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Students' Mathematical Reasoning Ability in Terms of Cognitive Style on Guided Inquiry Assisted by Question Cards

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Abstract

Mathematical reasoning ability and cognitive style are crucial topics in mathematics education. This study aims to analyze the effectiveness of the Guided Inquiry model assisted by Question Cards on students' mathematical reasoning and to examine reasoning ability in terms of students' cognitive styles, using a mixed-method approach with a Quasi-Experimental Design. The population of this study consists of ninth-grade students at SMP Negeri 22 Semarang for the 2024/2025 academic year, while the sample includes students from class IX G as the experimental group and class IX H as the control group. The subjects of this study are six students from class IX G, selected using purposive sampling based on the cognitive style categories of Field Dependent and Field Independent. The quantitative results show that the mathematical reasoning ability in the Guided Inquiry model assisted by Question Cards achieves classical mastery, with a higher proportion and average score of students compared to those in the PBL model. Additionally, cognitive style influences students' mathematical reasoning ability by 55.2%. Triangulated qualitative data further describe students' reasoning abilities in this model based on cognitive styles: students with a Field Dependent cognitive style can present mathematical statements, apply patterns to derive mathematical explanations, use fixed formulas, and draw conclusions, while those with a Field Independent cognitive style tend to be able to present mathematical statements, are less likely to apply patterns or use fixed formulas, but generally can draw conclusions.

1. Introduction

Education is a structured effort to develop an individual's potential in cognitive, affective, and psychomotor aspects, enabling them to contribute positively to society (Pristiwanti et al., 2022). Quality education will create competent human resources for the progress of a nation. Improving the quality of human resources can be achieved if the teaching and learning environment is enjoyable.

Mathematics plays a crucial role in education. It is a fundamental science that serves as the foundation for various fields of knowledge. The presence of mathematics in education is vital because it offers numerous benefits, such as being a tool, a source of knowledge, a character builder, and a means of shaping students' thinking patterns (Fathani, 2009). The National Council of Teachers of Mathematics (NCTM) states that mathematics learning encompasses five fundamental skills: problem-solving, mathematical reasoning, mathematical communication, mathematical connections, and representation. It is believed that mathematical reasoning provides meaning to every problem encountered in mathematics learning.

According to NCTM, reasoning is the ability to think critically and logically, including constructing arguments, testing hypotheses, and solving problems in a mathematical context. Sumarmo & Permana (as

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cited in Santosa et al., 2020) further explain that mathematical reasoning ability is essential for understanding mathematical concepts, investigating mathematical ideas, and applying mathematical arguments in a relevant mathematical context, making mathematics a meaningful learning experience.

Mathematical reasoning is divided into two main types: deductive and inductive. Deductive reasoning is the process of drawing specific conclusions based on general premises or principles that are already known to be true. In contrast, inductive reasoning is the process of drawing general conclusions based on observations of specific cases or data. In mathematics, inductive reasoning is used to identify patterns or relationships by observing specific examples, which are then generalized into a broader conclusion.

This study adopts the definition and indicators of mathematical reasoning synthesized from several existing definitions and indicators. Mathematical reasoning is the ability to think critically and logically in the process of drawing conclusions about mathematical problems. Based on the indicators mentioned by Sumarmo, the National Education Regulation No. 56 of 2004, and NCTM, relevant indicators were selected in alignment with the adopted definition. The use of these indicators ensures that the reasoning concept applied in this study is more relevant and aligns with the research objectives while also facilitating measurement processes, as the indicators become more structured and contextual. The mathematical reasoning indicators used in this study are outlined in Table 1 below.

