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Students' Errors in Solving PISA-Based Mathematical Problems Viewed from Cognitive Style

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ABSTRACT

Students' mathematical literacy is influenced by cognitive style which refers to individual variations in processing different subcomponents for the three main categories of cognitive processes which is perception, memory, and cognition. The difference of students' characteristic in processing the information affects how they solve the question. This study aims to identify students' errors in solving PISA-based mathematical problems based on Newman's theory. This study used case study method which was carried out in one of the junior high schools in North Bengkulu Regency, Bengkulu Province, involving 32 students of class 8th in the 2022/2023 academic year who had studied number pattern. The subjects in this research were chosen purposively, there were 3 Field Dependent (FD) students namely LFD, MFD, and HFD. Data in the research were collected using the Group Embedded Figure Test, mathematical literacy tests which is developed according PISA-based level, and interviews. The result showed that when solving problems, earlier stage of error affected another error which led to a incorrect sollution. According to newman errors, the dominant errors experienced by LFD student when solving mathematical literacy problems were comprehension errors, process skill errors, and encoding errors. The dominant errors experienced by MFD students were transformation errors and encoding errors. Furthermore, the dominant errors experienced by HFD students were comprehension errors and transformation errors.

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Introduction

Mathematical problem is not only about counting and doing the mathematical operation, but more than that it also requires strategy and reasoning to get the correct solulution. While solving mathematical problem, students will try to understand the given information,

transforming information to mathematical symbols and terms, using their ability to use the concept, fact, and procedure to solve the problem, and then interpret the result they have obtained. That process is called as mathematical literacy (OECD, 2019). Each student will have different perspective and strategies while solving the mathematical problem which is was influenced by cognitive style. Miller viewed cognitive style as individual variations in processing different subcomponents for the three main categories of cognitive processes which is perception, memory, and cognition (Zhang & Sternberg, 2005). The results of the study revealed that the way students use their mathematical literacy will be different according to their type of cognitive style, which is field dependent or field independent (Rum & Juandi, 2023). Field-independent students were able to use representational and reasoning skills appropriately and were able to express solutions in a structured and systematic manner using their own language. Meanwhile, field-dependent students were less able to use representational skills and less analytical in solving math problems. Furthermore, field-dependent students tended to use the same language as the problem.

The different characteristics of field-dependent students and field-independent students in applying their mathematical literacy influenced the results of students' work in solving mathematical problems using the PISA model. When answering PISA-style questions, participants generally made mistakes in three areas: comprehension, transformation, and writing or encoding (Pranitasari & Ratu, 2020). In addition, in the process skills error type, the subject did not know the procedures or steps in identifying the problem in the question, making the same error which made mistake in reading the question and failed to write important information and spot the question posed (Susanti, 2019).

According to several research, FD students tend to make many mistakes than FI students (Son et al., 2021; Virnanda et al., 2025). Students with different cognitive style will have different tendencies and strategies when solving mathematical problem that lead them to different type of error. Specifically, Son et al. (2021) stated that the majority of FD students made mistakes of any types, but particularly in the area of procedural, conceptual, and factual errors. In addition, Ratnaningsih et al. (2020) found that FD students tend to make innacuracy in the transformation stage, process skills especially during executing calculation, and make conclusions which was an effect from the previous errors that prevented them getting the correct solution. FD students frequently make mistakes in interpreting questions, transforming questions, adhering to process guidelines, and assembling final responses (Virnanda et al., 2025).

Understanding the kinds of errors students made when tackling mathematical problems is crucial for students and teachers to understand which aspects need to be optimized and corrected, preventing them from making the same error again. This will also help students develop their mathematical literacy skills to the fullest. The types of errors can be recognized by analyzing each step and process in the student's answer sheet using Newman's theory. Newman's theory was chosen because it classified errors using more criteria than other types of errors (Emiyanti, 2022). Newman grouped students' errors in detail into 5 types of errors, namely reading errors, comprehension errors, transformation errors, process skill errors, and encoding errors (Clement, 1980).

