ISSN 2502-5872 (Print)
ISSN 2622-3627 (Elektronik)

Volume 10 Number 1, February 2025, 237-253

ANALYSIS OF STUDENTS' ERRORS THROUGH NEWMAN'S THEORY IN ADDRESSING CRITICAL THINKING ABILITY QUESTIONS AS EXAMINED THROUGH COGNITIVE STYLE

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ABSTRACT

Mistakes frequently occur among students when interpreting mathematical problems or engaging with math exercises. This has contributed to the low PISA results in 2022, particularly reflected in a decline in mathematical proficiency, with Indonesia's average score decreasing by 1-3 points compared to previous assessments. Consequently, there is a pressing need to investigate the errors committed by students. This study aims to identify student errors through the lens of Newman's theory while addressing critical thinking ability questions in relation to cognitive style. The research design is descriptive qualitative, as it elucidates the mistakes made by students. The subjects of this study comprised 27 out of 84 seventh-grade students from SMP Negeri 139 Jakarta, who exhibited errors in responding to critical thinking ability questions involving combined material on flat-sided geometric shapes. The findings and conclusions of this study reveal that students with a Field Dependent (FD) cognitive style and those with a Field Independent (FI) cognitive style encounter reading errors, understanding errors, process skill errors, and coding errors; however, students with an FI cognitive style tend to make fewer mistakes than their FD counterparts.

Keywords: Error Analysis, Newman's Theory, Critical Thinking Skills Inquiries, Cognitive Style

How to Cite: Lupita, L., Meiliasari., & Hakim, L. E.(2025). Analysis Of Students' Errors Through Newman's Theory In Addressing Critical Thinking Ability Questions As Examined Through Cognitive Style. *Mathline: Jurnal Matematika dan Pendidikan Matematika, 10*(1), 237-253. https://doi.org/10.31943/mathline.v10i1.840

PRELIMINARY

The relatively low quality of education poses a significant challenge for educators striving to enhance the learning process. One of the initiatives to address this issue will involve a comprehensive analysis of the underlying causes. A primary factor contributing to this situation is the difficulties students encounter when studying mathematics. Many students perceive mathematics as a challenging subject, often leading to a range of complex problems that hinder their ability to achieve satisfactory learning outcomes.

According to the findings of the Program for International Student Assessment (PISA) 2022, Indonesia's ranking improved by 5-6 positions compared to 2018. Nevertheless, despite this advancement in ranking, Indonesia experienced a decline in mathematics scores. In the mathematics domain, which is the primary focus of PISA 2022, Indonesia's average score was 366, a decrease of 13 points from the previous score of 379 (Kemendikbud, 2023). The PISA framework encompasses problem-solving and critical thinking, suggesting that the low performance of Indonesian students reflects deficiencies in both problem-solving abilities and critical thinking skills.

Students' challenges are evident in the recurring errors they make, including those related to counseling, comprehension calculations, and logical mathematical reasoning when addressing mathematical problems (Hananta & Ratu, 2019). While mistakes are a natural part of the learning process, persistent difficulties indicate that the current learning approach may not be effective for students moving forward, necessitating intervention. This chapter discusses the cell error analysis method for measuring the tail, which is refined to reduce cell errors and thereby enhance mathematical prediction accuracy.

Error analysis is a research method aimed at identifying students' inaccuracies and the underlying reasons for them, serving as a guideline for designing classroom learning activities (Fitria, 2021). It delineates the various types of errors students make while solving mathematical problems and the factors contributing to these errors (Rina, 2017).

The challenges faced by students present obstacles that may lead to errors in solving mathematical problems across various topics in the curriculum (Utari, 2023). The interconnectedness of mathematical concepts contributes to students' difficulties in learning, as they must grasp and comprehend foundational concepts before delving into more advanced topics. Furthermore, the mathematical problems presented by the curriculum are designed to be accurate, allowing students to engage with varying levels of difficulty in each numerical cell. Consequently, as the challenges encountered by students increase, a more comprehensive analysis of the errors they commit is conducted.

