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Analysis of Students' Conceptual Understanding of Grouped-Data Mean Based on APOS Theory in Grade X at SMA Negeri 1 Jayapura

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Article Information

Keywords:

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ABSTRACT

Abstract content is typed in Arial Narrow, 11-point font, justified, italicized, and single-spaced. The abstract contains a summary of the research objectives, methods, and results. The abstract is limited to a maximum of 200 words. This study aims to analyze students' conceptual understanding based on APOS (Action, Process, Object, Schema) theory regarding grouped-data mean in Grade X at SMA Negeri 1 Jayapura. A descriptive qualitative approach was employed, with the researcher serving as the primary instrument. The participants were all 27 students in Grade X-11, who completed a constructed-response test on grouped-data mean to map the APOS stage they had attained. Based on the test results, six students were selected through purposive sampling using the principle of maximum variation sampling, with two students representing each of the Process, Object, and Schema stages, to participate in two Think Aloud sessions as a form of time triangulation. Data were analyzed through data reduction, data display, and conclusion drawing, and validity was examined through time triangulation and method triangulation. The results show that all participants had attained the Action and Process stages, as reflected in their ability to determine the class midpoint, calculate the frequency–midpoint product, and explain the steps for calculating grouped-data mean. For items 1 and 2, almost all participants consistently attained the Schema stage from the written test onward, whereas for the more complex item 3, some participants consistently attained the Schema stage only during the second Think Aloud session after initially being at the Process or Object stage. This difference was influenced more by nervousness and a lack of self-confidence during the interview than by instability in conceptual understanding. Thus, students' conceptual understanding of grouped-data mean varied between the Object and Schema stages, particularly for more complex contextual questions; therefore, teachers are advised to provide more varied contextual questions to encourage students to attain higher stages of understanding.

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ABSTRACT

This study aims to analyze students' conceptual understanding of grouped-data mean based on APOS theory (Action, Process, Object, Schema) in Grade X at SMA Negeri 1 Jayapura. This study employed a descriptive qualitative approach, with the researcher serving as the primary instrument. The research participants were all 27 students in Grade X-11, who completed a constructed-response test on grouped-data mean to map the APOS stage they had attained. Based on the test results, six students were selected through purposive sampling using the principle of maximum variation sampling, with two students representing each of the Process, Object, and Schema stages, to participate *in two* Think Aloud sessions as a form of time triangulation. Data were analyzed through data reduction, data display, and conclusion drawing, and validity was examined through time triangulation and method triangulation. The results show that all participants had attained the Action and Process stages, as reflected in their ability to determine the class midpoint, calculate the frequency–midpoint product, and explain the steps for calculating grouped-data mean. For items 1 and 2, almost all participants consistently attained the Schema stage from the written test onward, whereas for the more complex item 3, some participants consistently attained the Schema stage only during *the second* Think Aloud session after initially being at the Process or Object stage. This difference was influenced more by nervousness and lack of self-confidence during the interview than by instability in conceptual understanding. Thus, students' conceptual understanding of grouped-data mean varied between the Object and Schema stages, particularly for more complex contextual questions; therefore, teachers are advised to provide more varied contextual questions to encourage students to attain higher stages of understanding.

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1. Introduction

National education is administered on the basis of Pancasila and the 1945 Constitution of the Republic of Indonesia, which affirms that education aims to develop students' potential so that they become individuals who are faithful, knowledgeable, creative, and responsible. This is consistent with Law No. 20 of 2003 on the National Education System, which affirms that national education aims to develop students' potential so that they are able to think logically, creatively, and independently. Educational goals may be understood as a system of values whose validity and importance are mutually agreed upon and pursued through various educational activities, both within and outside schools (Aryanto dkk., 2021), and their attainment requires collaboration among the government, the community, and educational institutions. To improve the quality of national education, the Ministry of Primary and Secondary Education, through Regulation of the Minister of Primary and Secondary Education No. 13 of 2025, made curriculum adjustments at the primary and secondary education levels, including in mathematics instruction, a compulsory subject.