Table 1. Indicators of Mathematical Reasoning Ability

No	Indicators of Mathematical Reasoning Ability
1	Presenting mathematical statements in written form, drawings, or diagrams.
2	Applying patterns or relationships to derive an explanation of a mathematical situation
3	Manifesting calculations using fixed formulas
4	Drawing conclusions

Observations and interviews with mathematics teachers of ninth-grade students at SMP Negeri 22 Semarang revealed that many students still struggle to solve contextual problems. Students tend to be reluctant to work on problems and easily give up when faced with word problems. A preliminary ability test was administered to eight classes, each consisting of 30 or 32 students. One example of student work can be seen in Figure 1.

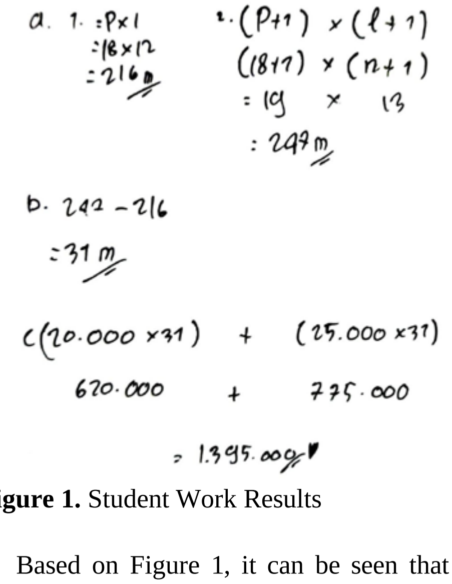

Figure 1. Student Work Results

Based on Figure 1, it can be seen that students have difficulty formulating problems and drawing conclusions on questions. Students also appear less able to plan solutions appropriately. The results of the initial ability test showed that only 16% of students were able to solve mathematical reasoning problems using all three indicators. Meanwhile, 34% of students managed to solve problems using two indicators of mathematical reasoning ability. This data indicates that the majority of students have not yet met all four indicators of mathematical reasoning ability.

Several factors influence students' mathematical reasoning abilities, including a lack of mastery of prerequisite material, inadequate problem-solving planning, and a lack of accuracy in calculations (Rismayanti & Komala, 2017). In formulating and generalizing a problem, each student naturally has different problem-solving methods (Rohmah et al., 2020). Every individual has distinct characteristics in terms of thinking ability, problem-solving skills, and ways of acquiring, storing, and applying knowledge. According to Yoga Suratman et al. (2019), one possible cause of differences in students' reasoning abilities is the variation in cognitive styles among students.

Cognitive style is a fundamental aspect of cognitive activity that refers to how individuals think, learn, and solve problems in relation to others (Witkin, 1976). Cognitive styles are stable and consistent with a person's behavior (Witkin et al., 1977b). Cognitive style serves as a bridge between intelligence and personality, reflecting how individuals receive, store, think about, and use information to solve problems and make decisions. Each student's mathematical reasoning ability naturally differs and can be influenced by their cognitive style (Witkin et al., 1977).

Witkin identified two types of cognitive styles: Field Independent and Field Dependent. According to Khoiriyah (2013), students with a Field Dependent cognitive style tend to rely on their surroundings to respond and process information holistically. These students are capable of analytical thinking, tend to be extroverted, have strong interpersonal skills, and enjoy interacting with teachers and peers during tasks. Conversely, Field Independent students are less interested in external events and more focused on their own ideas and concepts. They prefer minimal interaction and may appear less socially engaging. However, they are able to solve problems efficiently and accurately. The cognitive style grouping categories according to Zakiah (2020) are presented in Table 2.

Table 2. Cognitive Style Categories

Score	Cognitive Style Categories
$0 - 11$	Field Dependent
$12 - 18$	Field Independent

One of the reasons for students' low mathematical reasoning ability is their lack of engagement in the learning process (Rismayanti & Komala, 2017). The Guided Inquiry learning model provides opportunities for students to practice reasoning skills through self-conducted investigations. In this learning model, teachers act as facilitators and guides, creating conditions that allow students to construct their own understanding. According to Nurtamam et al. (2024), implementing the Guided Inquiry model significantly enhances mathematical reasoning compared to conventional teaching methods, particularly in analyzing mathematical problems, formulating arguments, and evaluating alternative solutions. However, the Guided Inquiry model alone may not be sufficient in fostering students' questioning and communication skills. Therefore, an additional teaching aid or medium is needed to help students formulate problems.

