficient learning approaches that cater to students' cognitive traits, ultimately improving the standard of mathematics teaching.

METHOD

This study uses a descriptive qualitative approach which was chosen because it allows researchers to explore in depth the types of student errors and their causes, based on the cognitive characteristics of each student (Lestari et al., 2024). Data were obtained from students' spoken and written words, as well as documentation observed in detail (Rahayu & Soleha, 2023).

In this research, the investigator utilized the analytical framework suggested by Miles and Huberman, which includes three components: reducing data, presenting data, and making conclusions or validating them (Ghazali, 2021).

The subjects of the study were students of class X IPA 1 at SMAN 1 Besuk, who were determined purposively based on the results of the Group Embedded Figure Test (GEFT) and preliminary analysis of the answers to the problem-solving test. This selection took into account the variation in the level of complexity of the errors that appeared as well as representatives of different cognitive styles, namely Field Independent (FI) and Field Dependent (FD). Each cognitive style was represented by three students who had fairly complex, complex, and very complex error categories, so that the total number of research subjects was six students.

To strengthen data collection, researchers utilized several tools: GEFT, a geometry problem-solving test in essay form, and interview guidelines. The GEFT tool serves to identify students' thinking styles with the criteria: a score of 0–11 for FD and 12–18 for FI. The problem-solving test was designed to find the type of error, while in-depth interviews aimed to explore the reasons behind the error.

The instrument has been tested for its validity through construct and content validity by experts (mathematics teachers and lecturers), with an average value of more than 4.00 indicating that this instrument is valid (see Table 1). Reliability testing is carried out by calculating internal consistency using the Cronbach Alpha formula (for written tests) and inter-rater tests (for interviews), so that it can be ensured that the instrument used is reliable.

Table 1. Recapitulation of Learning Validation Results by Experts

No	Objects being assessed	Average Value of Validation Results	Level Validation
1	GEFT Test (Group Embedded Figure Test)	4.14	Valid
2	Math Problem Solving Test	4.06	Valid

Based on Table 1, the average total validity of learning is in the interval: $3 \leq Va < 4$. Based on the validity criteria, it can be said that the learning developed is "Valid".

The data were analyzed using a model developed by Miles and Huberman, which is divided into three steps: data simplification, data depiction, and drawing conclusions or verification. The error analysis process was carried out by following Newman's procedure which consists of five steps: (1) errors in reading, (2) errors in understanding, (3) errors in changing, (4) errors in process skills, and (5) errors in the final answer. Data validity was strengthened through triangulation techniques using various sources (tests, interviews, and observations), re-examination of interview results, and discussions with colleagues to prevent bias in interpretation.

In each FD and FI group, students were grouped into three categories according to the errors they made, namely fairly complex, complex, and very complex errors. Furthermore, 1 student was selected from each category based on the type of error, so that the total subjects in this study were 6 students. Their errors were then analyzed using the Newman procedure and continued with interviews. The conclusions in this study were obtained from a comparison between the analysis of the results of the work and interviews conducted with the subjects, making it possible to identify errors and their causes in solving problems related to geometry material.

RESULTS AND DISCUSSION

The results of the researcher's initial interview with the mathematics teacher at SMAN 1 Besuk revealed that many grade X students immediately answered questions without understanding the context, even using inappropriate formulas. Observations and documentation of student assignments also showed patterns of errors that often occurred, especially during the stages of understanding and transforming problems. These findings emphasize the importance of research that emphasizes the relationship between cognitive style and the types of errors made by students.

Figure 1. Initial observation of class X at SMAN 1 Besuk

The results of initial observations in class also showed variations in approaches to solving problems, where some students tended to be able to solve problems independently but often made process errors, while other students seemed confused and needed guidance to start solving.

In determining the subjects for this study, the researcher initially conducted a GEFT test to determine the grouping of students based on their cognitive style, which is classified as Field Independent or Field Dependent.

