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Student's Logical Reasoning Ability in Terms of Sequential Thinking Style

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Abstract

Logical reasoning ability plays an important role in serving students understand and solves mathematical problems. The students' thinking style is one factor that affects how students solve problems. This study aims to reveal the student's logical reasoning ability based on a sequential thinking style. This research used a qualitative approach with a case study design. The subjects of this study included 15 grade 8 students due to limited access during the Covid-19 pandemic. We used Gregorc's thinking style questionnaire to classify students' thinking styles and three straight-line equation problems to reveal students' logical reasoning abilities. Four students, two for concrete and abstract sequential thinking styles, were interviewed to demonstrate their logical reasoning abilities. The results showed differences in students' logical thinking abilities in terms of thinking styles on constructing and establishing assumptions, assessing and testing, establishing generalizations, and determining conclusions indicators. Thus, it can be concluded that the thinking style can affect the students' logical reasoning abilities.

Abstrak

Kemampuan penalaran logis berperan penting untuk membantu siswa memahami dan menyelesaikan permasalahan matematika. Gaya berpikir siswa merupakan salah satu faktor yang mempengaruhi cara siswa memecahkan masalah. Penelitian ini bertujuan untuk mengungkap kemampuan penalaran logis berdasarkan gaya berpikir sekuensial. Penelitian ini menggunakan pendekatan kualitatif dengan desain studi kasus. Subjek penelitian ini meliputi 15 siswa kelas VIII dikarenakan keterbatasan akses pada masa pandemi. Peneliti menggunakan angket gaya berpikir Gregorc untuk mengklasifikasikan gaya berpikir siswa dan tiga soal tes materi persamaan garis lurus untuk mengungkap kemampuan penalaran logis siswa. Empat orang siswa, masing-masing dua siswa untuk gaya berpikir sekuensial konkrit dan abstrak, diwawancarai untuk menggali kemampuan penalaran logis siswa. Hasil penelitian menunjukkan terdapat perbedaan kemampuan berpikir logis siswa ditinjau dari perbedaan gaya bepikir sekuensial konkrit dan abstrak pada indikator membangun dan menetapkan asumsi, menilai dan menguji, menetapkan generalisasi dan menentukan kesimpulan. Dengan demikian dapat disimpulkan bahwa gaya berpikir dapat mempengaruhi kemampuan penalaran logis siswa.

Keywords: *Logical Reasoning Ability; Thinking Style; Concrete Sequential; Abstract Sequential*

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INTRODUCTION

Students' logical reasoning ability plays a vital role in understanding and improving mathematics skills (Ayuningtyas, Mardiyana & Pramudya, 2019). Roman, Gein and Gerkerova (2017) also argue that logical reasoning ability helps students in the successful mastery of mathematics subjects. Logical reasoning ability is a guideline for operations in mathematics, making mathematics one of the most intensive activities used by students in developing their logical reasoning abilities (Apaydin & Cenberci, 2018).

Today, mathematics learning yet facilitates students as the center of learning. As a result, students are less able to understand the material and tend to memorize the fact, principles, or procedures in mathematics. Besides, this learning situation causes the students' logical reasoning abilities low (Astuti, 2017). Students' logical reasoning ability is less able to develop because students are less trained in developing reasoning skills in solving problems and implementing mathematical concepts in real life (Nani, 2016). The low logical reasoning ability of students is a significant problem that needs to be solved to improve the quality of learning (Lanani, 2015)

Logical reasoning ability is a type of reasoning that prioritizes the investigation of information to obtain new knowledge (Utomo, Rahman & Fikrati, 2020). The reasoning is an attempt to make conclusions using the logic of rules based on pre-existing assumptions, principles, properties, and evidence (Khotimah & Masduki, 2019). Bronkhorst, Roorda, Suhre and Goedhart (2020) argue logical reasoning abilities include interpreting information from a particular context, making connections, and drawing conclusions based on the information provided. Fauziah, Minggi and Talib (2016) define logical reasoning as a step to draw logical conclusions in solving problems, including thinking systematically, setting arguments correctly and drawing conclusions. In this study, researchers use indicators of logical reasoning: collecting facts, building and establishing assumptions, assessing or testing assumptions, establishing generalizations, building supporting argumentation, examining or testing the correctness of argumentation, and determining conclusions (Dewi, Zahara & Handoko, 2019).

