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Students' Ability to Solve Arithmetic Problems Based on APOS Theory in Cognitive Styles Differences

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Abstract

This study describes the ability to solve systematic problems regarding field-dependent (FD) and field-independent (FI) cognitive styles in arithmetic material. Solving systematic problems based on the APOS theory (action, process, object, schema) describes the ability of each student's cognitive style. This type of research is descriptive, using a qualitative approach. The research subjects consisted of four students consisting of two students with an FD and two FI styles in class X SMA Negeri 1 Gemolong. Data collection methods are tests and interviews. The instruments in the research were the researchers themselves, the GEFT (Group Embedded Figure Test) test as an instrument in selecting research subjects, a test of the ability to solve arithmetic problems based on APOS and interview guidelines. The analysis technique used in this study is data reduction, data presentation, and conclusion. The results showed that students with a FI cognitive style were better at problem-solving than students with an FD cognitive style. Subject FI can solve mathematical problems systematically based on APOS theory, and FI can determine methods for solving mathematical problems and originate from their thoughts not influenced by other parties. Meanwhile, FD has difficulty solving problems systematically and understanding and making mathematical models, which tends to be problematic in understanding mathematical problems and solutions that do not originate from their thinking.

INTRODUCTION

Mathematics is a thought based on consistent and accurate reasoning rules. Therefore, mathematics can be used as a very effective thinking tool to look at various problems in mathematics or outside of mathematics. Mathematics is a science that has a vital role in education because many daily activities apply mathematics [1]. However, mathematics is still a very frightening thing for students. Not a few of those who only hear the word mathematics already imagine complex numbers and formulas. Most students feel that mathematics is complicated even though mathematics is compulsory at every education level [2]. Teachers are responsible in the student learning process to ensure that mathematics learning can be achieved as expected by determining the environmental conditions of students when learning where teachers are required to be innovative and creative [3]. The application of learning is generally carried out in one

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direction. The teacher is more dominant in learning; the teacher lectures while students are only limited to listening [4].

Two factors cause students to have difficulty learning mathematics: internal factors (from within the student), including IQ (Intelligence Quotient), student attitude or readiness, learning motivation, health, and sensory abilities. In comparison, external factors (from outside the students) include the lack of variety and learning methods that are applied when the teacher teaches, the use of instructional media that is not optimal, the less supportive infrastructure, and the family environment [5]. Teachers are expected to provide more space for students to be expressive and dare to speak. This can happen if there is good communication between students and teachers. Good communication is built by both parties. If only one party tries to build communication, achieving the learning objectives is challenging.

Handayani et al. [6] said that mathematics contains a collection of concepts and arithmetic operations, but in learning mathematics, students' understanding of concepts and understanding is more objective than developing calculation abilities. The level of understanding of each student's mathematical concepts differs, so they cannot be equated [7]. Conceptual understanding is the foundation for students' thinking in applying mathematics and using it in contextual problems [8]. Nurmutia stated that the ability to solve mathematical problems is an essential ability that must be possessed in learning mathematics so that it can develop and optimize analytical thinking, critical, creative, and other supporting abilities [9]. Problem-solving is one of the learning mathematics objectives. In order to achieve students who understand the material, a learning process is needed that is by students' interests. Teachers must understand each student's learning style by not equating all students with only applying a learning method.

Setyaningsih et al. explained that students are given demands to use their skills in solving mathematical problems in all conditions in other subjects and the real-world [10]. Cognitive style occupies an essential role in the process of developing skills and cognitive characteristics of students for the implementation of appropriate learning to know each individual's cognitive style, and cognitive style is a concept in determining attitudes, choices, or stable strategies to find out a person's unique way of receiving, remember, think, and solve problems in the problem-solving process [11]. Students can apply learning styles in the learning process and think by personality, solving everyday problems, and learning mathematics [12]. Supported by the opinion of Ratnah et al., cognitive style is an essential aspect of the learning process [13].