Table 2. GEFT Test Results

No	Name	Gender	Amount	Category
2	S2	Male	2	*Strongly FD*
27	S27	Male	3	*Strongly FD*
28	S28	Male	5	*Strongly FD*
22	S22	Male	5	*Strongly FD*
20	S20	Female	6	*Strongly FD*
13	S13	Male	6	*Strongly FD*
8	S8	Male	7	*Strongly FD*
11	S11	Male	7	*Strongly FD*
23	S23	Female	7	*Strongly FD*
10	S10	Female	7	*Strongly FD*
26	S26	Male	8	*Strongly FD*
1	S1	Male	8	*Strongly FD*
17	S17	Male	9	*Slightly FD*
9	S9	Female	9	*Slightly FD*
21	S21	Female	9	*Slightly FD*
16	S16	Male	10	*Slightly FD*
14	S14	Male	10	*Slightly FD*
12	S12	Female	10	*Slightly FD*
5	S5	Female	11	*Slightly FD*
3	S3	Male	11	*Slightly FD*
24	S24	Female	11	*Slightly FD*
18	S18	Male	12	*Slightly FI*
4	S4	Female	12	*Slightly FI*
7	S7	Female	13	*Slightly FI*
19	S19	Male	14	*Slightly FI*
25	S25	Female	16	*Strongly FI*
15	S15	Male	16	*Strongly FI*
6	S6	Male	17	*Strongly FI*

The following is a summary of the results of the GEFT test which was used to classify students according to their cognitive style:

Table 3. Percentage of Students' Cognitive Style Results

Cognitive Style	Frequency	Percentage
Field Dependent	21	75%
Field Independent	7	25%
Amount	28	100%

Most students, namely 75%, tend to have an FD thinking style, while the remaining 25% adopt the FI style. After identifying students with Field Independent and Field Dependent cognitive styles, the researcher gave 5 problem-solving test questions in essay form. Furthermore, the scores from the GEFT test and students' problem solving were checked for each student. Based on students' answers on the GEFT test, the researcher could find out the cognitive style possessed by the students. The results of the GEFT test showed that there were 7 students who had an FI cognitive style and 21 students who had an FD cognitive style. After the GEFT test, the researcher continued by giving a Problem Solving test. From the results of this test, 3 students were found with an FI cognitive style who were used as research subjects, and for students with an FD cognitive style, 3 students were also selected as research subjects.

Table 4. Number of errors of students with FI and FD cognitive styles

Category	FI	FD
Very Complex	2	2
Complex	4	11
Quite Complex	1	8

The problem-solving test in geometry revealed a variety of errors made by students. From the test results and initial analysis, six students were selected as research subjects to represent the variation in error complexity.

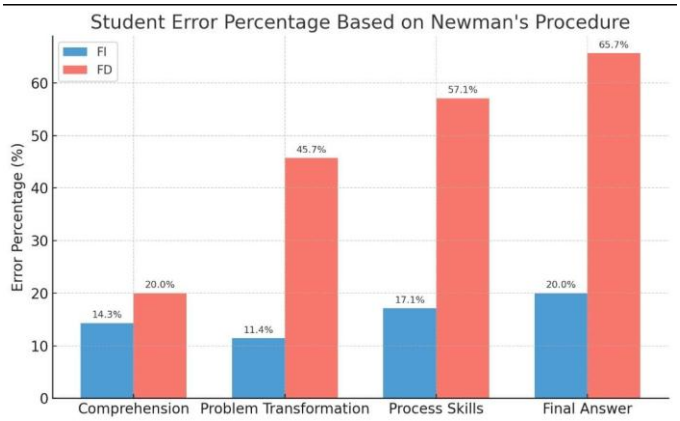

Figure 2. Percentage of student errors based on Newman's procedure

Based on the percentage of student errors in the image above, the graph shows that the average error of FD students (42.68%) is higher than that of FI students (12.97%), especially at the transformation, process skills, and final answer stages. It can be seen that the average percentage of FD errors is higher than the average percentage of FI errors. In the FI subject, errors most often occur in process skills and writing final answers. Meanwhile, for the FD subject, the percentage of common errors is mainly seen in transformation errors, process skills, and writing final answers.

Based on the results of the evaluation conducted in class X IPA 1 SMAN 1 Besuk in solving Problem Solving type questions regarding geometric solids, a series of interviews were conducted with 6 research participants. The participants consisted of FI group subjects with fairly complex errors (S21), FI group subjects with complex errors (S25), FI group subjects with very complex errors (S19), FD group subjects with fairly complex errors (S9), FD group subjects with complex errors (S26), and FD group subjects with very complex errors (S21). The results of the previous analysis showed that there were no reading errors among students from the FI and FD groups, although some students read quickly.