The capacity of an individual's cells to thrive in life can, among other factors, enhance their cognitive abilities. A crucial aspect of addressing the challenges they encounter is the cultivation of critical thinking skills, which involves a rigorous analysis of problems and the generation of alternative solutions to mathematical issues. To foster their skills and potential, students possess varying degrees of critical thinking abilities (Kurniawan et al., 2023).

One of the competencies to be attained through the study of mathematics is the capacity for critical thinking. Students' mathematical critical thinking skills are currently classified as inadequate, primarily due to a scarcity of learning materials and limited engagement with these materials during the educational process (Nasrullah et al., 2023). Critical thinking is essential for fostering development, as it serves as the foundation for learning, which in turn is crucial for achieving success in mathematics education. Critical thinking encompasses the ability to evaluate, analyze, and interpret information logically (Rahmaini & Candra, 2024). Proficiency in mathematical critical thinking is a vital skill that students must possess to keep pace with the advancements in IPTEK (Agus & Purnama, 2022).

The capacity for critical thinking cultivates the essential skills that students must acquire to assess information, foster rational thought, and address problems effectively (Pramesti & Sari, 2024). Critical thinking is characterized as reasonable and reflective thought focused on the decisions regarding what to believe or how to act (Ennis, 2011). It involves a systematic approach to contemplating the beliefs or actions taken (Susanto, 2016). Critical thinking encompasses a form of analytical reasoning that promotes the development of cognitive processes related to analysis and evaluation, initially involving the assessment of arguments based on logical consistency while identifying biases and fallacious reasoning (Arends, 2012).

According to Ennis, critical thinking indicators are categorized into five distinct types: 1) clarification, 2) development of basic support, 3) advancement of clarification, 4) formulation of strategies and tactics (Slavina, 2018).

Students' cognitive styles are significant factors influencing their responses to situations that impact academic decisions (Juliana et al., 2024). Cognitive style refers to the manner in which individuals process, store, and respond to various forms of environmental stimuli (Elennita et al., 2024). Cognitive style is integral to educational processes, serving as a key determinant of how students' characteristics affect their information reception and learning outcomes (Ellyana et al., 2022).

Cognitive style reflects cognitive activity (Wulan & Anggraini, 2019). It encompasses the manner in which individuals think, the frequency of their thoughts, their methods of processing and retaining information, and their application of information in problem-solving scenarios (Simuth & Sarmany, 2014). Cognitive style is divided into two categories: field-dependent (FD) and field-independent (FI) cognitive styles. The field-independent cognitive style is characterized by students who adopt a more analytical approach to problem-solving, breaking down problems into smaller components and establishing relationships among them. Students exhibiting a field-independent cognitive style rely on intellectual factors for information processing, making them less susceptible to external or environmental influences. Conversely, the field-dependent cognitive style describes learners who are significantly influenced by their surrounding conditions (Ginting & Nasultion, 2024).

In this research, the Newman Error Analysis (NEA) procedure is employed. The NEA process was introduced by Australian educator M. Annemarie Newman in 1977. Newman's student learning process adheres to a five-step method to address the question of mathematical understanding, specifically focusing on reading errors, comprehension errors, transformation errors, prose summary errors, and final answer encoding errors (Jha, 2012).

Based on the aforementioned explanation, it seems that the enhancement of students' critical thinking skills in mathematics is stagnating, as they continue to encounter difficulties in resolving critical thinking problems in this subject. Consequently, this study will delve deeper into the topic "Analysis of Students' Errors According to Nelwman's Theory in Addressing Critical Thinking Problems Through the Lens of Cognitive Style." In light of the background provided, the problem statement for this study is: "What errors do students make according to Nelwman's theory when addressing questions that assess critical thinking abilities in relation to cognitive style?"

METHODS

This research focuses on a cohort of seventh-grade students at SMP Negeri 139 Jakarta, who are engaged in the study of flat-sided squares. SMP Negeri 139 is the inaugural middle school situated at Jln Bunga Rampai No.38, Malaka Jaya, in the Duren Sawit District of East Jakarta City. The study employs a qualitative descriptive methodology. Conducted during the first semester of the 2023/2024 academic year, the research encompasses a population of 252 students across seven classes. The specific subjects of this study comprised only 12 students, as their critical thinking skills were found to be lacking. This necessitates a more in-depth analysis of the errors made by the students.