One of the varied dimensions of a cognitive style explored and applied in education is the FD and FI dimensions. Individuals with different cognitive styles have different ways of solving problems. Individuals with an FD cognitive style tend to understand problems globally or by the influence of the surrounding environment, so others easily influence them and find it challenging to use their conscience. However, FI can be better than FD because the surrounding environment does not easily influence individuals with a FI cognitive style, and can use their conscience in solving problems. Dede and Setyaningsih argue that FD is a person's tendency to understand existing information, be less good at expanding structures, and focus more on social aspects [14].

The Field Independent (FD) can analyze and syntactically the information obtained and develop a broader structure [14]. With a variety of cognitive styles, the cognitive processes of each student are likely different according to the information received by students [15]. Many

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students do not know their cognitive style, so here, the role of the teacher is vital in helping students find the cognitive style they already have and further develop these students' abilities.

Based on the results of the researcher's interview with the mathematics teacher at SMA Negeri 1 Gemolong, some students had difficulty understanding arithmetic material and found it challenging to convert the information contained in word problems to mathematical models. If this condition continues, it will be more difficult for students to complete the next stage because, at the initial stage, students have experienced difficulties. So from the start, students should emphasise understanding the concept of learning material.

APOS theory can assist teachers in analyzing students' understanding of arithmetic concepts so that teachers can determine the level of understanding of concepts and solve mathematical problems. APOS theory has four stages: *Action, Process, Object,* and *Schema.* APOS theory was first discovered by Ed Dubinsky in 1991 in "Reflective Abstraction in Advanced Mathematical Thinking." This APOS theory is developed from Piaget's theory of intellectual development, namely the ability to think abstractly [16]. In Rahayu's research, he stated that students are in four stages of mental mechanisms: interiorization, the action stage leading to the process stage. Encapsulation, namely the process stage leading to the object stage; coordination, namely the process stage leading to the process stage and de-encapsulation, namely the object stage leading to the process stage [17].

Based on these descriptions, it can be analyzed and given solutions to minimize misunderstandings in solving mathematical problems. As well as the factors that cause students' difficulties in the ability to solve mathematical problems, especially in arithmetic material, therefore the researchers conducted a study, "Students' ability to solve arithmetic problems based on the APOS (*Action - Process - Object - Schema*) theory in terms of differences in cognitive styles of SMA Negeri 1 Gemolong students.".

METHOD

This research is descriptive research with a qualitative approach. This research was conducted at SMA Negeri 1 Gemolong in November 2022. The population is class XB which consists of 36 students. The selection of the population class was based on suggestions from the mathematics teacher who taught class X and had met the criteria, namely (1) students who had received the arithmetic material taught by the teacher before conducting the research. (2) students can communicate fluently and explain each mathematical step to solve arithmetic problems. The determination of research subjects was seen from the GETF (Group Embedded Figures Test t) test results. Data collection methods are written tests and interviews.

The instrument in this study was, First, the GEFT Test (Group Embedded Figures Test t), the use of the GEFT test discovered by Witkin. The provisions for the GEFT assessment are given a score of 1 for the correct answer and 0 for the wrong answer, with a total score obtained from 0 to 18. If students get scores with a score range of 0-9, then these students are grouped as students with an FD cognitive style [18]. If students get scores with a score range of 10-18, these students are grouped with students with a FI cognitive style. After the GEFT test was completed, the researcher processed the results of the answers and was able to group students in class XB into two groups, namely the FD cognitive style group and the FI cognitive style group. Data were

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obtained from four students who were the subject of the study two students with an FD style and two with an independent field style. It can be seen that students have FD and FI cognitive styles.

Second, a test of the ability to solve arithmetic problems based on APOS by giving two questions about arithmetic material description to four selected subjects with the same questions and working time. The following is a test instrument to measure the ability to solve arithmetic problems based on the APOS theory used in this study.