Students' logical reasoning abilities are closely related to thinking styles. According to Apriliana, Handayani and Awalludin (2019), a well-formed thinking pattern will create reasoning and logical thinking. Hence, thinking cannot be separated from the process of reasoning (Fauzi, Rahmatih, Indraswati & Husniati, 2020). Thinking also involves problem solving, decision making and logical reasoning (Apaydin & Cenberci, 2018).

One of the factors affecting problem-solving skills is the characteristics of the student's way of thinking (Rahmah, Adila, Mardiyana & Saputra, 2021). The thinking style and logical reasoning are essential role in solving problems (Saygili, 2017). Thinking style is a mindset that distinguishes how students receive and process information during learning and use the information in solving problems (Muflihah, Ratnaningsih & Apiati, 2019). Mohamed and Alghraibeh (2015) consider the thinking style as a brain dominance that can make a person select a strategy to solve a problem and adapt to his abilities. Wardani, Mardiyana and Subanti (2016) argue that the thinking style is a way of looking at a problem and how to respond it.

A person who studies mathematics tends to carry out thought processes (Susiaty, Prihatin & Hartono, 2021). Students' thought processes can run well if teachers

actively participate in learning (Nugroho, Nizarudin, Dwijayanti & Tristianti, 2020). According to Silwana, Subanji, Manyunu and Rashahan (2021), when a person cannot move from a particular situation to the desired position with an action, the other solution is to go through the thought process.

Gregorc divided thinking styles into four types, namely concrete sequential (CS), abstract sequential (AS), concrete random (CR), and abstract random (AR) (Rahmy, Usodo & Slamet, 2019). These four thinking styles are present in every learner, however, one is more dominantly used (Zakir, 2015). Students in the sequential thinking style category tend to have left-brain dominance, while students in the random category tend to have right-brain power (Utami, Pramudya & Slamet, 2020).

According to Deporter and Hernacki (Fauziah et al., 2021), the CS style receives information according to reality and processes information logically, orderly, linearly, and sequentially. This thinking style uses physical senses such as sight, hearing, touch, taste, and smell to know reality. The CS style, like particular directions or orders and procedures, easily remember information, formulas, and special rules. Gregorc (in Toktarova & Panturova, 2015) explains that students with a CS style must be good at logical reasoning abilities, rules and facts.

Susanti et al. (2017) argue that the thinking style related to the ability of logical reasoning is the AS thinking style. According to DePorter and Hernacki (2016), AS style tend to think conceptually in analyzing the information. Their thinking processes are logical, rational, and intellectual. According to Masruroh, AS is a thinking style with high reasoning ability and tends to be critical and analytical (Utami et al., 2020). DePorter and Hernacki (as cited in Firdaus et al., 2019) argue that AS style prefers analyzing the situation before making a decision or acting.

Research on students' logical reasoning ability based on the thinking style in a straight-line equation material is still limited. Therefore, it is necessary to conduct in-depth research on students' logical reasoning abilities based on their thinking style in solving straight-line equation problems. This research will focus on students' logical reasoning abilities of CS and AS thinking styles.

The purpose of the study is to portray the differences in the student's logical reasoning ability of CS and AS thinking styles in solving straight-line equation problems. This research is significant in uncovering the relationship between logical reasoning ability and student learning styles, especially the Gregorc model. This study is helpful for teachers to design the appropriate mathematics learning strategies according to the students' characteristics.