Educational media is a crucial tool that strengthens the connection between teachers and students (Yanuarti & Rusman, 2019). This media can take the form of teaching aids or technology-based tools suited to the subject matter. One such learning medium is the Question Card. A Question Card is a card containing questions related to the studied material, which students are required to answer (Rohmah et al., 2019). The use of Question Cards provides students with initial questions to stimulate their interest in the learning process.

Based on the discussion of the issues outlined above, this study applies the Guided Inquiry model from the perspective of students' cognitive styles, assisted by Question Cards, to analyze students' mathematical reasoning abilities. The objectives of this study are to analyze the effectiveness of the Guided Inquiry model assisted by Question Cards in enhancing students' mathematical reasoning, to describe students' mathematical reasoning based on cognitive style in the Guided Inquiry model assisted by Question Cards, and to analyze students' reasoning abilities in relation to their cognitive styles.

2. Methods

This section describes when the research has been performed. The researchers explain experimental design, equipment, data collection methods, and control types. Authors describe the research area, location, and also explain the work done. The general rule to keep in mind is that this section should describe in detail and clearly so that the reader has the basic knowledge and techniques to be duplicated.

The method used in this research is a mixed-method approach. According to Sugiyono (2017), a mixed method is a research approach that combines quantitative and qualitative methods simultaneously, but with different weightings. The use of the quantitative method aims to determine the effectiveness of the impact of Guided Inquiry learning on students' mathematical reasoning abilities. Simultaneously, the qualitative method is used to focus on students' mathematical reasoning skills, utilizing Question Cards and examining the influence of cognitive styles in the implementation of the Guided Inquiry learning model.

The quantitative method in this study employs a Quasi-Experimental Design using a post-test only control design. The first group is the experimental group, which applies the Guided Inquiry learning model assisted by Question Cards, while the other group uses the Problem-Based Learning model. Each group is given a mathematical reasoning ability test to measure students' mathematical reasoning skills.

The qualitative method used in this study serves as complementary data to the results obtained from the quantitative method. In this study, the qualitative method involves the GEFT test developed by Witkin et al. (1977) and interviews that support the quantitative data, specifically related to students' cognitive styles. The post-test only control design experiment is presented in Table 3.

Table 3. *Posttest Only Control Design*

Group	Sample	Treatment	Posttest
Experiment	R	X	O_1
Control	R	Y	O_2

Description:

R = The selection of experimental and control groups is done randomly

O_1 = *Post-test of the experimental group*

O_2 = *Post-test of the control group*

X = Learning treatment using the Guided Inquiry learning model assisted by Question Cards

Y = Learning treatment using the Problem-Based Learning model

This study focuses on ninth-grade students at SMP Negeri 22 Semarang in the 2024/2025 academic year, with a total of eight classes as the population. The sample was selected using a simple random sampling technique, where two classes were randomly chosen and divided into an experimental group using the Guided Inquiry model with Question Cards and a control group using Problem-Based Learning. The research subjects were selected through purposive sampling based on students' cognitive styles, determined by the GEFT test. They were then categorized into two groups: Field Dependent and Field Independent. Six students, consisting of three with high mathematical reasoning skills (Field Independent) and three with low mathematical reasoning skills (Field Dependent), were selected for interviews. The independent variables in this study are the learning model and cognitive style, while the dependent variable is students' mathematical reasoning ability. Data collection used both quantitative and qualitative methods, including mathematical reasoning tests, GEFT tests, and interviews. The primary data obtained were analyzed to determine the effect of the learning model on students' mathematical reasoning abilities. The data collection technique involved tests consisting of mathematical reasoning questions and the GEFT test. The test instruments were first piloted to ensure validity, reliability, discriminating power, and difficulty level before being administered to the experimental and control groups.