1. SMA Negeri 67 Jakarta will hold a report card that all parents will attend. In a room, there will be 20 seats in the first row, and in each subsequent row, there will be five more seats than in the previous row. If there are 12 rows of chairs in the room, how many seats are there?
2. Pak Yanto is making a brick wall. The number of bricks in each layer forms an arithmetic sequence. If the number of bricks in the top layer is ten and the 32 layers that have been laid require 1,312 bricks, what is the number of bricks in the bottom layer?

The results of the student's answers were analyzed at each stage assessment. The results of this study obtained four subjects representing each cognitive style, two subjects with FD and FI cognitive styles. Third, the interview guide to the four selected subjects. Before implementing the three data collection methods, there was instrument validation that had been declared valid by the validator, namely the class X mathematics teacher. Through descriptive research with this qualitative approach, researchers could understand phenomena about the things experienced by research subjects presented in the form of descriptive words. What is described in this study is the ability of students to understand arithmetic material based on the APOS theory in terms of FD and FI cognitive styles.

RESULTS AND DISCUSSION

In carrying out the first test given the GEFT cognitive style test (Group Embedded Figure Test), the results obtained were five students in the Field Independent category and 31 students in the Field Dependent category. It can be seen that students have FD and FI cognitive styles.

Table 1. Cognitive Style Test Results

Cognitive Style	Score	The Number of students
FD	$0 \leq s \leq 9$	31
FI	$9 \leq s \leq 18$	5

Based on the criteria that have been described in the method selected by students as subjects, the subject initials in the study are:

Table 2. Selected Research Subjects

No	Code	Name	Cognitive Style
1	FD1	KVV	Dependent Fields
2	FD2	AK	Dependent Fields
3	FI1	DN	Independent Fields
4	FI2	IIM	Independent Fields

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The code used to make it easier to view student profiles, some of the codes used by researchers:

Q : Researcher
FD1 : Field Dependent Student 1
FD2 : Field Dependent Student 2
FI1 : Field Independent Student 1
FI2 : Field Independent Student 2
NS1 : Problem Number 1
NS2 : Problem Number 2

1. FD Student Arithmetic Problem Solving
   a. Subject FD1 question number 1

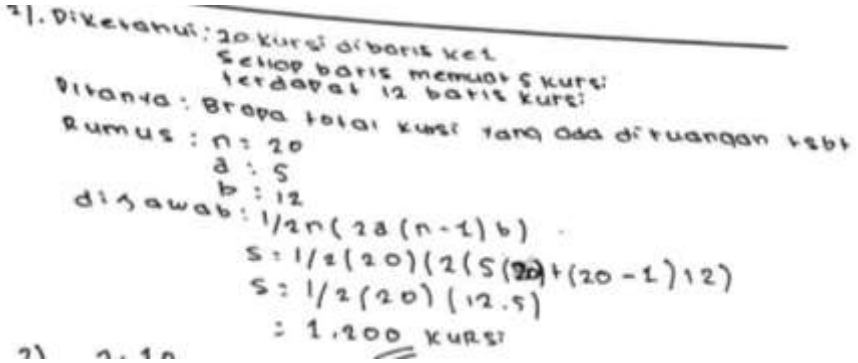

Figure 1. FD1-SN1 Solution

PSN1 : What is known and asked from the question?
KVV-SN1 : What is known from the question of 20 seats in row 1, each row contains five seats, and there are 12 rows of seats, Miss. If you are asked how many seats are in the room, Ms
PSN1 : Do you have difficulty determining what is known and what is asked and converting it into a mathematical model?
KVV-SN1 : Yes miss, I forgot
PSN1 : Try to explain where you got the formula you wrote!
KVV-SN1 : I do not know, miss, I forgot
PSN1 : How do you know that the solution uses this formula?
KVV-SN1 : I know that the total formula is Sn miss,
PSN1 : Are you sure about the Sn formula for solving this problem? $\frac{1}{2}n(2a(n-1)b)$?
KVV-SN1 : God willing, I am sure
PSN1 : Try to state the conclusion of your solution number 1!
KVV-SN1 : conclusion, so the total seats in the room are 1,200 seats

