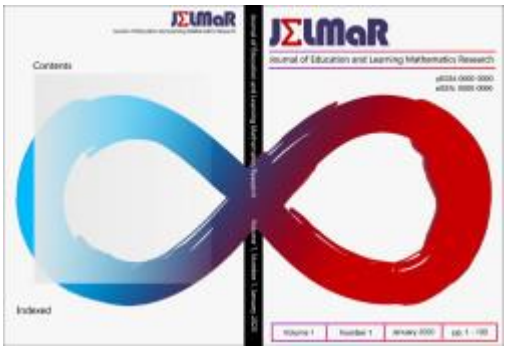

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Analysis of Geometry Problem Solving Based on APOS Theory for Class IX Students

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***Abstract**: This study aims to describe students geometry problem solving abilities based on APOS theory in terms of field dependent and field independent cognitive styles. This type of research is descriptive research with a qualitative approach. The research subjects were 4 students of class IX SMPN 1 Jember which were grouped based on cognitive style, namely 2 students with field independent cognitive style and 2 students with field dependent cognitive style. Methods of data collection using problem solving tests and interviews. The results of data analysis show that FD students tend to be able to write and mention information in questions, but still have difficulty in explaining the meaning of the questions. FI students tend to be able to write and explain information on questions. At the process stage, FI and FD students were able to model and explain the stages well, but FD still had errors in changing the shape of the mathematical model correctly. At the object stage, FI students work on questions freely, while FD students work on questions in detail or fixate on structured steps, FD students also have difficulty explaining their work. At the schema stage, FI and FD students can explain how to use the information in the problem, but FD students still experience errors from the process stage to drawing conclusions as a solution. Field independent students tend to be free or not fixated on complete and detailed steps, while field dependent students tend to be bound or fixated on complete and detailed steps.*

Keyword: mathematics problem solving, APOS theory, cognitive style,

INTRODUCTION

Mathematics is one of the subjects taught to students from elementary school to high school. Mathematics is often referred to as an exact science related to reasoning (Sunardi, 2009). Problem solving is an attempt to solve problems that are not yet known how to solve them directly. Problem solving ability is an ability that belongs to high-level thinking skills in solving problems in the form of non-routine questions. Until now there are still math problems that are always considered difficult by students in the process of solving them, so that some students are still unable to solve problems. Students are required to be able to solve mathematical problems until they find the right answer for the problem (Heryani, Y. & Ramadani, R., 2019). Based on the teaching experience, the researcher found that some of the students still had difficulties in understanding the concept and its application in the problem so that students could only work on the same problem with the examples given. Even in problems related to problem solving, most students still seem confused about what steps to take and how to solve them.

Understanding of a mathematical concept is the result of the construction or reconstruction of mathematical objects. Construction and reconstruction is carried out

through activities in the form of actions, processes, and objects that are organized in a scheme to solve mathematical problems. These activities are framed in the theory of APOS (*Action, Process, Object, and Schema*). APOS theory can be used as an analytical tool to describe how mathematical knowledge is formed in a person and can be used to see whether a student's understanding of mathematical concepts has reached a certain stage or not (Dubinsky, E., 2001).

Through the PAMER UN application, data is obtained from the Research and Development Ministry of Education and Culture which shows that student data at SMP Negeri 1 Jember on geometry and measurement materials as well as on indicators interpreting the combined area of two flat shapes is still relatively low. One of the allegations of the emergence of the inability of mathematics teachers to motivate students to appreciate and understand the lack of problem solving skills in the real world (Suwito, A, 2014). To overcome these problems, a sequence or procedure is needed to find out the extent to which students can solve problems using mathematical concepts in a coherent and detailed manner by using the APOS theory.

In solving a math problem each student has a different way. This is because each individual has characteristics that are not shared by other individuals. The difference in mathematical logical intelligence is known as cognitive style where each individual has a different process or effort in processing, storing, using, or responding to information based on environmental conditions and situations (Susanto, H, A., 2015). Argarini revealed that cognitive style is an individual characteristic in thinking, feeling, remembering, solving problems and making decisions. Cognitive style has an influence in a person's life, for example determining the academic field, determining how to learn, how a person interacts with other people, and so on (Argarini, D., Budiyono, & Sujadi, I., 2014). Cognitive styles can be distinguished into several groupings, the grouping is based on students' psychological differences in dealing with their environmental situations. Based on this grouping, cognitive styles are distinguished into *Field Dependent* (FD) and *Field Independent* (FI) cognitive styles (Usodo, B., 2011).