Acoording to Newman (Clement, 1980) someone who wanted to get the right solution for a mathematical problem must follow this hierarchy: (1) reading the problem; (2) understanding what was read; (3) changing the problem in the form of words into an acceptable mathematical form; (4) processing the chosen mathematical form; and (5) writing the answer in an acceptable form. This meant that before carrying out the mathematical process to get the correct answer, students first interpreted the meaning of the mathematical question (Prakitipong & Nakamura, 2006). Students must be able to clearly understand what was being discussed in the question

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(Fauzi & Diansyah, 2021). However, students encountered various errors in solving mathematical problems (Kusumawati et al., 2022). These errors prevented them from arriving at the correct solution. To deepen the type of errors from students' work in solving PISA-based mathematical problem especially for those who have field dependent cognitive style, the researcher interested in conducting research on students' errors in solving PISA-based mathematical problems viewed from cognitive style in one of the junior high schools located in Bengkulu province.

Method

Research Type

This research used a qualitative approach. The method used in this research was a case study. According to Saldana (2011), a case study focuses on one unit for analysis, such as one person, one group, one event, one organization, and so on. Cases are limited by time and activity where researchers use a predetermined time-based data collection process to gather comprehensive information (Creswell, 2014). A case study approach is used to determine and describe the field dependent students' error in solving PISA-based mathematical problem students.

Subject

The subjects in this study were 8th grade students at SMPN 01 North Bengkulu and 8th grade students at SMPN 04 North Bengkulu. The 8th grade students of SMPN 4 North Bengkulu became the research subjects for the validation test and reliability test. The validation test was carried out on Thursday, August 24, 2023. The 8th grade students of SMPN 1 North Bengkulu became the research subjects to analyse students' errors in solving PISA-based mathematical problems viewed from their cognitive styles. The subjects were selected using a purposive sampling technique, where sample selection was based on certain predetermined criteria.

In this study, the focus of the study are field-dependent cognitive styles. The instrument used to group students according to their cognitive styles is the Group Embedded Figure Test (GEFT). There were three subjects in this study. Researchers chose to use a scoring guideline using the median test score as a categorization reference to categorize the cognitive style from the result of GEFT (Benbasat & Dexter, 1982; Wang et al., 2003). This is because categorization based on the median of raw scores can be used on data that is normally or non-normally distributed, has skew, and contains outliers (DeCoster et al., 2011). The median in the data on student GEFT scores is 8, so students who scored <8 of the total score are grouped into the field-dependent type.

After categorizing students into their cognitive style, researcher then group them according to their initial mathematical ability (KAM), KAM was collected from their final mathematical score given from the homeroom teacher. From the 32 students' final mathematics scores (x), the average (μ) was 83.28 and the standard deviation (σ) was 7.09. Students who had score $(x) \geq 90.37$ categorized into high level, students who had $76.19 \leq score\ (x) < 90.37$ categorized into medium level, and students who had $score\ (x) < 76.19$ categorized into low level.

There were three subjects in this research. The three subjects each represent students with a field-dependent cognitive style with low, high, and medium levels of KAM. One subject has a field-dependent style with low ability (LFD), one subject has a field-dependent style with

medium ability (MFD), and one subject has a field-dependent style with high ability (HFD). The list of subjects in this study is presented in Table 1

Table 1. Research Subject Data

Cognitive Style	KAM Category	Subject Initial
Field dependent	Low	LFD
	Medium	MFD
	High	HFD

Table 1 above is a list of research subjects consisting of 3 people, each of whom represents each cognitive style category and KAM category.

Instrument

The primary instrument in this study was the researcher herself. Therefore, the presence of a researcher could not be replaced by another person in the design stage, selecting research subjects, data collection, analysis, interpretation, and drawing conclusions of the study. The researcher was assisted by supporting instruments to collect the information and data needed in this study. The supporting instruments used in this study were PISA-based test questions, Group Embedded Figure Test (GEFT) questions, validation sheets, and interview guidelines with students.