METHOD

The research method used in this study is a qualitative approach with a case study design. This research was carried out at one of the state junior high schools in Klaten Regency. Due to access constraints during the pandemic, the subjects were selected from 15 8-grades students. The selection was carried out by first providing a questionnaire for grouping types of thinking styles adopted from the Gregorc thinking style questionnaire to subjects (DePorter & Hernacki, 2016). Based on the questionnaire, the number of students in each type of thinking style is presented in Table 1.

TABLE 1. Types of thinking styles

Types of Thinking Styles	Number of Students
Concrete Random	3
Random Abstract	4
Concrete Sequential	5
Abstract Sequential	3

Furthermore, students with a CS and AS style are given a test of logical reasoning ability. Then two students of each thinking style with the highest test scores were selected. The assessment rubric used to give scores on the logical reasoning ability test is presented in Table 2.

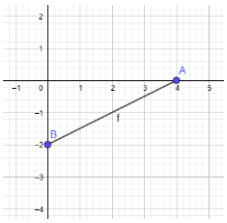
The data collection techniques result from logical reasoning ability tests and interviews. The test is carried out to determine the student's logical reasoning ability with CS and AS thinking styles. The test consisted of three questions of the straight-line equation that were closely related to reasoning. It takes good reasoning ability to solve the problem of straight-line equations (Adiyanti & Aini, 2019). Before research, the researcher compiled five questions to determine students' logical reasoning ability (Amelia, 2021). Based on the validation of two experts in mathematics education, it is recommended to use three questions. The problems are on the straight-line equation through points and parallel lines, straight line equation through points and gradients, and gradient value accompanied by figures as presented in Table 3.

Based on the test results, researchers interviewed the subjects to reveal information about students' logical reasoning abilities in the problem-solving process. The data was validated using triangulation techniques. Triangulation techniques are the use of different data

TABLE 2. Logical reasoning ability assessment rubric

Indicators	Description	Score
Gathering facts	Students are unable to explain all the facts available in the problem	0
	Students can explain all the facts in the problem, but incorrect	1
	Students can explain all the facts in the problem correctly	2
Determining the assumptions	Students are unable to explain the certain assumptions	0
	Students can explain certain assumptions, but incorrect	1
	Students can explain certain assumptions correctly, along with logical reasons	2
Examining the assumptions	Students are unable to explain the steps of the solution	0
	Students can explain the steps of the solution, but incorrect	1
	Students can explain the steps of the solution correctly	2
Determining the generalizations	Students are unable to explain the solution	0
	Students can explain the solution, but incorrect	1
	Students can explain the solution correctly	2
Constructing the supportive arguments	Students are unable to explain other ways to obtain the solution	0
	Students can explain other ways to obtain the solution, but incorrect	1
	Students can explain other ways to obtain the solution correctly	2
Checking the correctness of arguments	Students are unable to explain the steps of the solution in other ways to obtain the same result	0
	Students can explain the steps of the solution in other ways to obtain the same results, but incorrect	1
	Students can explain the steps of the solution in other ways to obtain the same result correctly	2
Drawing the conclusions	Students are unable to explain conclusions	0
	Students can explain conclusions, but incorrect	1
	Students can explain conclusions correctly	2

TABLE 3. Test of students' logical reasoning ability

No	Question
1	An equation of lines through points (-2,5) and parallel lines $x - 3y + 2 = 0$ a) Which line equation in the following answers is most appropriate for the problem without calculating? A. $3x - y = 17$ C. $x + 3y = -17$ B. $3x + y = 17$ D. $x - 3y = -17$ b) By calculating, determine the equation of the line
2	A straight-line intersection through a point $(0, -2)$ and gradients $m = \frac{3}{4}$ a) Which line equation in the following answers is most appropriate for the problem without calculating? A. $-3x + 4y + 8 = 0$ C. $3x + y + 8 = 0$ B. $x + 4y + 12 = 0$ D. $x - 4y + 8 = 0$ b) By calculating, determine the equation of the line
3	An equation of lines through points $A(4,0)$ and $B(0, -2)$, as in the following picture:  a) Which gradient value in the following answers is most appropriate for the problem without calculating? A. $m = -2$ C. $m = -\frac{1}{2}$ B. $m = 2$ D. $m = \frac{1}{2}$ b) By calculating, determine the gradient value of the line equation