There are various selection techniques for choosing and implementing sampling methods. Purposive sampling is employed because the sample cannot be selected randomly. According to Sugiyono (2018), purposive sampling is a technique for gathering data through careful consideration of specific criteria. The primary focus of this research is to select students who meet the established selection criteria. The reflection of the object in this study occurred when the researcher was preparing to conduct the investigation. The criteria for reflection included: first, students had received instruction on the topic of flat-sided squares; second, the selected subjects were initially assessed regarding their cognitive style using the GEFT test; third, students underwent preliminary ability tests, and subsequently, they were selected based on their cognitive levels, which will be detailed in the table below:

Table 1. Sampling Methodology

Cognitive Approach	Early Collection (Cognitive Level)		
	Low	Currently	Tinggi
Field Dependent	2 Siswa	2 Siswa	2 Siswa
Field Independent	2 Siswa	2 Siswa	2 Siswa

The fourth criterion stipulates that students can make errors while solving problems, as evidenced by the outcomes of the critical thinking ability assessment. The fifth criterion indicates that students can effectively articulate their thoughts both orally and in writing.

RESULT AND DISCUSSION

1. Outcomes of the study

We conducted research and analyzed data from a study involving the cognitive styles of 84 students. Our findings revealed that 59 students exhibited a field-dependent (FD) cognitive style, while 25 students demonstrated a field-independent cognitive style. The classification of students into each cognitive style was achieved through a method known as the GEFT test. The Group Embedded Figures Test (GEFT) is a measurement tool developed by Witkin (1971) and utilized to assess cognitive styles, specifically field-dependent and field-independent. The GEFT comprises three parts: the first part consists of 7 questions, the second part includes 7 questions, and the third part contains 9 questions, resulting in a total of 23 questions.

Table 2. Student Data According to Cognitive Style

Kelas	Gaya Kognitif		Jumlah Siswa
	FD	FI	
7C	18	10	28
7D	23	6	29
7E	18	9	27

Based on the data presented, 84 students who participated in the GEFT test were analyzed, revealing that 59 students exhibited a Field Dependent (FD) cognitive style, while 25 students demonstrated a Field Independent (FI) cognitive style. This indicates that the most prevalent cognitive style among the participants is the Field Dependent cognitive style.

Following an analysis of the data from students classified as possessing a high-level cognitive style and those with an in-level cognitive style, we proceeded to examine the results of the critical thinking test administered to 84 students. It was observed that numerous students encountered difficulties in addressing the critical thinking test questions related to flat-sided shapes and rectangles. The test comprises three questions, and the results are evaluated according to the Newman error procedure. Table 3 presents the errors committed by the students. When summarized, the students' performance can be categorized according to the error list for each question number as follows:

Table 3. Overview of Errors in Students' Responses

Jenis Kesalahan	Soal								
	Nomor 1			Nomor 2			Nomor 3		
	√	S	TK	√	S	TK	√	S	TK
Membaca	25	2	0	24	2	1	14	11	2
Pemahaman	14	12	0	14	12	1	10	15	2
Transformasi	10	14	3	11	7	9	3	4	20
Keterampilan Proses	8	12	7	1	8	18	3	4	20
Pengkodean	5	9	13	0	3	24	2	2	23

Based on the data presentation of students' responses to written questions regarding critical thinking in the context of geometric shapes and flat-sided rectangles, the researcher identified numerous errors stemming from the stages of the experiment conducted by 27 students. Notably, the majority of errors occurred during the stage of comprehension.