The experimental group was given a Guided Inquiry learning model assisted by Question Card. The students' mathematical reasoning ability test was given at the end of the learning to measure the students' mathematical reasoning ability after the treatment given, while the control group was given a Problem Based Learning model and a mathematical reasoning ability test at the end of the learning to find out the effects of the treatment that had been given, while the GEFT test is a test instrument developed by Witkin (1973) in the form of picture questions to find out the type of cognitive style possessed by students. Data analysis was carried out by processing data from the instrument trial in the trial class to determine validity, reliability, discriminatory power, and level of difficulty. Data analysis includes quantitative and qualitative analysis. Data analysis is used to describe data so that conclusions can be drawn easily about population characteristics based on samples.

3. Results & Discussions

Quantitative data analysis was conducted on the results of the mathematical reasoning ability test for students in the class that received the Guided Inquiry learning model assisted by Question Cards and the class that received the PBL model. Qualitative data analysis was carried out through data triangulation, combining the results of the mathematical reasoning ability test with subject interviews. The analysis and discussion of both quantitative and qualitative data on students' mathematical reasoning ability tests are presented as follows.

3.1. Result and discussion Quantitative

The results of the initial data prerequisite test indicate that the sample classes used in the study—those taught using the Guided Inquiry learning model assisted by Question Cards and those taught using the PBL model—have a normal data distribution, homogeneous variance, and no significant mean difference between the two classes. Thus, both samples come from the same conditions. In this study, class IX G was assigned the Guided Inquiry model assisted by Question Cards, while class IX H was assigned the PBL model.

In Hypothesis 1, a classical completeness test was conducted, showing that students' mathematical reasoning ability using the Guided Inquiry model assisted by Question Cards achieved classical completeness. From the standard normal table with probability $(0.5 - \alpha)$ with $\alpha = 5\%$, the critical value is $Z_{table} = 1.645$. Based on calculations using Excel, the obtained value is $Z_{calculated} = 1.89 \geq Z_{table}$, so H_0 is rejected, meaning that students in the Guided Inquiry learning model assisted by Question Cards achieved classical completeness in the mathematical reasoning ability test. This completion is inseparable from the learning tools used, where the Guided Inquiry learning model accustoms students to understand concepts by conducting investigations under the guidance of teachers. The Question Card media used in the study has been made with an attractive appearance containing questions that must be solved by students. Bruner's learning theory emphasizes the existence of an active search process by individuals and produces effective and meaningful learning (Nugroho et al., 2013). The Guided Inquiry learning model assisted by Question Cards also guides students in the process of thinking about what has been learned so that they can understand and find concepts while remaining under the guidance of teachers. According to Vygotsky's theory, students need to learn through interactions with teachers, parents, and peers. Through this interaction, students can develop new ideas, gain knowledge, and expand their intellectual abilities (Chandra & Anggraini, 2015). The Guided Inquiry learning model assisted by Question Cards is implemented in groups under the guidance of teachers, thus creating social interactions that facilitate the exchange of ideas between individuals.

In Hypothesis 2, a two-proportion difference test was conducted, showing that the proportion of students achieving completeness in mathematical reasoning ability with the Guided Inquiry model assisted by Question Cards was greater than that of students in the PBL model. From the standard normal table with probability $(0.5 - \alpha)$ with α = 5%, the critical value is $Z_{table} = 1.645$. Based on calculations using Excel, the obtained value is $Z_{calculated} = 2.19 \geq Z_{table}$ = 1.645, so H_0 is rejected, meaning that the proportion of students' mathematical reasoning ability in the Guided Inquiry model assisted by Question Cards is greater than that in the Problem-Based Learning model. The difference in learning devices used in the classroom with the Guided Inquiry learning model is the Question Card with an attractive question display. Each question is designed according to the material being studied and the questions are contextual so that they are relevant to everyday life (Devi et al., 2019). This is what guides students to be able to think so that students can understand and find concepts. Students also feel more interested in the existing questions because students can easily imagine them because the questions are contextual.