The errors experienced by students from the FI and FD groups in understanding the questions were the lack of depth of understanding of the questions and errors in writing variables. In addition, students from both groups also did not include information that was known and asked. However, the FI group, although they did not record this information, were still able to re-explain the problem in the questions in their own words. On the other hand, the FD group, although they recorded the known information, when retelling the contents of the questions, they were still less accurate. This error in understanding was shown by S25 and S19 from the FI group as well as S9, S26, and S21 from the FD group.

Mistakes in understanding the problem often arise because students who only glance at a problem may prematurely assume it is difficult, leading to a lack of motivation to explore it further. This tendency results in decreased accuracy in subsequent steps. This observation is supported by interview data in which students admitted feeling overwhelmed at first glance and chose not to reread or analyze the problem in depth. In addition, students are also in a hurry to finish their assignments quickly. Mistakes made by students from the FI and FD groups in problem transformation include mistakes in writing mathematical models, writing mathematical models but incompletely, and ignorance of the steps that need to be taken. Mistakes in problem transformation were made by S21, S25, and S19 from the FI group and S9, S26, and S21 from the FD group. The factors causing the mistakes in transformation are students' panic, so they rush in working on the problem, do not read the problem thoroughly, assume that recording what is known and what is asked in the problem is not important, and lack of understanding of the information implied in the problem. Mistakes by the FI and FD groups in process skills include mistakes in performing mathematical operations, only recording part of the solution process, and having difficulty in continuing the solution process.

Errors in process skills occurred in students S25 and S19 from the FI group, as well as S9, S26, and S21 from the FD group. Factors that cause errors in these process skills are students' lack of understanding of the steps that need to be taken to work on the questions, lack of accuracy in calculations, and limited time when completing the task. Based on the analysis that has been done previously, it was found that the FI and FD groups made errors in writing the final answers, such as not including the final answer, making mistakes when writing the final answer, the final answer not in accordance with the existing question, not concluding the final answer, and not rechecking the final answer written. The subjects who made errors in writing the final answer were S21, S25, S19 from the FI group and S9, S26, S21 from the FD group. The causes of errors in writing the final answer were students' lack of concentration, carelessness, rushing, and no checking of the final answer.

Based on the discussion above, it can be seen that individuals from the FI group experienced difficulties in understanding problems, errors in changing problems, errors in process skills, and errors in compiling final answers. The three individuals from the FI group experienced errors during the final answer writing stage. The results of the FI group's error percentage showed that errors at the process

skills stage reached 17.14% and at the final answer writing stage were 20.00%. Factors causing errors in FI subjects include lack of calm when answering questions, rushing to complete, minimal understanding of the steps that need to be taken to complete the questions, lack of accuracy in calculations, limited time when completing, and not rechecking the answers that have been written. This finding is supported by research from Selvinia Putri, Asmaul Husna, (2021)which shows that students with FI cognitive style tend to experience errors at the process skills stage and the answer writing stage.

To explore the types of errors made by students, in-depth interviews were conducted with six research subjects. The analysis was conducted based on the stages of Newman's procedure.

1. Misunderstanding

   Errors in the understanding stage occur when students cannot interpret the information from the question comprehensively. FD students usually record information but are less precise when re-explaining the contents of the question. On the other hand, FI students, although they do not record thoroughly, can logically re-explain the contents of the question (Khusna et al., 2021).

2. Transformation error

   Students face challenges in creating mathematical models of the problems presented. Some students are in a hurry and cannot grasp information that is not directly stated. FD students make more mistakes at this stage, for example using the wrong or incomplete model (Wibawa et al., 2023).

3. Process skills errors

   Errors in process skills occur when students do not follow the solution steps consistently, make mistakes in mathematical operations, or only write down part of the process. Often, this is caused by a lack of accuracy and time pressure during the exam (Dinda Amalia and Windia Hadi, 2020).

4. Final answer error

   Many students do not recheck the final results, so the answers do not match the context of the question. FD students have a higher tendency to skip this stage, while FI students tend to check even though they are not completely accurate (Wati et al., 2023).

5. Cause of error

   Based on interviews, the main causes of errors include: the habit of rushing, being less thorough, not understanding implied information, and a lack of reflective thinking strategies. This is in accordance with the findings of Kanata et al (2022) that the FD cognitive style is more dependent on external context, while FI is more analytical.