Errors in the reading stage are evident from the students' responses; however, multiple interviews were conducted to identify these errors more thoroughly. Students exhibiting a field cognitive style frequently commit reading errors. The reading errors associated with FD1T1's response to question number 2 are notable. The reading mistakes made by the research subjects with a field cognitive style include the following: failing to read the question in its entirety and misinterpreting what is being asked. Below is FD1T1's answer to question number 2:

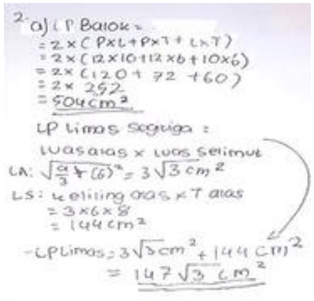

Figure 1. Answer Subject FD1T1 Question Number 2

Based on the response of subject FD1T1 in Figure 4.2, it is apparent that a reading error occurred. However, following the interview, it became clear that FD1T1 struggled with reading and subsequently repeating the questions, resulting in comprehension errors, transformation errors, a lack of procedural skills, and inaccuracies in final answers or coding errors. The errors were not evident as the students had not completed their responses.

Based on the students' performance and the interview outcomes, it can be concluded that FD1T1 committed a reading error on question number 2. This error occurred due to the limited time allocated to the remaining questions, with question number 2 being the last one addressed, leading to some information being overlooked or not read at all.

2. Misunderstanding (Comprehension Error)

The misconceptions among students with the Field of Determination (FD) cognitive style are evident from their responses and the interviews conducted. The misconceptions were identified in the subject of FD2T2 in number 1. This study revealed that students misinterpret the information presented in the questions, and some fail to recognize critical details, leading to a misunderstanding of the text.

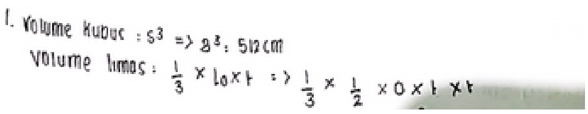

Figure 2. FD2T2 Transformation Error in Question 1

Figure 2 illustrates that numerous individuals have erred in comprehending or applying the principles of pyramid volumes. Following a group interview with FD2T2, it was determined that FD2T2 had derived the base by multiplying by ½. This may have resulted from a misunderstanding on the part of the FD2T2 subject. The subject misinterpreted question number 3, as evidenced by the accompanying image of the results, which illustrates the misunderstanding as follows:

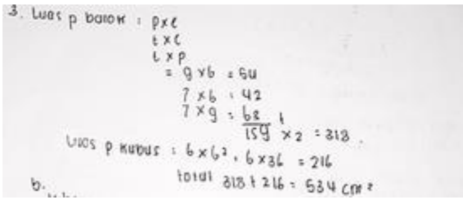

Figure 3. FD2T2 Subject Misunderstanding Error in Question Number 3

The image above illustrates several misunderstandings, specifically that students fail to identify or calculate the base and circumference of the cube when the composite shapes consist of cuboids and spherical cubes. The interview for FD2T2 was conducted; however, the failure to document or seek a foundation for the questions and related areas stemmed from their inability to comprehend the reading questions presented to them. This led to FD2T2 misinterpreting the meanings of the sentences they encountered.

3. Process Skills Error

The error in the process skill is evident in the FD2T2 problem presented in question number 1. In this instance, the error in the process skill arises from the student's miscalculation. In students with a cognitive style focus (FD), several errors were observed in the procedural skills related to question number 1, including mistakes in the calculation process, as evidenced by the results of the FD2T2 problem-solving task presented below:

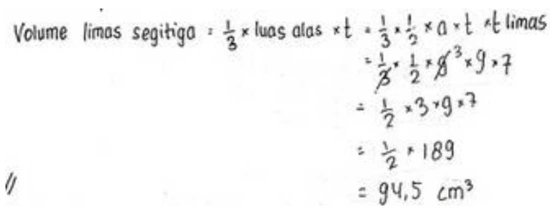

Figure 4. Errors in Process Skills by Subject FD2T2 in Number One

Based on Figure 4, it is evident that the FD2T2 problem encountered multiple errors during the problem-solving process. This was attributed to misunderstandings related to the calculation of the pyramid's volume, which led to inaccuracies in addressing the problem. FD2T2 did not make any errors in the process skill related to question number 3. This was due to the fact that the students encountered difficulties in process comprehension, as evidenced by the results of the process work of FD2T2 outlined below:

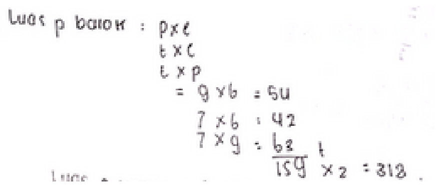

Figure 5. Errors in the Prose Skills of Subject FD2T2 in Number 3

Based on Figure 5 related to subject FD2T2 in the work concerning question number 3, there were several errors in the process skills. This was due to multiple inaccuracies in the calculation process and misunderstandings in the comprehension process.