The characteristics of APOS theory are applied and linked to problem solving indicators. To find out a student is at a certain stage, it is enough to fulfill one of the indicators. The relationship between APOS theory characteristics and problem solving indicators in this study can be seen in Table 1 as follows.

Table 1. Correlation between APOS Theory

APOS Theory Phase	Characteristics	Problem Solving Indicators
Action	a. Requires detailed steps to perform the transformation. b. Performance in the form of procedural activities.	IA1. Students can write down the elements that are known and asked in the questions. IA2. Students can explain the information in the questions orally.
Process	a. To carry out the transformation does not need to be directed from external stimuli.	IP. Students can change what is known in the problem into a mathematical model.
Object	a. Can perform actions on objects. b. Object is a conceptual understanding.	IO1. Students are able to explain solving problems and the steps used along with the reasons according to the method of completion orally. IO2. Students can determine the solution to the problem in the problem.

APOS Theory Phase	Characteristics	Problem Solving Indicators
Schema	a. Can connect actions, processes, objects, a concept with other concepts. b. Understand the various rules or formulas that need to be involved or used.	IS1. Students can draw conclusions by connecting actions, processes, and objects. IS2. Students can explain the completion process that has been written from beginning to end finding answers orally.

Adaptation: Mulyono (2011)

Based on the description that has been described, a research was carried out with the aim of knowing the problem-solving ability of students' geometry, especially the combined area of flat shapes based on the APOS theory on each student with different cognitive styles. Therefore, the research title was obtained in the form of "Analysis of Geometry Problem Solving Ability of Class IX Students of SMP Negeri 1 Jember Based on APOS Theory Viewing from the Cognitive Style of *Field Dependent* and *Field Independent.*

METHOD

The type of research is descriptive research with a qualitative approach. The research subjects were four students of class IX D SMP Negeri 1 Jember. The stages in this research are making research instruments, determining the place and research subject, applying for a research permit, and coordinating with the teacher to determine the research schedule, determining the subject, collecting data, and analyzing research data. Data collection was carried out on February 24 and 25, 2022. The research instrument made in this study was a problem-solving ability test in the form of two questions describing the area of the combined flat shapes, and interview guidelines to obtain more in-depth information and to complete the answers of students who had not yet been answered. Seen in the results of student work. The instrument that has been made, needs to be validated to determine the validity of the instrument. Validation was carried out by two lecturers of Mathematics Education at the University of Jember and one mathematics teacher at SMP Negeri 1 Jember. The validation results show that the problem-solving ability test is declared valid with a score of 2.81 from a scale of 3, while the interview guide is declared valid with a score of 2.84 from a scale of 3. The next step is to give the GEFT test to all students of class IX D SMP Negeri 1 Jember. to classify students according to their cognitive style. Furthermore, 4 subjects with the highest scores on each cognitive style were selected, namely 2 students with *field dependent* (FD) and 2 students with *field independent* (FI). Subjects who have been selected to represent each cognitive style are given problem-solving ability test questions to determine students' problem-solving abilities based on APOS theory and interviews are conducted to obtain deeper information on the results of students' work in completing the problem solving ability test.

RESULT AND DISCUSSION

Based on the results of the GEFT test data analysis, from 32 students, 6 students had a *field dependent* and 26 students had a *field independent cognitive style.* The research subjects were selected by 2 students with the highest scores on each type of cognitive style. Furthermore, the four subjects were given problem solving tests and interviews.

Students' geometric problem solving abilities based on APOS theory in terms of *field dependent* and *field independent* described by paying attention to the suitability and tendencies of students as research subjects that represent both types of cognitive styles and seen from problem solving indicators based on APOS theory, namely action, process, object and schema.

Data on the results of the problem-solving ability test and student interviews based on the APOS theory at the Action stage, are presented as in Table 2.