The results of research conducted by Dinda Amalia & Windia Hadi, (2020) revealed that there are several factors that cause errors in FI. Among these factors are confusion in understanding the steps to work on the problem, running out of time, lack of accuracy, rushing when working, not having time to draw conclusions, and being less accustomed to formulating conclusions. In the FD group, all three subjects made errors at all stages, including reading the problem, understanding the problem, making transformations, process skills, and writing the final answer. Based on the percentage of errors, the FD group showed that the three largest errors occurred at the problem transformation stage of 45.71%, process skills of 64.67%, and writing the final answer of 65.71%. The errors that occurred in the FD group were caused by a lack of calm when working on the problem, rushing to finish immediately, not understanding the intent of the problem, not knowing the demands implied in the problem, difficulty in retelling the contents of the information in the problem, not knowing the steps required for solving, not knowing the calculations, not knowing the time to complete, and not rechecking the final answer that had been written. This is supported by research conducted by Authority (2023)which reveals that students with FD cognitive style often make mistakes, such as mistakes in changing problems, mistakes in process skills, and mistakes in writing final answers. According to the research results A. Wibawa and friends (2023), factors that cause errors in students with FD cognitive style include lack of accuracy, rushing, not being careful in carrying out multiplication operations, the consequences of previous errors, and lack of habit in summarizing conclusions.

Students from the FD group showed a higher frequency of errors compared to those from the FI group, as evidenced by the average error percentages: 12.97% for FI students and 42.68% for FD students. This result aligns with (Wati et al., 2023), who found that students with a Field Dependent cognitive style tend to make more mistakes than those with a Field Independent style. Similarly, (Kanata et al., 2022) reported that FI students possess a deeper conceptual understanding and are more capable of interpreting information from mathematical problems in greater detail, resulting in fewer errors. These findings are further supported by earlier cognitive theory proposed by Witkin (as cited in Thomas, 1990), which emphasized that FI students are better equipped to handle analytical and abstract tasks, such as those in science and mathematics, due to their ability to work independently of surrounding contexts. In contrast, FD students tend to rely on external cues and are more socially oriented, making them better suited to tasks involving interpersonal interaction and memorization, such as in social studies or language learning (Wang & Kao, 2022). The convergence of these studies highlights a consistent pattern: cognitive style significantly impacts student performance in mathematics, particularly in problem-solving contexts. However, research examining this relationship in the context of detailed error analysis especially using frameworks like Newman's procedure remains limited. This study contributes to filling that gap by providing empirical evidence on the specific types and frequencies of errors committed by students with different cognitive styles.

CONCLUSION

Based on data analysis and discussion of errors made by students with Field Independent (FI) cognitive style, several types of errors were identified, namely errors in understanding questions, errors when changing questions, deficiencies in process skills, and errors in compiling final answers. Of the four types of errors, the most common are errors related to process skills and final writing. Meanwhile,

for students with Field Dependent (FD) cognitive style, the types of errors seen include errors in understanding questions, errors in question transformation, lack of process skills, and errors in compiling final answers. Among these errors, the most common are errors in question transformation, process skills, and writing final answers. The number of errors made by students with FD cognitive style is greater than that of students with FI cognitive style.

The causes of errors in the FI group include restlessness when working on the questions, rushing to complete them, not understanding the steps to be taken to answer the questions, errors in determining the mathematical model, lack of accuracy when performing arithmetic operations, insufficient time to complete the task, and not rechecking the answers given. Meanwhile, the reasons for mistakes among students in the FD group include not paying close attention to questions, a lack of concentration while completing tasks, hurrying to finish quickly, misunderstanding the meanings of questions, challenges in interpreting implicit information, limited grasp of problem-solving procedures, incorrect calculations, trouble in developing mathematical models, poor time management, and not reviewing their final answers. These results carry significant practical importance for teachers and curriculum developers. Teaching methods should include more structured guidance, detailed modeling, and chances for repeated practice to aid students with a Field Dependent cognitive style. Moreover, using scaffolding techniques and visual supports may assist these learners in processing and understanding information better. Looking ahead, this emphasizes the significance of adopting cognitive-based personalized learning strategies. By adjusting teaching to match students' cognitive traits, educators can enhance comprehension, minimize systematic mistakes, and encourage fairer learning results in mathematics education.

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