4. *The Encoding Error*

Final Answer/Coding Errors in Field Dependent students have occurred in the FD2T2 problem. This is due to students' misunderstandings and errors in their procedural skills. This is illustrated in Figure 6 presented below:

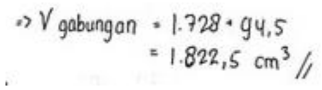

Figure 6. Coding Errors by Subject FD2T2 in Question 1

In Figure 6, the FD2T2 sample indicated errors in the final answer (encoding error). This occurred due to the students' misunderstandings and inadequate procedural skills. This finding aligns with the results of the FD2T2 student work test for question number 3, where students exhibited errors in comprehension and deficient procedural skills, leading to inaccuracies in calculating the final answer.

1. Description of the Errors Made by Students with a Field-Independent Cognitive Style in Addressing Critical Thinking Questions

a) Skill Deficiency

In students exhibiting the Independent (FI) cognitive style, errors occurred in the calculation operations performed by FI1S1, followed by inaccuracies in documenting the steps or procedures for executing the cell work. What actions should FI2S2 undertake? The findings from the image analysis and the interview regarding question number 2 indicated that there were deficiencies in the process skills.

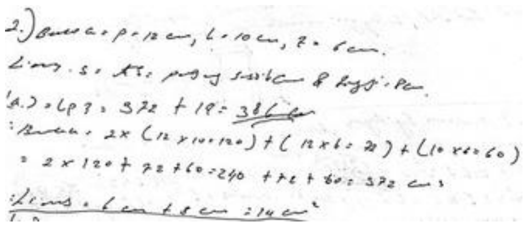

Figure 8. FI1S1 Process Skills Errors Question 2

Based on the image of the student's work results above, FI1S1 erred in the process skill, specifically in the calculation operation while addressing the problem in question number 2. FI1S1 also made an error in determining the beam's surface area. Based on the interview results, FI1S1 has come to the realization that he made an error in calculating or manipulating the cell numbers that had been revised by the researcher. He expressed feelings of panic and frustration due to the limited time remaining to complete the task, which led to a procedural skill error on question number 2. In question number 3, subject FI1S1 again committed a procedural skill error. Below are the responses from FI1S1 reflecting this procedural skill error.

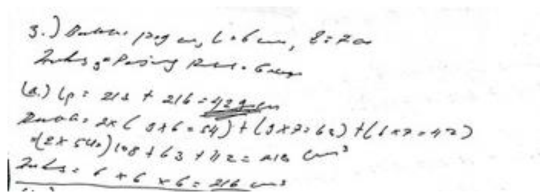

Figure 8. FI1S1 Process Skills Errors in Question 3

Based on FI1S1's response to question number 3, FI1S1 only succeeded in bouncing the ball off the block. However, in doing so, FI1S1 repeated the same error made in question number 2. Instead of continuing to bounce the ball off the block, FI1S1 bounced the ball off the car. The root of the issue lies in the researcher's uncertainty regarding the subsequent steps. The research indicated that subject FI1S1 was unaware and confused when attempting to reflect the joint volume of his/her beam. This confusion arose from FI1S1's misinterpretation of the steps or procedures involved in the beam and beam re-reflection process, leading to an inability to accurately reflect the joint volume of these processes. Consequently, it can be concluded that FI1S1 has encountered a deficiency in the skill level associated with this process.

b) Coding Error (Final Response)