collection to obtain data from the same source (Alfansyur & Mariyani, 2020). In this study, researchers used triangulation by comparing the results of logical reasoning ability tests and interviews. Data analysis techniques are guided by the Miles and Huberman model, which consists of data reduction, data presentation and verification or drawing conclusions (Sakiah & Effendi, 2021).

RESULT AND DISCUSSION

Result

This section presents the student's answers related to their logical reasoning ability with CS and AS thinking styles. Students with the CS style are coded by K1 and K2, and A1 and A2 code students of the AS style. The differences in the logical reasoning ability of both thinking styles are discussed.

Gathering Facts

Four subjects can correctly explain the known and asked information from the three questions in the gathering facts indicator. It is shown in the K1 answer related to question number 1, as presented in Figure 1.

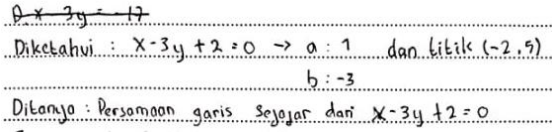


Figure 1. The answer to question number 1 by K1 on the indicator of collecting facts

Figure 1 indicates that K1 is able to write the known information on the first problem correctly, i.e., the equation of the lines $x - 3y + 2 = 0$ with $a = 1$ and $b = -3$ and the point $(-2,5)$. K1 is also able to write the asked information in the question, namely the parallel line equation of $x - 3y + 2 = 0$. This answer is supported by the excerpt of the interview with K1

"The information obtained from the problem is known to be the equation of the line $x - 3y + 2 = 0$ so obtained value $a = 1$ and $b = -3$, the point $(-2,5)$ and asked the equation of parallel lines."

Determining the Assumptions

Four subjects can correctly explain assumptions from the three questions in the building and establishing assumptions indicator. It is shown in the example of the answer of subject K1 related to question number 1 presented in Figure 2.

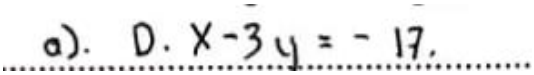


Figure 2. The answer to question number 1 by K1 on the indicator builds and sets assumptions

Figure 2 indicates that K1 writes the answer assumption correctly, that is, the line equation $x - 3y = -17$. Although all subjects can write assumptions correctly, there are differences in both thinking styles. Subjects with CS style can give logical reasons in conjecturing their assumptions. This is shown in the excerpt of the interview with K1 related to question number 1. K1 says, "I chose that answer because first I look for one whose pattern is the same as the equation of the line $x - 3y + 2 = 0$. So, it is likely the shape of the equation of its lines that contains $x - 3y$ or $3y - x$. Among the four answer choice options, the corresponding answer is $x - 3y = -17$." Conversely, students with AS cannot argue the reasons in conjecturing their assumptions. This is shown in the excerpt of an interview with A1 related to question number 1 "I am confused, so just guess."

Examining the Assumptions

In the indicators assessing or testing the assumptions, subjects with CS thinking style can write the steps used in solving the problem correctly. This is shown in the example of the K2 answer related to question number 3 (see Figure 3).