Mathematics is a field that equips students with the ability to think logically, analytically, systematically, critically, and creatively (Astuti dkk., 2016). Mathematics plays an important role as a fundamental branch of knowledge (Anggraini, 2024) that trains students to think creatively, systematically, and logically when solving various problems (Silfia & Pranyata, 2021). Despite its significant role in life, students continue to regard mathematics as a difficult, abstract, and boring subject (Hadiyanti dkk., 2022), which contributes to their limited problem-solving ability and conceptual understanding (Wahyuningsih dkk., 2019). Conceptual understanding of mathematics can be defined as an individual's ability to know and master a concept in depth (Gustina dkk., 2021), enabling students to make sense of each mathematical idea and principle rather than merely memorize procedures (Nailopo dkk., 2022).

However, Indonesian students' conceptual understanding remains far below *expectations; the 2022 Programme for* International Student Assessment (PISA) results showed that Indonesia ranked 63rd out of 81 countries, with an average mathematics score of 366, indicating a serious gap in students' problem-solving abilities (Achmad dkk., 2024). Conceptual understanding can be identified through three main indicators: the ability to restate a concept in one's own words, the ability to classify objects according to particular characteristics, and the ability to use concepts or algorithms to solve problems (Apriyono dkk., 2025).

The gap in conceptual understanding is particularly evident in statistics, especially in the topic of the grouped-data mean, which requires students to integrate several concepts simultaneously, such as class intervals, frequency, class midpoint, and the grouped-data mean formula. Students frequently make errors when solving word problems in statistical contexts, ranging from misunderstanding the intent of the questions and making computational errors to incorrectly applying formulas (Ramadoni & Hafizh, 2023). The extensive scope of material that must be delivered within a limited time further exacerbates this condition, making it difficult for teachers to explain concepts in depth and often causing students to have difficulty recalling prerequisite material learned previously (Setyorini dkk., 2022).

These conditions indicate the need for an analytical framework that can systematically reveal the stages of students' thinking in constructing conceptual understanding of mathematics. One relevant framework is APOS (Action, Process, Object, Schema) theory, which explains students' mental constructions through four stages: Action, Process, Object, and Schema (Firdaus, 2023). According to Ardiantoro (Rahmawati, 2018), at the Action stage, students still depend on external instructions and carry out procedures by rote; at the Process stage, students begin to carry out and explain steps independently; at the Object stage, students understand concepts in depth and are able to use their properties to solve problems; and at the Schema stage, students are able to integrate the Actions, Processes, and Objects they have mastered into a coherent knowledge structure. According to Nuryati and Darsinah (Handika dkk., 2022), learning will be successful when it is combined with students' stages of cognitive development; therefore, APOS theory is considered appropriate for analyzing conceptual understanding of the grouped-data mean because this material requires students to relate various statistical concepts gradually and systematically.

Several previous studies have applied APOS theory to analyze students' conceptual understanding of mathematics across various topics, such as sequences and series, the Pythagorean theorem, and geometric transformations. These studies consistently found that students' conceptual understanding remained largely at the Action and Process stages, whereas

relatively few students reached the Object and Schema stages. Nevertheless, studies specifically examining the grouped-data mean at the senior high school level across all four APOS stages in depth and using the Think Aloud technique as time triangulation remain scarce. This specificity constitutes the distinction and novelty of the present study: it reveals the profile of Grade X students' conceptual understanding of the grouped-data mean through a comprehensive examination of the Action, Process, Object, and Schema stages, while also identifying the obstacles that arise at each stage of concept formation.

Based on the foregoing, this study aims to analyze Grade X students' conceptual understanding of the grouped-data mean at SMA Negeri 1 Jayapura based on APOS theory, with the following research question: What is Grade X students' conceptual understanding of the grouped-data mean at SMA Negeri 1 Jayapura based on APOS theory?

2. Methods

Research Design

This study employed qualitative research with a descriptive approach aimed at describing or explaining the problem under investigation (Fiantika dkk., 2022). This approach was selected because the study sought to describe in depth Grade X students' conceptual understanding of the grouped-data mean based on the stages of APOS theory, namely, Action, Process, Object, and Schema. In its implementation, the researcher served as the primary instrument, supported by a test sheet as a supplementary instrument, and analyzed the data through data reduction, data display, and conclusion drawing.