In students exhibiting the Field Independent (FI) cognitive style, coding errors occur, specifically mistakes in deriving the final answer due to calculation errors at the process skill level, particularly in FI1S1 for questions 1, 2, and 3, and FI2S2 for questions 1 and 2. Regardless of the answer outcomes, the errors are as follows:

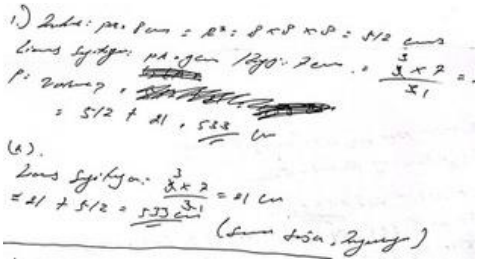

Figure 9. FI1S1 coding error in question one

The individual involved in the cell encountered a misunderstanding regarding the cell problem, leading to an error in interpreting the requirements of the task. The individual only erred in addressing part a and did not proceed with parts b and c. Nevertheless, despite the misunderstanding of the cell problem, the student did not err in calculating the final answer.

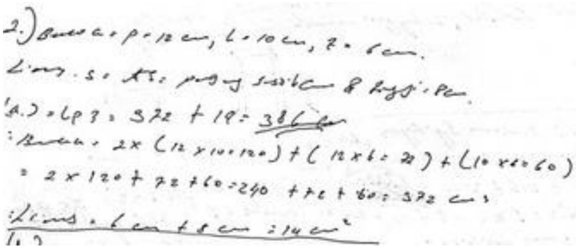

Figure 10. FI1S1 coding error in question two

FI1S1 also committed a coding error on question number 2. This is evident from the results of FI1S1's work in summarizing the outcomes of the completed tasks. The analysis at the cell stage reveals that FI1S1 made an error in the cell's skill process, leading to a miscalculation within the cell, which ultimately resulted in the coding error.

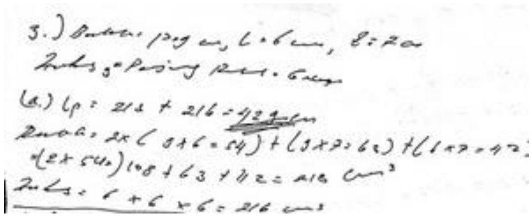

Figure 11. FI1S1 coding error in question three

Based on the answer sheet FI1S1 for question number 3, the subject did not accurately represent the base, the subject, and the circumference of the cuboid. The subject only incorporated what was known to the class in the rules after the discussion, resulting in a coding error.

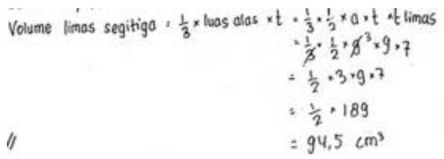

Figure 12. FI2S2 coding error in question one

FI2S2 mel experienced a spelling error in question number 1. The subject encountered a spelling mistake that led to an error in determining the final answer. Furthermore, the subject did not provide the necessary responses to the questions in parts a, b, and c.

The interview results indicated that the subject experienced confusion regarding the cell problem, which hindered his progress. Consequently, the subject struggled to comprehend the cell problem, leading to coding errors.

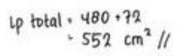

Figure 13. FI2S2 coding error in question two

Similarly to number 1, subject k encountered a coding error in number 2. FI2S2 erred in ascertaining the final answer due to a prior misunderstanding in the previous task. Students exhibiting a high initial ability in FI cognitive style tend to commit transformation errors, process skill errors, and final answer errors. Those with a medium initial ability in FI cognitive style are prone to comprehension errors, skill errors, and final answer errors. Conversely, students with a low initial ability in FI cognitive style frequently make reading errors, comprehension errors, skill errors, and final answer errors.

The subsequent discussion will focus on the errors encountered by students with FD cognitive style:

1. Reading errors exhibited by students with the Field Delving (FD) cognitive style in this study are evident from the analysis of students' work and are further elucidated by the findings from interviews, specifically:
   - Insufficient comprehension of the questions leads to students misinterpreting what is being asked.
   - Students do not accurately record the data.