Before the test was administered to students, the test sheets were validated by several validators, who were experts in mathematics. After several minor revisions based on the validators' suggestions and comments, the PISA-based test instrument was finally usable to be tested among students. Furthermore, to determine the validity of each item and the reliability of the mathematical literacy test, the questions were tested on 20 students, whose validity was then assessed using the Rasch Model data processing with the Winstep application..

Collecting and Analysis

This research was conducted at SMPN 1 Bengkulu Utara and SMPN 4 Bengkulu Utara in the odd semester of the 2023/2024 academic year in 8th grade students. The study took place from August 21 to September 8, 2023. On Thursday, August 24, 2023, the first study was conducted with 20 students. This study was conducted to test the validity of the questions that would be tested on students with field-dependent cognitive styles. After the validity of the questions was obtained through Rasch Model data processing with the Winstep application, the questions were then tested on 8th grade students at SMPN 1 Bengkulu Utara. On Wednesday, August 30, 2023, a study was conducted on 32 students to assess their cognitive styles and a written test was conducted to assess their errors in solving PISA-based mathematical problems. The selected subjects were divided into two groups: The Field Dependent (FD) group and the Field Independent (FI) group. Three students were then selected from the FD, each representing students with high, medium, and low mathematical abilities, resulting in three students who became research subjects. The data collected then proceeded to the data processing stage. Data were analyzed continuously until saturation reached the data point. The analysis technique used in this study consisted of three steps proposed by Miles and Huberman (Moleong, 2019): data reduction, data presentation, and conclusion drawing.

Results and Discussion

When solving mathematical problems, students made several errors that resulted in inaccurate answers and solutions. There were several types of error found which was later be

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classified according to Newman's theory, specifically five types of error: reading, comprehension, transformation, process skill errors, and encoding. This happened because students were lack practice in writing down known information and the questions asked in the problem, confused in deciding method or formula needed to solve the problem, inaccuracy in carrying out calculations, and rarely writing or summarizing conclusions in the final answer (Halim & Rasidah, 2019). Table 2 showed the results of errors made by six research subjects in solving mathematical problems.

Table 2. Student Errors in Solving Mathematical Problems

Number of Question	Type of Error	Number of Students	Percentage
1a	*Comprehension Error*	2	66.67%
	Transformation error	1	33.33%
1c	*Encoding Error*	1	33.33%
	Comprehension error	1	33.33%
	Process skill error	1	33.33%
	Encoding error	1	33.33%
2a	*Comprehension error*	3	100%
	Process skill error	1	33.33%
	Encoding error	1	33.33%
2b	*Comprehension error*	2	66.67%
2c	*Comprehension error*	2	66.67%
3a	*Comprehension error*	1	33.33%
	Transformation error	3	100%
3b	*Comprehension error*	1	33.33%
	Process skill error	1	33.33%
3c	*Comprehension error*	1	33.33%
4a	*Comprehension error*	1	33.33%
	Encoding error	1	33.33%
4b	*Comprehension error*	2	66.67%
	Transformation error	2	66.67%
	Process skill error	3	100%
	Encoding error	3	100%
4c	*Comprehension error*	3	100%
	Encoding error	1	33.33%
5a	*Comprehension error*	3	100%
5b	*Comprehension error*	3	100%
Total		26 Errors	

Table 2 shows the types of errors made by 3 students in solving mathematical problems. Students made the most errors in comprehension errors that led them difficult to provide correct answer for question number 2a, 4c, and 5. The most frequent error students made when solving all mathematical problems was comprehension errors. Of the 26 errors, there were 13 comprehension errors, 4 process skill errors, 4 encoding errors, and 3 transformation errors. This is in line with Siagian et al. (2022) that the most common error was comprehension errors. In addition, errors in writing the final answer (encoding errors) also included in a high level of errors (Fazzilah et al., 2020; Halim & Rasidah, 2019; Suratih & Pujiastuti, 2020).