It can be seen in Figure 1 and interview excerpts that FD1-SN1 is in the action stage. Subjects answered "yes" when asked whether they had difficulty determining what was known and being asked and changing it in a mathematical model. Stages of the process, Process Subject explained that he did not know what formula to use. From the answers, the subject could not reflect on the problem given, so he could not find the solution

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formula. In the object stage, the subject uses the formula to solve the problem. The formula used is correct, but in the substitution process, it is not quite right, and during the interview, the subject admits that he is wrong in using the formula and does not understand how to solve it correctly. In schematic stages, the subject does not write conclusions on the answer sheet, but during the interview, the subject can determine the conclusions from the results of his work. However, it has not been able to connect actions, processes, and objects in problem-solving.

b. Subject FD1 question number 2

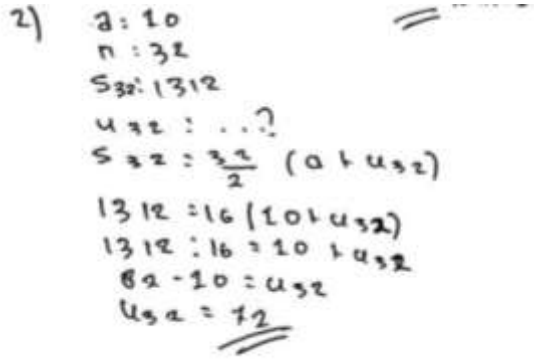

Figure 2. FD1-SN2 Completion

PSN2	:	How do you determine what is known and what is asked in the problem?
KVV-SN2	:	you know it is usually at the beginning and middle of the question sentence. You were asked about it at the end of the question, miss
PSN2	:	Please explain how to get known and asked!
KVV-SN2	:	the first is 10 layers of stone on the top so there are 10. There are 32 layers of stone so there are 32. Out of 32 layers, you need 1,312 bricks. That is what you know. If you ask how many bricks are in the bottom layer, I understand that is what you are looking for U_{32} , miss
PSN2	:	Why don't you write down the formula for solving problem number 2?
KVV-SN2	:	I do not know what formula to use, miss, because what was asked was the number of layers of bricks at the bottom of the 32nd layer, so use S_{32}
PSN2	:	Why don't you write down the formula used in the stages of this object?
KVV-SN2	:	I also forgot miss, I am in a hurry to substitute Miss immediately
PSN2	:	Try to explain how you solve the problem!
KVV-SN2	:	I use the formula $S_n = \frac{n}{2}(a + U_{32})$ I substitute the known numbers and get the result $U_{32} = 72$
PSN1	:	Why didn't you write the conclusion at the end of problem number 2?
KVV-SN1	:	I forgot to miss that at the end, there is a conclusion

It can be seen in Figure 2 and interview excerpts that FD1-SN2 were in the action stage, the subject could write down what was known and asked, but during the interview, the subject could not explain how to change the information in the problem into a mathematical model. At stages of the process, the subject did not write down what formula was used. The subject did not know what formula was used from the interview results. In

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the object stage, the subject directly substituted into the formula to solve the problem, but in the process, it was wrong. In the interview, the subject said that the formula used was a S_nRush formula and did not write down the process stage. In schematic stages, the subject does not write conclusions and cannot conclude the final results without knowing the relationship between the theory of action, processes, and objects in problem-solving.