Table 2. Description of Problem Solving Ability Test Results and Student Interview Results at the Action Stage

Cognitive Style	Student	Description
Field Dependent	FD_1, FD_2	• Able to re-explain the meaning of the problem in their own language • Write down what is known and asked in the question • Mention the information contained in the questions in full
Field Independent	FI_1, FI_2	• Able to re-explain the meaning of the problem in their own language • Write down what is known and asked in the question • Mention the information contained in the questions completely.

students *Field dependent* and *field independent* tend to fulfill the Action stage in the geometric problem solving process based on APOS theory, the problem solving abilities of *field dependent* and *field independent* as indicated by FD_1, FD_2, FI_1 and FI_2, all of them have fulfilled the action stage in solving geometric problems properly and correctly. This can be seen from the ability of *field dependent* students and *field independent* in writing down the information contained in problems 1 and 2 (IA1). Students are also able to mention information and elements that are known orally in problems 1 and 2 (IA2). The following is an excerpt from an interview with FI students at the action stage.

$P_3$01	:	*Ok, now try Nafa to explain the problem in question number 1 by using her own language*
$FI_3$01	:	*Mrs. Elda who owns the plot of land that is shown in this picture as large as . For areas that are not shaded and want to plant flowers in the shaded area. The problem is how much land will be planted with flowers*
$P_3$02	:	*Then what is known and asked in the question?*
$FI_3$02	:	*The base is known , the height of the large triangle , the height of the small triangle , the area of the shaded area . What is being asked is the area of the shaded field*

students are *Field dependent* able to write and mention the information contained in problems 1 and 2. FD students are able to understand the meaning of the problem and are able to explain in their own language. The following are the results of the work of FD students in the action stage.

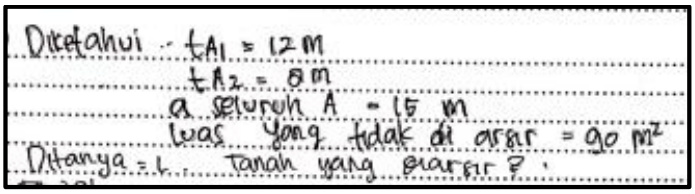

Figure 1. FD Student Work Results in the Action Stage

Data on the results of the problem-solving ability test and student interviews based on the APOS theory at the Process stage, are presented as shown in Table 3.

Table 3. Description of Problem Solving Ability Test Results and Student Interview Results at the Process Stage

Action	Student	Description
Field Dependent	FD_1, FD_2	• Wrong in modeling the problem in the problem into a form or mathematical model • Able to explain the stages in modeling
Field Independent	FI_1, FI_2	• Able to correctly model the problem in the problem into a mathematical form or model • Able to explain the stages in modeling

Students *Field dependent* and *field independent* tend to fulfill the process stage in solving geometry problems based on APOS theory.students' problem solving abilities *Field independent* shown by FI_1 and FI_2, all of them have fulfilled the process stage in solving geometry problems properly and correctly.students *field independent* in changing what is known in problems 1 and 2 into a mathematical model properly and correctly (IP). The following are the results of the work of FI students at the process stage.

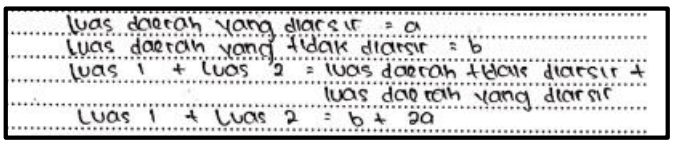

Figure 2. FI Student Work Results at the Process Stage

Students *Field dependent* shown by FD_1 and FD_2, all have fulfilled the process stage in solving geometric problems, but there are still some mistakes made in modeling the problem into mathematical form. This is because *field dependent* are not used to working on problems such as problems 1 and 2. For the writing style of *field dependent* there are those who write mathematical models before and after the completion process. There is also the writing of mathematical models with symbols and with words. The following are the results of the work of FD students at the process stage.

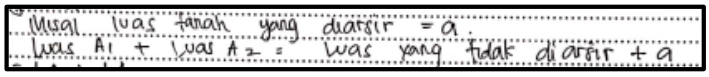

Figure 3. FD Student Work Results at the Process Stage

The results of the problem-solving ability test and student interviews based on the APOS theory at the Object stage are presented as shown in Table 4.