In Hypothesis 3, a two-mean difference test was conducted, showing that the average mathematical reasoning ability of students in the class with the Guided Inquiry model assisted by Question Cards was higher than in the class with the PBL model. The Guided Inquiry class achieved an average score of 83, with the lowest score being 52 and the highest 100, while the PBL class obtained an average of 77, with the lowest score being 48 and the highest 100. From the student t-distribution table with a probability of 0.95 and $df = 58$, the critical value is t_{table}= 1.670. Based on calculations, the obtained value is $t_{calculated} = 2.02 \geq t_{table} = 1.670$, so H_0 is rejected, meaning that the average mathematical reasoning ability test results in the Guided Inquiry model assisted by Question Cards are greater than or equal to the average test results in the Problem-Based Learning model. Although both models have their own advantages, in the context of this study, Guided Inquiry assisted by Question Cards proved to be more effective because the average class with the Guided Inquiry learning model assisted by Question Cards was more than the average class with the PBL model.

In Hypothesis 4, a simple linear regression test was conducted, showing that cognitive style influences students' mathematical reasoning ability in the Guided Inquiry model assisted by Question Cards. The regression coefficient test results showed $R^2 = 0.552$, meaning that students' mathematical reasoning ability in the Guided Inquiry model assisted by Question Cards is influenced by cognitive style by 55.2%, while the remaining 44.8% is influenced by other factors such as students' prior ability, teaching methods, learning environment, motivation, and other factors. In line with research conducted by Mirlanda & Pujiastuti (2018) which shows that the Field Dependent cognitive style influences mathematical reasoning ability by 14.6% and the Field Independent cognitive style influences mathematical reasoning ability by 31.3% that students with the Field Independent type have higher reasoning ability compared to students with the Field Dependent type.

3.2. Result and discussion Qualitative

3.2.1 Analysis of FI Subject Test and Interview Results

The results of the qualitative analysis show that students with a Field Independent (FI) cognitive style who were taught using the Guided Inquiry learning model assisted by Question Cards demonstrated superior mathematical reasoning abilities. Based on the mathematical reasoning ability test, in the indicator of presenting mathematical statements, FI students were able to clearly write down the given information and formulate the questions provided in the problem. This aligns with Yekti et al. (2016), who stated that students with an FI cognitive style can identify problems completely and systematically.

For the second indicator, which involves connecting facts or patterns to obtain mathematical representations, FI students were able to analyze and derive mathematical explanations from the given problems. This ability was evident in the GEFT test, where FI students found it easier to identify simple shapes within complex structures and could disregard irrelevant elements. This finding is supported by Ngilawajan (2013), who stated that FI students excel at distinguishing essential information from the context and are more selective in processing received information.

For the third indicator, which involves determining formulas, FI students sometimes did not explicitly write down the formulas. However, interview results showed that they were able to correctly state the formulas they used. This finding supports research by Janah et al. (2021), which states that FI students tend to be more effective in correctly applying mathematical formulas to solve problems.

For the fourth indicator, which involves drawing conclusions, FI students were able to provide results that aligned with their calculations, demonstrating accuracy in their mathematical reasoning. The following shows a picture of the work of FI type students on the indicator of presenting mathematical statements.