c. Subject FD2 question number 1

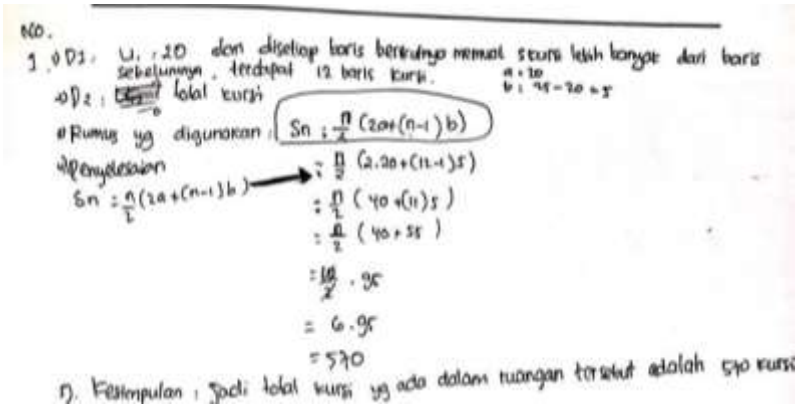

Figure 3. Completion of FD2-SN1

PSN1	:	What is known and asked from the question?
AK-SN1	:	On the question, $U_1$20 in each subsequent row contain five more seats than the previous row and 12 rows of seats. The total number of seats is asked, Ms.
PSN1	:	Do you still have difficulty determining what you know and what you are asked from story questions?
AK-SN1	:	Yes sis, I'm confused as to what the numbers are
PSN1	:	Try to explain where you got what you wrote!
AK-SN1	:	I use the formula $S_n$because if you look for the total, use the formula S_n, U_1it's 20, so a=20, each next row contains 5 more seats than the previous row, so b = 5, there are 12 rows of seats, you're asked for the total seats, Ms.
PSN1	:	How do you know that this solution uses the formulaS_n?
AK -SN1	:	Because what you asked was total, so you used the formulaS_n
PSN1	:	How do you conclude?
AK-SN1	:	From what you asked, because what was asked was the total number of seats available, so the conclusion is that the total seats in the room are 570 seats
PSN1	:	Can you explain the relationship between the action, process, and object of the solution you have worked on?
AK-SN1	:	I do not know, sis

It can be seen in Figure 3 and excerpts from the FD2-SN1 interview in the action stage that the subject answered "yes". Stages of the process: The subject can explain what formula should be used and why to use the formula. Stages of objects, Subjects use formulas in solving problems. The formula used is precise and can explain the calculation

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process in the settlement. In schematic stages, the subject can write conclusions on the answer sheet but cannot connect actions, processes, and objects in solving problems.

d. Subject FD2 question number 2

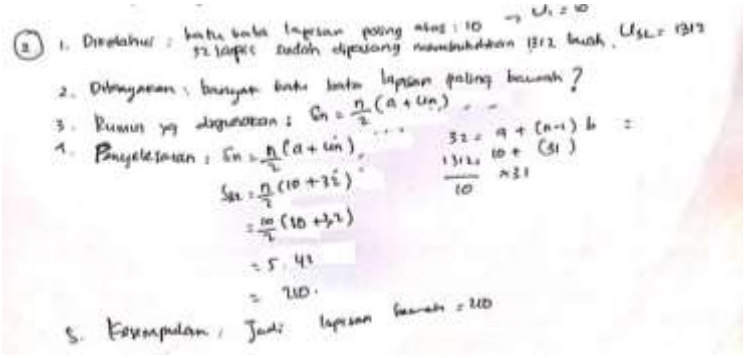

Figure 4. Completion of FD2-SN2

PSN2 : Please explain how to get known and asked!
AK-SN2 : In question, there is information that there are ten bricks at the top, meaning that $U_1 = 10$there are 32 layers for the first layer. 32 layers of bricks require 1,312, so$U_{32} = 1.312$
PSN2 : Do you still have difficulty determining what you know and what you ask from story questions?
AK-SN2 : Yes miss
PSN2 : What formula did you use, and why did you use the formula?
AK-SN2 : I'm using the formula S_n, Miss, because I'm looking for the total, Miss
PSN2 : How do you conclude?
AK-SN2 : Same as question number 1, from what you asked, because what was asked was the number of layers at the bottom, so the conclusion is that the bottom layer is 210 bricks.
PSN2 : Can you explain the relationship between the action, process, and object stages in solving the problem?
AK-SN2 : I do not know, sis

Action stage, the subject could write down what was known and asked, but during the interview, the subject could not explain how to get this known and asked. During stages of the process, the subject did not write down what formula was used. From the interview, the subject did not know what formula was used. In the object stage, the subject directly substituted into the formula to solve the problem, but in the process, it was wrong. In the interview, the subject said that the formula used was a S_nRush formula and did not write down the process stage. In schematic stages, the subject does not write conclusions. During the interview, the subject can only conclude the final results without knowing the relationship between the theory of action, processes, and objects in problem-solving.