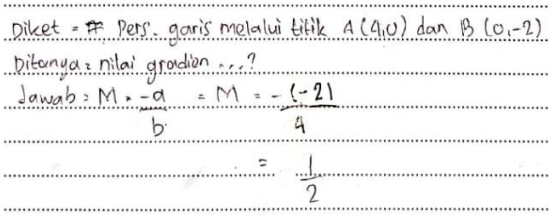


Figure 3. Answer to question number 2 by subject K2 on indicators assessing or testing assumptions

Figure 3 shows that K2 writes the steps on the solution, starting from writing down what is known and what is asked from the question first. Then K2 writes the formula $m = \frac{a}{b}$. Next, K2 writes $m = -\frac{(-2)}{4}$. Then K2 writes $m = \frac{1}{2}$ as the solution to the problem. This is in line with the results of an interview with K2 "After I obtained what was known from the question, namely point A(4,0) and point B(0,-2), and asked the gradient value. I try to solve it using the formula $m = \frac{a}{b}$. From these two points, the value of $a = -2$ and $b = 4$, then I substitute to the formula just now, so $m = -\frac{(-2)}{4}$. After that, I simplify the result $\frac{1}{2}$."

On the other hand, the subject with AS thinking style is written the steps for solving the problem incorrectly. This is shown in the example of the A2 answer related to question number 3, as presented in Figure 4.

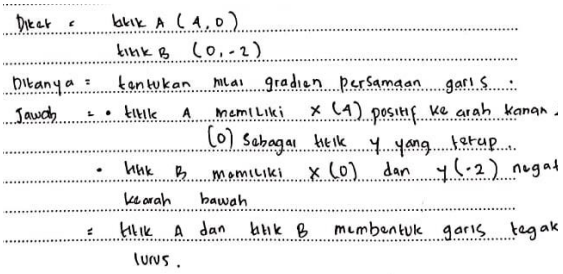


Figure 4. The answer to question number 3 by A2 on the indicator of assessing or testing assumptions

Figure 4 shows that A2 able to write the known and asked information from the question first, then writes the steps of the solution correctly. A2 is also able to write the first statement that point A has $x(4)$ positive value, so towards the right and y (0) is a fixed point. Then A2 writes the second statement that point B has $x(0)$ and $y(-2)$ is negatively valued so that it is towards the bottom. Next, A2 writes the last statement: points A and B form a perpendicular line. This answer is in line with the excerpt of the interview with A2 "I am also confused, why I can answer this. For point A, $x(4)$ is a positive value, so the direction to the right and $y(0)$ are fixed points. While point B has $x(0)$ then $y(-2)$ negative value, so the direction to the bottom. So that points A and B form a perpendicular line".

Determining the generalizations

In the indicators establishing generalizations, subjects with CS style can write the solution to the problem correctly. This is shown in the example of the K1 answer related to question number 2 as presented in Figure 5.

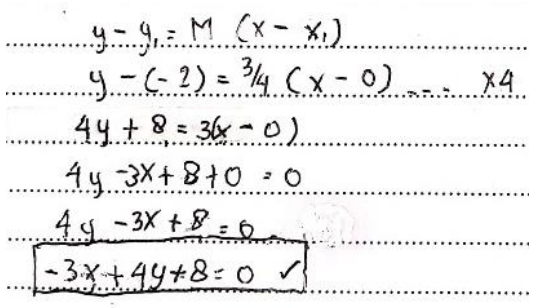


Figure 5. The answer to question number 2 by K1 on the indicator establishes generelation

Figure 5 shows that K1 writes the solution of solving the problem correctly, namely $-3x + 4y + 8 = 0$. This is also in line with the excerpt of an interview with K1 "So the straight-line equation is $-3x + 4y + 8 = 0$."

In contrast, the AS style subject can incorrectly write the solution steps. This is shown in the example of the A1 answer related to question number 2, as presented in Figure 6.

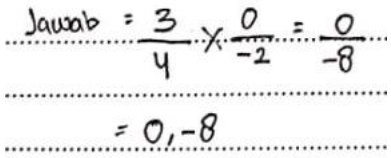


Figure 6. The answer to question number 2 by A1 on the indicator establishes generalization

Figure 6 indicates that A1 writes that the solution to the problem is 0,-8. However, the solution is incorrect. The interview excerpt supports this answer: "So the result is 0,-8."