   This aligns with Sulyitno's (2015) assertion that in instances of reading errors, students may read the text but misinterpret the meaning of the question. It is understood that reading involves not only the text itself but also requires careful analysis of the question.

2. The misconceptions held by FD students are:
   - It is inappropriate to reflect the purpose of the question, as it overlooks crucial information.
   - Error in interpreting the regulations
   - Inability to articulate existing knowledge in writing

   This aligns with the findings of Lulsiana (2017), which indicated that Field Survey (FD) respondents struggled to articulate their knowledge and inquiries regarding the problem statement, leading to inaccuracies in the survey's outcomes.
3. FD students' transformation errors encompass:
   - Students often err in rounding mathematical models.
   - Incorrect procedure
   - Inaccurate representation of the pyramid volume rule

   The transformation errors identified in this study primarily involved students who struggled or made errors in converting the problem into a mathematical model. This aligns with the findings of Delwi and Kartini (2021), which indicated that transformation errors arose from students' inability to accurately translate the information presented in the problem into a mathematical framework.
4. FD students exhibit errors in procedural skills that include:
   - Incorrect calculation methods and inaccurate representation of steps or procedures for problem-solving.
   - Incorrect arithmetic operation

   This aligns with the findings of Andriyani and Ratul (2018), which indicate that students with the FD cognitive style tend to err, specifically in the rounding of mathematical models.
5. Coding errors in research subjects exhibiting an FD cognitive style encompass:
   - Erroneous in reaching the final conclusion due to inaccuracies in formulating the question.
   - Erroneous in reaching the final conclusion due to an error in calculation or a misstep in procedural skills.

According to Sulyitno (2015), an error in the final answer arises when a student fails to deliver the correct and appropriate response. Meanwhile, students exhibiting low initial ability in FI cognitive style tend to make errors in comprehension, procedural skills, and final answer accuracy.

1. Misunderstandings in subjects characterized by low initial abilities, specifically:
   - misinterpreting the intent of the question or mirroring what was inquired on the soulrangal
   - It is impossible to ascertain what is known.

   It is evident that students continue to struggle with comprehending the questions, a notion corroborated by the findings of Mulbarokah and Nulsantara (2020), which indicate that students still face challenges in understanding the content of the questions.
2. The conversion of this issue into a cognitive style is referred to as Field Integral (FI):
   - Students do not fully document mathematical models.
   - Students inaccurately convert information from the problem into a mathematical model.

   This aligns with the research conducted by Sullistyorini et al. (2018), which indicates that FI students encounter planning errors, specifically transformation errors.
3. The process skill error identified in this research subject with the Field Involvement (FI) cognitive style is that students err in selecting or evaluating the steps necessary to execute or complete a task. The errors committed by FI students in procedural skills are not attributable to conceptual misunderstandings or misconceptions; rather, they stem from inattention, time constraints, and haste in their execution. This aligns with the findings of Sullistyorini et al. (2018), which indicate that while FI students possess a deeper understanding when addressing questions, they tend to err due to a lack of focus.
4. Final Answer Error in this research subject regarding Field Inference (FI) cognitive style inaccurately reflects the conclusion of the answer. Consistent with the study conducted by Andriyani & Ratul (2018), students with FI tend to err in recording the final grade. In general, students with the Field Independent cognitive style (FI) do not exhibit reading errors. Various research findings associated with the Field Independent cognitive style indicate that students commit errors across the five stages of Newman; however, this study diverges from prior research.

CONCLUSION

The presented data indicates that students with FD cognitive style and FI cognitive style primarily commit reading errors, comprehension errors, procedural skill errors, and coding errors. However, upon final analysis, it is evident that only a limited number of students with FI cognitive style encounter errors in comparison to those with FD cognitive style.

ACKNOWLEDGMENT

This research was supported by a research grant from the Directorate of Research, Technology and Community Service (DRPTM) with master contract number 064/E5/PG.02.00.PL/VI/2024. We are very grateful for the financial support provided. We also thank SMP Negeri 139 for allowing us to carry out the research, and we do not forget to thank the parents who always support us in completing the research.

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