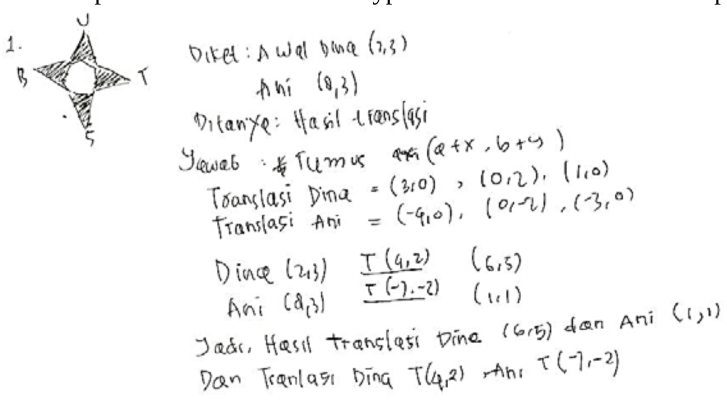

Figure 2. Student work type FI-1 Number 1

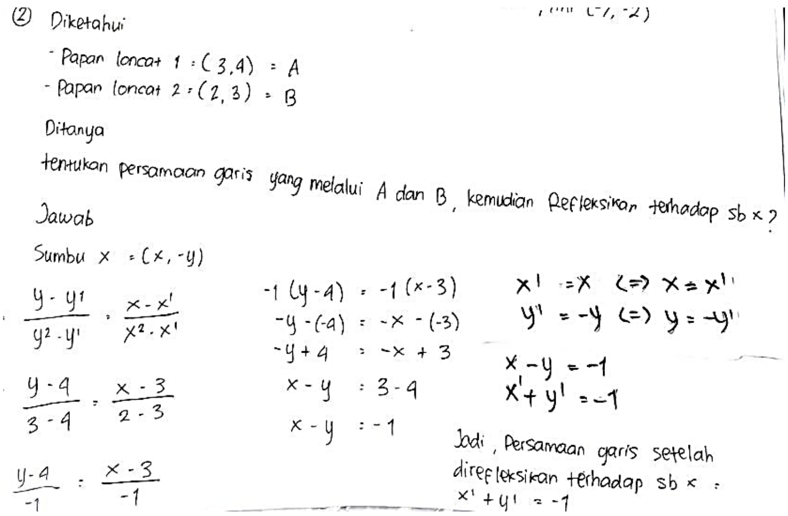

Figure 3. Student work type FI-2 Number 2

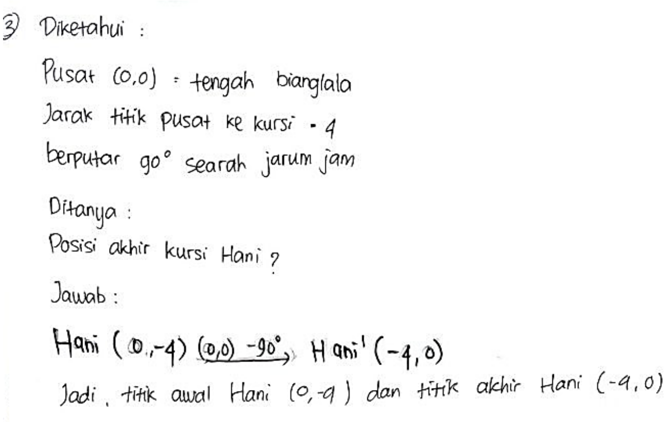

Figure 4. Student work type FI-2 Number 3

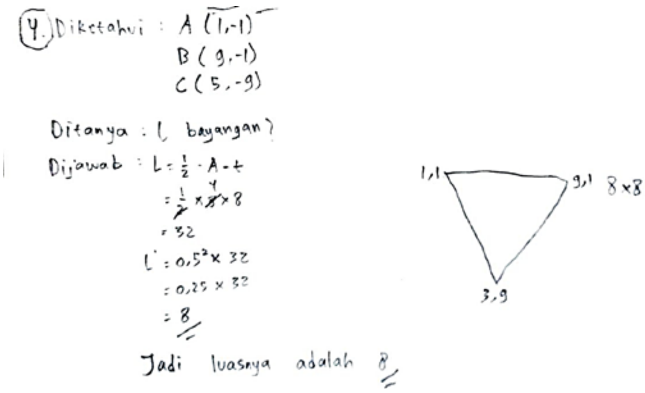

Figure 5. Student work type FI-3 Number 4

3.2.1 Analysis of FD Subject Test and Interview Results

Students with a Field Dependent (FD) cognitive style who were taught using the Guided Inquiry learning model assisted by Question Cards exhibited lower mathematical reasoning abilities compared to FI students. When presenting mathematical statements, FD students often struggled to clearly write down the given information and formulate the questions provided in the problem. This is in line with Ngilawajan (2013), who stated that FD students tend to be influenced by context and often struggle to filter essential information. This difficulty is reflected in their challenges in structuring mathematical statements and drawing conclusions. The following shows a picture of the work of FI type students on the indicator of presenting mathematical statements for question number 1.

When asked to connect facts or patterns to obtain mathematical representations, FD students had difficulty identifying the mathematical conditions and explanations in the problem. As a result, they often omitted these steps in their answers, indicating that they struggled to correctly connect facts or patterns. This is consistent with research by Wijaya (2020), which found that FD students tend to only absorb given concepts and struggle to reorganize received information.

When determining formulas, FD students did not write them in their answers because they had difficulty identifying the appropriate formulas for the given problem. This suggests that FD students struggle to determine and apply the necessary formulas. This finding is supported by Maswar et al. (2022), who stated that FD students tend to be slower in solving mathematical problems and often lack confidence in selecting appropriate steps or formulas. When drawing conclusions, FD students sometimes provided incorrect results based on their calculations, and some did not write conclusions at all. This indicates that FD students have difficulty drawing conclusions that accurately reflect their calculations. The following shows a picture of the work of FD type students on the indicator of presenting mathematical statements.