Errors in solving mathematical literacy test questions not only occured among low-ability students, but also among medium-ability and high-ability students. Students stated that PISA-based mathematical problem test was more difficult than questions usually given by teachers at school because the questions presented were in the form of word problems. This meant that students were not yet accustomed to non-routine questions presented in the form of word problems, resulting in students potentially making errors when solving these questions. This

statement was supported by the results of research by Adilla et al. (2020) which stated that students made errors when answering word questions, where these errors consisted of errors in understanding information, errors in problem transformation, errors in arithmetic operations, and errors when answering word problems. These errors were caused by a tendency of failing in understanding the problem situation, not being comprehensive, not completing the problem solution according to what the question required, and not practicing to solve the questions, especially word problems (Sundayana & Parani, 2023).

LFD student made various errors when completing questions from levels 1 to 5. Overall, LFD student was able to answer two questions correctly. This was in line with the findings of Akib et al. (2018) that the lower student's intelligence tendency, the higher the level of errors that may occur. LFD student tended to make comprehension errors because he still did not understand or misunderstood the meaning of the sentences presented in the questions. Figure 1 below showa LFD's work on solving sequence problem.

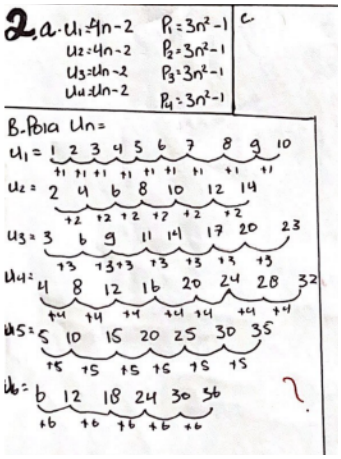

Figure 1. LFD's Answer Sheet

The question wanted the student to get the value of U_n and P_n by applying the given formula. Instead of using the formula, LFD student wrote the new sequence which was unrelated to the question. According to the interview, it was known that the student did not get the idea how to substitute the value of n to the given formula. He knew it should be replaced with something, but he was unsure what it was and got confused. LFD also admitted that he did not know what was the meaning of n in the formula. LFD failed to realize that the n was actually refered to the nth term which showed that this student still lack understanding in algebra. Thus, these errors caused LFD student to write incorrect answers when working on PISA-based mathematical problem. In addition, LFD student experienced transformation errors (Astutik & Purwasih, 2023; Ratnaningsih et al., 2020; Virnanda et al., 2025). These errors occured because LFD student could not write information using the correct mathematical symbols and could not write the appropriate formula to solve the existing problem. This was in line with the statement of Virnanda et al. (2025) which stated that FD students could not describe the elements that are known and asked and even though they understood the elements that were asked in the question, they were not able to describe it. Transformation errors could also be caused by a lack of understanding of the problem, inaccuracy, and errors in choosing a solution method (Istiqomah & Zakiyah, 2017). These factors also contributed to students' difficulty in transforming problems and causing them to end up answering questions incorrectly. This statement aligned with the findings of Yuliyani & Setyaningsih (2022), who found that students with field dependent cognitive style were still low in selecting appropriate strategies, using symbols, operations, and mathematical formulas.

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LFD student also experienced process skill errors when solving PISA-based mathematical problem. This occured because student incorrectly determined the procedures and strategies to use in solving the problem. It could happen because LFD student experienced the comprehension errors when reading the question. Furthermore, LFD student also experienced process skill errors because he could not continue the procedure when using formulas to solve the problem. Process skill errors included errors in using procedures and arithmetic operations, and the inability to continue the solution to the problem (Junaedi, 2012; Suratih & Pujiastuti, 2020). This statement is also supported by Son et al. (2021) which found that FD students tend to have struggle in executing mathematical procedures and solve the algebraic questions systematically. Comprehension errors experienced by LFD student also led to encoding errors, which ultimately result in LFD student writing answers that were irrelevant to what was asked in the problem. Misunderstanding problems would lead to another mistake because when students were unable to comprehend the particular information and what the problem was asking them to solve, they would make errors when transforming the information and implementing the procedure to solve the problem (Aziza & Eratika, 2022; Istiqomah & Zakiyah, 2017).