Constructing the supportive arguments

The four subjects on all three problems could not construct a supportive argument. The answer sheet shows that the they did not write other ways to obtain the solution. This is also following the excerpt of an interview with one of the subjects, K1, related to question number 2, which says, "I have no other way to find straight line equations. I only know the formula $y - y_1 = M(x - x_1)$."

Checking the correctness of arguments

The four subjects on all three problems cannot check the argument's correctness. This can be seen in the answer sheet, where they do not write the steps to check the correctness of the solution. This is supported by the excerpt of an interview with one of the subjects, A2, related to question number 2, which says, "I can't check whether my answer is correct or not"

TABLE 4. Comparison of Logical Reasoning Ability of CS and AS

Indicators	CS	AS
Gathering facts	Students can explain the available information in the problem correctly	Students can explain the available information in the problem correctly
Determining the assumptions	Students can explain the assumptions correctly and provide logical reasons for determining their assumptions	Students can explain the assumptions correctly, but cannot give logical reasons and tend only to guess to determine their assumptions
Examining the assumptions	Students can explain the steps of the solution systematically	Students are unable to explain the steps of the solution systematically
Determining the generalizations	Students can write the solution correctly	Students tend to obtain the solution based on calculations, but incorrect
Constructing the supportive arguments	Students are unable to explain other strategies to obtain the solution	Students are unable to explain other strategies to obtain the solution
Checking the correctness of arguments	Students are unable to explain the steps of the solution using other strategies	Students are unable to explain the steps of the solution using other strategies
Drawing the conclusions	Students can explain conclusions correctly	Students are unable to explain conclusions

Drawing conclusions

In the indicator of establishing conclusions, a subject with a CS thinking style can write a statement of conclusions based on the results of solving the problem. This is shown in the answer of K2 related to question number 3 presented in Figure 7.

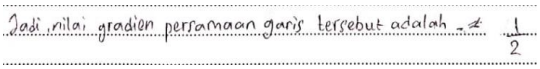


Figure 7. The answer to question number 3 by K2 on the indicator sets the conclusion

Figure 7 shows that K2 writes the conclusion correctly, i.e. the gradient value of the line equation is $\frac{1}{2}$. This is in line with the excerpt of the interview with K2 "So the conclusion in question number 3 is that the gradient value is $\frac{1}{2}$." In contrast, the AS style subject cannot write conclusions on the answer sheets.

Discussion

The comparison of the logical reasoning ability of students with CS and AS thinking style in solving straight-line problems are presented in Table 4. The table shows that all subjects can explain information in the problems correctly. They can correctly write and explain the known and asked information in the problems. This is supported by previous research that students with a CS thinking style can collect facts systematically by writing the information in the problem (Upu & Sulfianti, 2018). Nurhami et al. (2022) and Fitriana et al. (2019) also explain that students with AS thinking styles can understand the available information on the problem. Hence, there are no differences in students' logical reasoning ability on the gathering facts indicator.

Furthermore, in determining the assumptions, students with CS thinking styles can correctly determine assumptions and provide logical reasons for

guessing their assumptions. They can write the answers correctly based on the choices available on the questions and explain the process of determining the assumptions. This is supported by previous research that students with CS thinking styles are able to guess the assumptions (Fauziah et al., 2021). On the other hand, students with AS thinking styles, while able to determine the assumptions appropriately, are unable to provide logical reasons and tend to guess. This is in line with Firdaus et al. (2019) that students with AS thinking styles cannot provide reasons to determine the assumptions.

In examining the assumptions, students with a CS thinking style can systematically explain the steps of the solution. This is supported by previous studies that students with a CS thinking style are able to explain the steps of the solution on the answer sheet clearly and systematically (Isyrofinnisak, Kusmayadi & Fitriana, 2020). In contrast, students with AS thinking styles are unable to explain the steps of the solution systematically. It is also in accordance with previous research that students with AS thinking styles are unable to solve the problem correctly and systematically (Muflihah et al., 2019).