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2. FI Student Arithmetic Problem Solving
   a. Subject FI1 question number 1

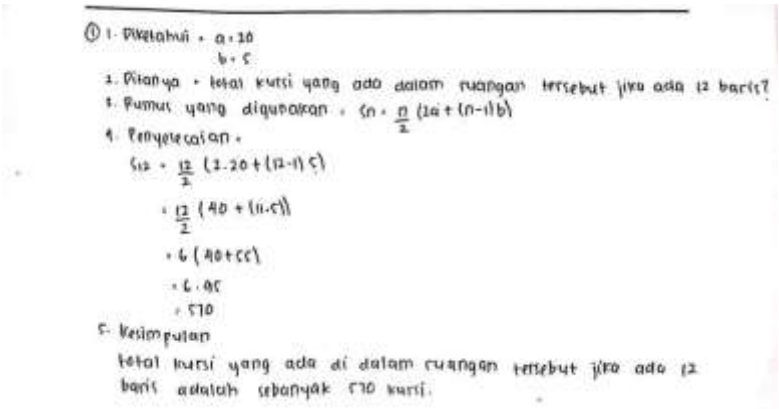

Figure 5. FI1-SN1

PSN1 : Try to explain where did you get what was known and asked
DN-SN1 : In the question, a sentence says a room is arranged with 20 seats in the first row U_1. The difference is five because each row adds five seats, which you know, miss. If you are asked if there are 12 rows of seats in the room, how many seats are there in that room, sis?
PSN1 : Why do you use the formula S_n?
DN-SN1 : Because those who were asked about the total number of seats, Miss
PSN1 : After knowing the formula, what do you do next?
DN-SN1 : I substituted any known numbers and was asked into the formula $S_n$miss, I divided and multiplied first the number that was less, then added and multiplied miss
PSN1 : How do you conclude?
DN-SN1 : From what was asked, miss, what was asked was a total, so the conclusion is that the total that was sought earlier obtained a total of seats
PSN1 : Can you explain again the results of your work from the known action stages to the conclusion of the schematic stages?
DN-SN1 : first, I searched to find out and was asked first, then I knew what was being asked and what formula to use, then I did it and got results, Ms.

It can be seen in Figure 5 and interview excerpts that FI1-SN1, in the action stage, the subject can determine what is known and asked and can change it into a mathematical model. At the process stage, the subject can explain why using the formula and reflect on problem-solving. In the object stage, the subject uses the formula and can solve the problem correctly. In schematic stages, Subjects can explain back the results from the action, process, and object stages.

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b. Subject FI1 question number 2

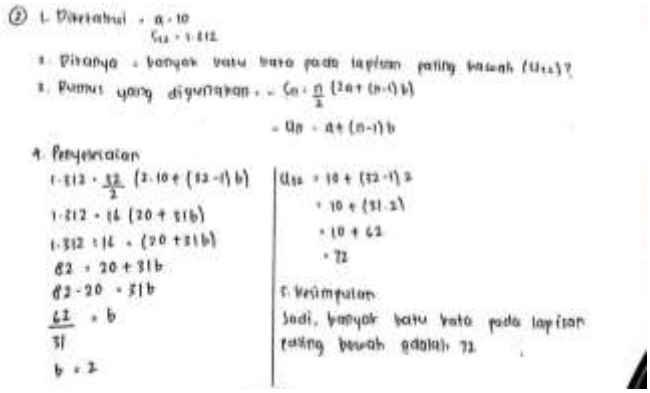

Figure 6. Completion of FI1-SN2

PSN2 : How do you determine what is known and what is asked in the problem?
DN-SN2 : It is the same as the first question, you know, it is usually at the beginning and the middle of the question sentence, asked about it at the end of the question, miss
PSN2 : Try to explain why you use two formulas!
DN-SN2 : I used the formula S_n to find the difference sis, from the formula S_n you got the difference and plugged it into the formula U_n to find U_{32} it sis
PSN2 : Can you explain again the results of your work from the known action stages to the conclusion of the schematic stages?
DN-SN2 : I searched to find out and was asked about the problem, then decided on a formula, continued to solve it, then concluded, Ms.