The dominant errors experienced by LFD student was comprehension errors and process skill errors. When LFD student experienced comprehension errors, he was having difficulty in understanding the information, keywords, and the question being asked. This left them confused about which strategies and procedures to use. The comprehension errors and process skill errors experienced by LFD student ultimately resulted in LFD student experiencing encoding errors. This supports the statement that FD students frequently make errors while constructing mathematical models, using process skills to manipulate algebra and calculation, and obtaining conclusions because they made mistakes in the earlier stage (Ratnaningsih et al., 2020).

Similar to LFD student, MFD student also experienced errors when solving problems on PISA-based mathematical problem. MFD student experienced comprehension errors, making him unable to understand what he actually had to do to answer the question. Most of the comprehension errors experienced by MFD student were caused by their lack of understanding of the information and keywords in the question. This behavior aligned with the findings of Junaedi (2012), who found that the error made in comprehension errors was students not fully identifying what was being asked. This caused MFD student unable to solve the question correctly. MFD students also experienced transformation errors, characterized by inaccurate formulas written by MFD student on their answer sheets when he was trying to find the formula of the number pattern. This is in line with Astutik & Purwasih (2023) which stated that FD students made many mistakes in transformation errors. Furthermore, student also misread information using mathematical symbols when solving problems with formula indicators. Figure 2 below shows MFD's answer for question number 4 and the error is shown in point B.

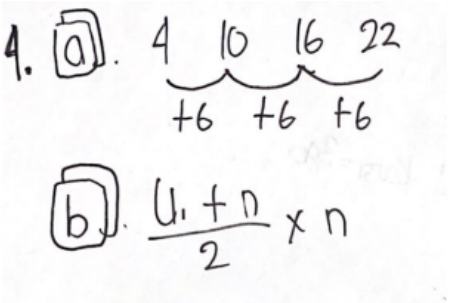

Figure 2. MFD's Answer Sheet

The question was asking about determining the formula to get the number of sticks for nth term. MFD already wrote the formula, but it was wrong. From the interview, it was known that he thought the formula he wrote is the formula to get the difference between two terms. he planned to use the difference together with the first term. His statement showed that he used a wrong formula and wrote the wrong symbol while applying the formula which led him to get a wrong answer. Because of this error, it affected another error which was skill errors. He was unable to carry out procedures correctly when using formulas, which was indicated by his misinterpretation of symbols meaning. These errors alligned with the research findings of Prasetyo & Rudhito (2016), who found that students sometimes had difficulty remembering the formulas they needed to apply, did not read the questions carefully, and did not fully understand the meaning of the questions when solving math problems. Furthermore, MFD student experienced encoding errors caused by comprehension errors which was not understanding the keywords in the question. This statement was in line with Siagian et al. (2022), who found that student with moderate ability made errors in reducing the information and selecting the data needed to solve the problem, resulting in answers that did not match the context of the question. These errors led students to carry out inappropriate procedures.

The dominant error experienced by MFD student was comprehension errors. When experiencing comprehension errors, MFD student had difficulty understanding the information, the meaning of the question, and the keywords in the problem. This difficulty left student confused when determining the appropriate strategies and procedures. On certain problems, comprehension errors experienced by MFD student resulted in making other errors or even being unable to answer the problem at all.

HFD student also experienced errors when solving mathematical literacy problems. The majority of errors experienced by HFD student were comprehension errors. These errors happened because HFD student were unable to understand the keywords in the question, unable to identify important information, and did not understand the meaning of the data in the problem. These errors caused HFD student to struggle answering the questions because he did not know the appropriate strategy to use. Furthermore, in certain cases, these errors even prevented HFD student from being able to answer the question. Similar to LFD and MFD students, HFD student also appeared to have difficulty in writing information using mathematical symbols. Therefore, HFD student experienced transformation errors. This was consistent with the findings of Siagian et al. (2022), who found that students were not get used to understand the word problems, making it difficult to translate information into equations. HFD student also made errors when performing arithmetic operations. Figure 3 below shows the incorrect calculation that HFD student made when solving poin 4b.