In the indicators establishing generalizations, CS students can explain the solution appropriately. This is in line with the previous studies that students with a CS thinking style are able to find patterns or mathematical properties to make generalizations (Fauziah et al., 2021). In contrast, AS thinking style students are unable to explain the steps to solve the problem appropriately. The findings also follow the research by Kristanti and Kriswandani (2018) that the lack of understanding of concepts causes AS students are unable to answer the problems correctly.

On the indicators of building supportive arguments, all subjects are unable to explain other ways to obtain the solution. Previous studies also revealed that students with a CS thinking style only focus on using one way to solve problems. They cannot provide other strategies to solve the problems (Firdaus, Nisa & Nadhifah, 2019). Other studies have also revealed that students with AS thinking styles are unable to provide other ways or assumptions to obtain the solution in the first way (Lestanti et al., 2016).

On the indicator of checking the argument's correctness, all subjects cannot explain the steps of the solution using other strategies. Previous studies also showed that students with a CS thinking style did not re-examine the results of the answers that had been obtained (Rahmah & Saputro, 2021). Research by Patimah and Murni (2017) and Lestanti et al. (2016) also showed that students with AS thinking styles are less likely examine of problem-solving results.

In the last indicator, drawing the conclusions, CS students can explain the conclusions correctly. This is in line with the study by Fitriana et al. (2019) and Firdaus et al. (2019) which shows that students with a CS thinking style can draw conclusions correctly. In contrast, AS thinking style students are unable to explain conclusions correctly. This is in line with the previous studies, which stated that students with AS thinking style are unable to explain the conclusion correctly (Herlina; Susanti et al., 2017).

This research shows that students with CS and AS thinking styles have differences in solving mathematical problems in terms of logical reasoning indicators. Students' logical reasoning abilities are needed to help students understand mathematics, improve mathematics skills, and help students' successful mastery of mathematics (Ayuningtyas, Mardiyana & Pramudya, 2019; Roman, Gein & Gerkerova 2017). Understanding

students' thinking styles can help teachers formulate the appropriate strategies to improve students' logical reasoning ability in solving mathematical problems.

The finding of this study also reinforces previous studies that most students are unable to use other strategies or alternative ways to solve mathematical problems. Based on the characteristics of students who tend to imitate the teacher's problem-solving strategies, the less student's logical reasoning ability may be because the teacher did not present different strategies or alternative steps to solve mathematical problems. Thus, the finding can provide information related to the less teachers' ability to facilitate students to explore various alternative problem solving. The ability to solve problems using various methods or approaches is helpful for students to face the challenges of the various complex problems in the 21st century.

Although this research provides beneficial information for teachers, there is a limitation to this study. This study only focuses on subjects with CS and AS thinking styles. The other thinking style, namely CR and AR, have not been studied. Research on students with CR and AR thinking styles will provide more comprehensive research findings on the relationship between thinking styles and logical reasoning.

CONCLUSION

Students with a CS thinking style have different characteristics from students of AS thinking styles in solving mathematical problems regarding logical reasoning indicators. CS and AS thinking style students can explain the assumptions correctly on the indicator of determining the assumptions. CS students can provide logical reasons for their assumptions, whereas AS students tend to guess only. CS students can use systematic steps to solve problems on indicators examining the assumptions. In contrast, AS students are unable to solve problems using appropriate steps. Furthermore, on the indicators determining generalizations and drawing conclusions, CS students can solve problems and draw conclusions appropriately. Conversely, AS students are unable to solve problems and draw conclusions appropriately.

This finding provides valuable information that teachers need to understand students' thinking styles to be able to improve logical reasoning skills. Increasing students' logical reasoning will impact on students' ability to solve mathematical problems. Although this study provides significant information, the subjects used are limited to sequential thinking styles. Expanding the subject with another thinking style will provide insightful conclusions for this study.

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