It can be seen in Figure 6 and interview excerpts that FI1-SN2, in the action stage, the subject can determine what is known and asked and can change it into a mathematical model. At the process stage, the subject can explain why using the formula and reflect on problem-solving. In the object stage, the subject uses the formula and can solve the problem correctly. In schematic stages, Subjects can explain back the results from the action, process, and object stages.

c. Subject FI2 question number 1

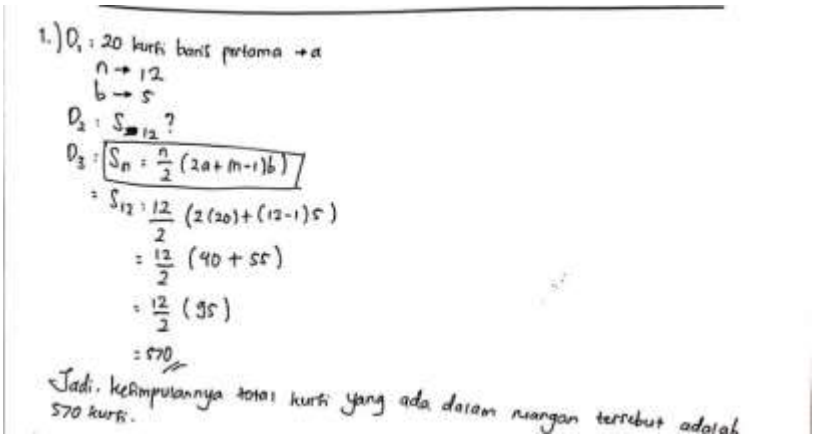

Figure 7. Completion of FI2-SN1

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PSN1 : How do you determine what is known and what is asked in the question?
IIM-SN1 : After looking at the numbers and reading them, I can tell that you know, for example, if there are a number 20 rows of seats in the first row, it means that if you ask questions, they are usually at the beginning or end of your questions, often at the end, miss.
PSN1 : why do you use the formula S_n?
IIM-SN1 : S_n to find the number, miss, from what is known, it can be entered into the formula S_n
PSN1 : How do you conclude?
IIM-SN1 : From what was asked about Ms
PSN1 : Can you explain again the results of your work from the known action stages to the conclusion of the schematic stages?
DN-SN1 : Yes, ma'am. First, I looked for information and was asked the questions. After that, I found out what formula was used from what was known and asked, and then the same goes for solving using the formula and getting results. The results are conclusions and answer Miss's question.

It can be seen in Figure 7 and interview excerpts that FI2-SN1 is in the action stage. The subject can determine what is known and asked and change it into a mathematical model. At the process stage, the subject can explain why using the formula and reflect on problem-solving. In the object stage, the subject uses the formula and can solve the problem correctly. In schematic stages, Subjects can explain back the results from the action, process, and object stages.