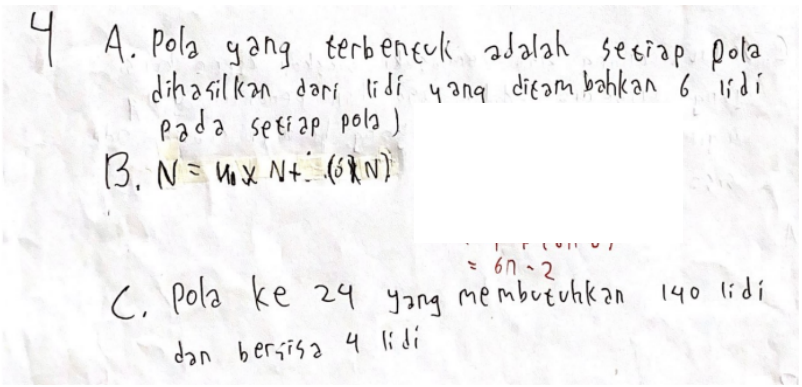

Figure 3. HFD's Answer Sheet

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HFD already wrote the answer even though he did not write the process how to get it. Unfortunately, the answer was wrong. Later during the interviewed, it was found that he knew the solution and got the answer by counting manually. This behaviour conveyed that he understood the question and strategy he applied. Meanwhile during the calculation process, he made mistakes which led him to get incorrect answer. These results were also consistent with Yuliyani & Setyaningsih (2022), who found that FD students made errors in calculations. Another error made by HFD student in process skills was an error when executing the substitution procedure. This error was actually caused by a comprehension error he experienced, which resulted in an incorrect procedure being executed. This comprehension error also caused HFD student to experience encoding errors because he failed to understand what the question was actually asking.

The dominant errors experienced by HFD student were comprehension errors and transformation errors. When experiencing a comprehension error, it meant that HFD student was having difficulty understanding the information, the meaning of the question, and the keywords in the problem. This difficulty left student confused about which strategies and procedures to apply when solving the problem. On certain questions, comprehension errors guided to other errors or even being unable to answer the question at all.

Conclusion

The dominant errors experienced by LFD student when solving mathematical literacy problems were comprehension errors, process skill errors, and encoding errors. The dominant errors experienced by MFD students were transformation errors and encoding errors. Furthermore, the dominant errors experienced by FIS students were comprehension errors, the dominant errors experienced by HFD students were comprehension errors and transformation errors. The higher stage of error mainly happened because students made error in the earlier step and fail to understand what the question actually asks to answer. Almost all students were seen to have struggle in transforming particular information to mathematical words so it leads them to a confusion in choosing which strategy they should apply to execute the step of solution, some of them also doing a wrong calculation and do not know how to do the substitution procedure when solving sequence problems. However, the study is conducted with only 3 subjects from 32 students in a Junior High School in North Bengkulu, which limits the representativeness of the sample. The relatively small sample size restricts the breadth of perspectives represented and may not fully capture the diversity of experiences relevant to the topic. Nevertheless, the study contributes important initial understandings that can serve as a basis for future research. Further studies with larger and more varied samples, conducted across different contexts and materials, are recommended to strengthen the validity and applicability of the findings.

Conflict of Interest

The authors declare that there is no conflict of interest.

Authors' Contributions

A.M.R 100% contributed in this writing. she collected the data and conceived the research idea presented in this article. She also actively participated in the development of the theory, methodology, data organization and analysis, discussion of the results, and approval of the final version of the work. The author declares that the final version of this paper has been read and approved.

Data Availability Statement

The author declares that data sharing is not possible, as no new data was created or analyzed in this study.

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