Table 4. Description of Problem Solving Ability Test Results and Student Interview Results at the Object Stage

Process	Student	Description
Field Dependent	FD_1	• Unable to re-explain the results of his work at the object stage properly and correctly • Lack of understanding of the concept • Wrong in determining the solution to the problem of
	FD_2	• Able to explain back the results of his work at the object stage properly and correctly • Lack of understanding of the concept • Wrong in determining the solution to the problem

Process	Student	Description
of Field Independent	FI_1	• Less thorough in the work so that the solution is wrong, but justification is done • Able to explain the settlement steps clearly and correctly • Able to determine problem solutions correctly
	FI_2	• Not writing detailed steps • Able to explain the settlement steps clearly and correctly • Able to determine problem solutions correctly

students *Field dependent* and *field independent* tend to fulfill the object stage in the geometric problem solving process based on APOS theory.students' problem solving abilities *Field independent* shown by FI_1 and FI_2, all have fulfilled the object stage in solving geometry problems properly and correctly. This can be seen from the ability of FI_2 in solving problems 1 and 2 by using the appropriate method and steps (IO1) to obtain the expected solution to each problem (IO2), while FI_1 are able to solve problem 2 by using appropriate methods and steps to obtain the expected solution.students were$_1$ able to use appropriate methods and steps, but the solution obtained was not quite right, this was because FI_1 were less thorough in the work process, namely in doing calculations, but students realized mistakes and then corrected them. The following are the results of the work of FI students at the object stage.

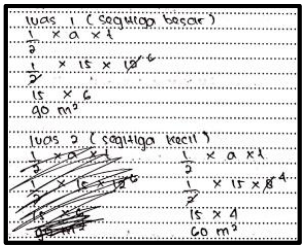

Figure 4. FD Student Work Results at the Object Stage

Student *Field dependent* shown by FD_1 and FD_2, all of which have fulfilled the object stage in solving geometry problems.students$_1$ and FD_2 in solving problems 1 and 2 using appropriate methods and steps, but the solutions obtained from both are still not quite right, it is because FD_1 and FD_2 wrong in modeling the problemmathematics at the previous stage. In addition, FD_1 also has difficulty in explaining the problem solving process carried out, due to a lack of understanding of the concepts that FD_1, while FD_2 is able to explain the problem solving process again, but still experiences errors in the counting process, this is because students FD_2 is less thorough in the work process. The following are the results of the work of FD students at the object stage.

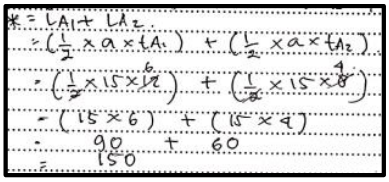

Figure 5. FD Student Work Results at the Object Stage.

The results of the problem-solving ability tests and student interviews based on the APOS theory at the Schematic stage are presented as in Table 5.

Table 5. Description of Problem Solving Ability Test Results and Student Interview Results at the

Cognitive Style	Student	Description
Field Dependent	FD_1	• Able to explain in utilizing the information contained in the object stage for the next stage • Wrong in determining the final answer • Able to explain the working process from start to finish finding answers to
	FD_2	• Able to explain in utilizing the information contained in the object stage for the next stage • Wrong in determining the final answer • Able to explain the work process from start to finish finding answers
Field Independent	FI_1	• Able to explain in utilizing the information contained in the object stage for the next stage • Able to determine the final answer correctly after doing a little justification • Able to explain the working process from start to finish finding the answer to
	FI_2	• Do not write completely in solving problems • Able to explain in utilizing the information contained in the object stage for the next stage • Able to determine the final answer correctly • Able to explain the working process from beginning to end finding answers.