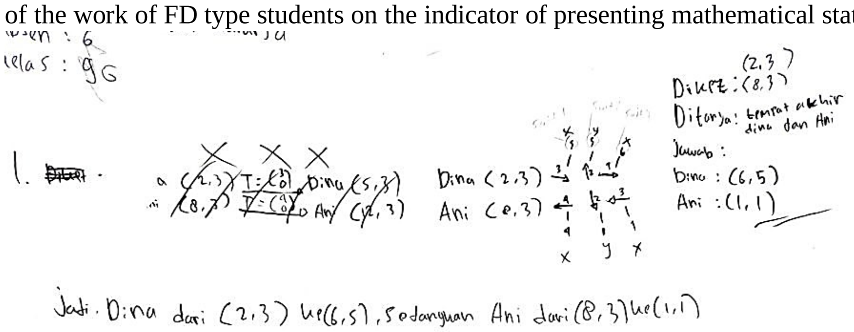

Figure 6. Student work type FD-1 Number 1

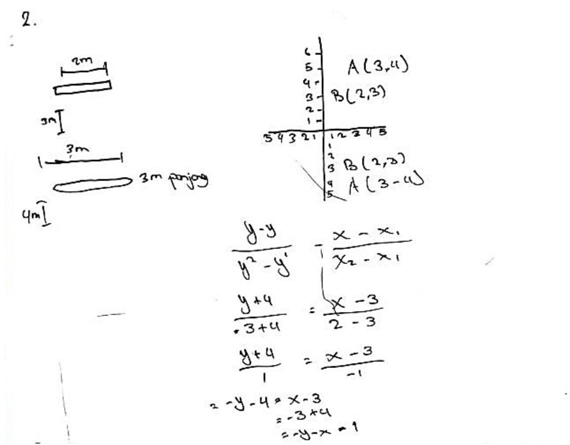

Figure 7. Student work type FD-2 Number 2

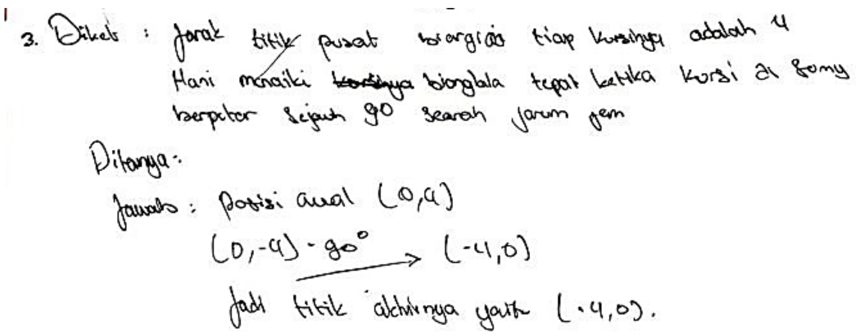

Figure 8. Student work type FD-2 Number 3

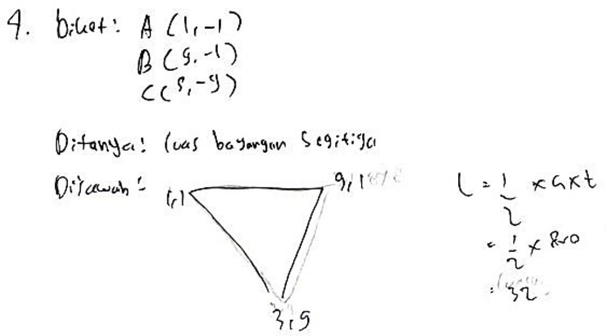

Figure 9. Student work type FD-3 Number 4

4. Conclusion

Based on the analysis and discussion, the conclusions are as follows: 1) Effectiveness of the Guided Inquiry Learning Model Assisted by Question Cards on Students' Mathematical Reasoning Ability which is marked with a) The results of the mathematical reasoning ability test on the topic of geometric transformations using the Guided Inquiry model assisted by Question Cards achieved classical mastery; b)The proportion of students who met the minimum mastery criteria (KKM) in the Guided Inquiry learning model assisted by Question Cards was higher than the proportion of students who met the KKM in the PBL learning model; c) The average test results of students' mathematical reasoning ability in geometric transformations with the Guided Inquiry learning model assisted by Question Cards were higher than the average test results of mathematical reasoning ability in geometric transformations with the PBL model; d) The influence of cognitive style on students' mathematical reasoning ability in the Guided Inquiry learning model assisted by Question Cards was 55.2%, while the remaining 44.8% was influenced by other factors; 2) Description of Students' Mathematical Reasoning Abilities Based on Cognitive Style (Field Dependent and Field Independent) which is marked with a) Subjects with FI cognitive style have higher mathematical reasoning ability compared to subjects with FD type. In the first indicator, FI subjects are able to present mathematical statements correctly. They can write and explain the information given in the problem and the questions asked correctly. In the second indicator, FI subjects successfully apply patterns or relationships to produce mathematical explanations. They can find mathematical conditions or explanations correctly, although some subjects do not write them completely. Furthermore, in the third indicator, some FI subjects can write the formulas used correctly. However, some others are less accustomed to writing formulas, although they are still able to find the correct answers. Finally, in the fourth indicator, FI subjects are able to draw conclusions accurately; b) Subjects with FD cognitive style tend to have lower mathematical reasoning ability compared to FI type subjects. In the first indicator, FD subjects are generally able to present mathematical statements correctly. However, some subjects do not include known information or questions asked in the problem. In the second indicator, FD subjects tend to have difficulty in applying patterns or relationships to produce mathematical explanations. Most of them do not write the requested mathematical explanation or conditions because they have difficulty describing the mathematical conditions according to the problem. In the third indicator, some FD subjects are able to write formulas correctly, although their understanding of the appropriate formulas to solve the problem is still lacking. Finally, in the fourth indicator, FD subjects tend to be less able to draw conclusions correctly. Some do not complete the answers on the worksheet, while others provide incomplete answers.

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