d. Subject FI2 question number 2

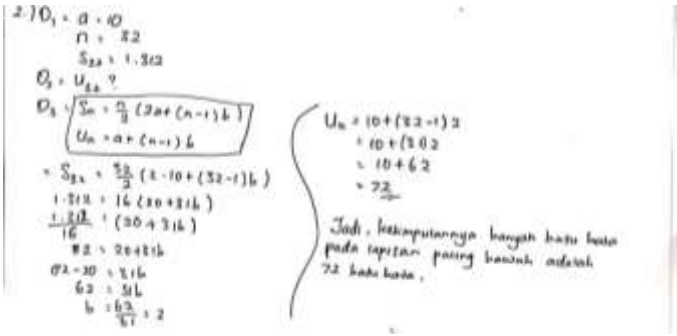

Figure 8. Completion of FI2-SN2

PSN2 : How do you determine what is known and what is asked in the problem?
IIM-SN2 : After reading it, you can know what the number in the question is, miss
PSN2 : Give an example
IMM-SN2 : If there is a number 32, then 32 is the layer, miss, it means you know the U
PSN2 : How about those who were asked?
PSN2 : Why do you use two formulas?
IMM-SN2 : The formula $S_n$to find out the difference, miss, $U_n$to find the 32nd layer
PSN2 : What do you do next after knowing you must use the formula?
IIM-SN2 : I searched using the formula $S_n$first, miss, to find out the difference. After knowing the difference U_n, I used the formula. After searching for $U_n$it, U_{32}I got the number of bricks in the 32nd layer

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PSN2 : How do you find the conclusion of the problem?

IIM-SN2 : From the results of the search U_{32}, 72 bricks were obtained. When asked about the number U_{32}, the conclusion is that the number of bricks in the lowest layer is 72.

PSN2 : Can you explain again the results of your work from the known action stages to the conclusion of the schematic stages?

IIM-SN2 : find out if a=10, n=32, S_{32}=1.312. Asked U_{32} formula $S_n \frac{n}{2}(2a + (n-1)b)$ dan $U_n = a + (n-1)b$

It can be seen in Figure 8 and interview excerpts that FI2-SN2 is in the action stage. The subject can determine what is known and asked and change it into a mathematical model. At the process stage, the subject can explain why using the formula and reflect on problem-solving. In the object stage, the subject uses the formula and can solve the problem correctly. In schematic stages, Subjects can explain back the results from the action, process, and object stages.

Based on the results of the study represented by four research subjects on the subject of FD cognitive style, namely KKV and AK, and FI cognitive style (FI), namely DN and IIM, it can be seen that the cognitive style used in solving arithmetic material problems, the first step is to look at the type of questions and trying to find information from the questions. The results and discussion show that FD and FI cognitive style studies have differences in problem-solving. Students with FI styles are better because they can solve problems mathematically. According to the APOS stage, FI students also solve mathematical problems with their thinking and are not easily influenced by other people's thoughts. In contrast, FD is considered not good because students have been unable to solve problems systematically and stop at certain stages before reaching the final stage or scheme of the APOS theory. FD students also did not solve the problem from their thinking. It was judged that during the interview process, they were still confused with the results of their work.

These results are in line with the opinion of previous research, and there are differences; namely, FD subjects tend to be difficulty in achieving the object and scheme stages, but FD subjects can achieve the action, process, object, and scheme stages systematically and precisely [6]. Subject understanding of FD is still limited to the object stage because FD subjects have not been able to apply understanding and knowledge well enough. While the understanding of the subject FI is already at the Schematic stage, it is systematic and complete. Students with style FD are considered not good at solving mathematical problems because they cannot fulfil all the indicators of solving mathematical problems based on the APOS theory [19]. In contrast, students with the FI style are considered very good at solving mathematical problems because they can fulfil all the indicators of solving mathematical problems based on the APOS theory. Students with FI and FD cognitive styles have different tendencies to solve the problem. So, it can be concluded that FI is better than students' FD in solving problems [20]. Update researchers provide to teachers and subjects, so teachers know students' cognitive styles and help teachers determine appropriate learning methods.

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CONCLUSION

A FI cognitive style is better at problem-solving than students with an FD cognitive style. Subject FI can solve mathematical problems systematically based on APOS theory. FI can determine methods for solving mathematical problems and originate from their thoughts, not influenced by other parties. Meanwhile, FD has difficulty solving problems systematically and understanding and making mathematical models, it tends to be challenging to understand mathematical problems, and solutions do not originate from their thinking.

Researchers who wish to conduct similar research should increase the number of subjects or research more than the two study classes studied to obtain more accurate data and further research so that the scope reaches schools with poor-quality education in Indonesia is high. Increased schools in large areas such as urban and reached schools in rural areas**.**

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