Students *field dependent* and *field independent* tend to fulfill the Schematic stage in the geometric problem solving process based on APOS theory, the problem solving abilities of *field dependent* and *field independent* as indicated by FD_1, FD_2, FI_1 and FI_2, all of which have fulfilled the schematic stage in solving geometric problems properly and correctly.students *field independent* in utilizing information on the previous question or stage to complete the next stage until a good and correct conclusion is drawn (IS1). While *field dependent* are able to take advantage of the information contained in the problem or previous stage to complete the next stage until a conclusion can be drawn, but there are still errors made by *field dependent* both from the process stage to drawing conclusions as a solution to mathematical problems. The following are the results of the work of FI and FD students at the schema stage.

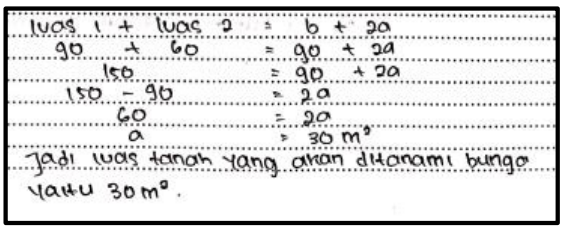

Figure 6. FI student work results at the schema stage

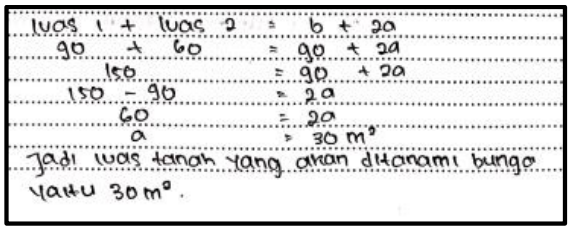

Figure 7. FD student work results at the schema stage

In this study, it was seen that *field independent* were able to understand and apply the concepts contained in the material. Combined area of flat shapes. It can be seen in solving problems, *field independent* able to understand the intent and purpose of the questions.cognitive style students *Field independent* solve the problem with their own strategy or experience. In solving problems, FI students complete freely or not glued to the steps that are arranged in a complete and detailed manner. This is supported by the results of research conducted by Purnomo (2017) which revealed that *field independent* more creative in solving mathematical problems than *field dependent students.* Meanwhile, students with *field dependent* do not understand and apply the concepts contained in the broad composite material of flat shapes. It can be seen in solving problems, students with *field dependent* wrong in modeling mathematics and students have difficulty in explaining the completion process they are doing. In solving problems, FD students complete the steps in a complete and detailed manner.

Based on the description described above, the *field independent* are better at fulfilling the indicators than the *field dependent*. This is supported by the results of Alimuddin's research (2019) which states that in completing a task or solving a problem (*problem solving*) that requires a skill, *field independent* will produce better than *field dependent individuals.* In addition, the results of research conducted by Prabawa (2017) show that students with *field independent* (FI) tend to have better problem solving abilities than students with *field dependent* (FD). Likewise with the results of research conducted by Prabowo et al. (2019), the results obtained show that *field independent* score higher than *field dependent*.students *Field independent* able to solve problems at each level of the game in a short time and get fewer errors than field dependent students.

The results of this study indicate that students with *field independent* fulfill the stages completely and *field dependent* fulfill incompletely but both are able to fulfill all stages of the APOS theory in the problem solving process, this is contrary to the results of research conducted by Afgani et al. (2017) that there are no students who reach the process, object or schema stage perfectly. FI students tend to work on questions freely, while FD students tend to work on questions in detail or fixate on the steps that are fully structured but still experience errors in the problem solving process, especially at the process and object stages. This is also supported by the statement expressed by (Nasution, 2006), that FI students do not need detailed instructions, while FD requires more instructions to understand something, even they should be arranged step by step in solving mathematical problems.

CONCLUSION

In the action stage, students *field dependent* cognitive style and *field independent* able to write and state the information properly and correctly. At the stage of the process *independent field is* able to convert into a mathematical model correctly, while the *field dependent* there are still errors made because they are not able to model the problem in the form of a mathematical model correctly. At the object stage, students with *field independent* able to solve problems with the correct steps and solutions, while students with *field dependent* are not able to solve problems with correct steps and solutions schema stage *field*

independent able to utilize information in the previous question or stage to complete the next stage until a good and correct conclusion can be drawn, while students with *field dependent* still have errors from the process stage to drawing conclusions as a solution to the problem. Students *field dependent* and *field independent* were able to fulfill all stages of APOS theory.

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