Research Participants

This study was conducted at SMA Negeri 1 Jayapura during the second semester of the 2025/2026 academic year. The research participants were all 27 students in Grade X-11, all of whom completed a written constructed-response test on the grouped-data mean to identify the APOS stages they had attained. Participant selection was subsequently conducted u*sing purposive* sampling based on t*he principle of maximum* variation sampling (Patton, 2002), namely, selecting participants by considering representation across various achievement-stage categories to obtain a richer and more comprehensive account (Sugiyono, 2019). Based on the written test results, all students had attained the Action stage, and thus no variation in characteristics was identified at that stage; therefore, participant selection focused on students who demonstrated variation at the Process, Object, and Schema stages, with two students selected at each stage, resulting in a total of 6 participants selected for further analysis.

Data Collection Techniques

Data were collected through two techniques: tests and Think *Aloud. The* conceptual understanding test was administered individually and consisted of three constructed-response questions on grouped-data mean. It was developed based on indicators of conceptual understanding at each stage of APOS theory, and participants were given 120 minutes to complete it. The test was closely supervised, with students seated apart and prohibited from communicating with one another, to ensure that the results reflected individual a*bility.* Subsequently, Think Aloud, a data collection technique requiring participants to verbally express every thought that arose while solving a problem without interpreting or justifying their reasoning (Ericsson & Simon, 1993), was conducted twice (Think Aloud 1 on 22 May *2026 and* Think Aloud 2 on 26 May *2026) with* the six selected participants to examine students' thought processes in greater depth. Data validity was examined through time triangulation by comparing the consistency of the written test results with the two Think Aloud sessions, *as well as* through method triangulation and content validation of the instrument by mathematics teachers and expert lecturers.

Data Analysis Techniques

The data obtained were analyzed using qualitative data analysis techniques conducted continuously from the data collection process until all data had been collected, through three stages. First, data reduction involved summarizing, categorizing, and focus*ing the* test and Think Aloud data according to the Action, Process, Object, and Schema stages of APOS theory. Secon*d, data* display involved organizing each participant's written test and Think Aloud results into systematic descriptions based on the stages of APOS theory. Third, conclusion drawing involved formulating final findings regarding the stages of conceptual understanding attained by each participant based on valid and consistent evidence from the triangulation results, so that the conclusions could address the research question.

3. Results and Discussion

Written Test Results and Participant Selection

The written test was administered on 20 May 2026 and lasted 120 minutes. The instrument consisted of three constructed-response questions on grouped-data mean. The work of all 27 Grade X-11 students was scored and categorized based on

indicators of conceptual understanding at each stage of APOS theory, as presented in Table 1.

Table 1. Indicators of Mathematical Conceptual Understanding Based on APOS Theory in Grouped-Data Mean

APOS Stage	Measured Ability
Action	Determining the class midpoint f*rom* x_i) the interval; calculating the frequency–midpoint product; ($f_i x_i$) *d*irectly applying the grouped-data mean formula to obtain the mean value.
Process	Explaining the steps for calculating the grouped-data mean in writing; explaining the mean as the center of the data based on a frequency distribution table; modifying procedures according to the characteristics of the question; reviewing the calculation steps and results.
Object	Determining the use of the grouped-data mean method based on the characteristics of interval data; modifying solution strategies; demonstrating conceptual rather than merely procedural understanding.
Schema	Solving contextual or nonroutine problems involving grouped-data mean; connecting the concept of mean with other concepts; drawing overall conclusions about the relationships among formulas, procedures, and the concept of mean.

Based on the indicators in Table 1, the classification results for all students in Grade X-11 are presented in Table 2.

Table 2. Classification Results of All Grade X-11 Students Based on APOS Stages

No.	APOS Stage	Number of Students
1	Process	8
2	Object	7
3	Schema	12
Total		**27**

Table 2 shows that all 27 students in Grade X-11 had progressed beyond the Action stage, the most basic stage of mental construction. Eight students were at the Process stage, seven were at the Object stage, and 12 were at the Schema stage, the highest stage. Although the students' distribution across APOS stages was dominated by the Schema stage, 15 students remained at the Process and Object stages, indicating that some students' mental constructions were still developing. Based on these classification results, the researchers selected six students as research p*articipants* through purposive sampling, a*pplying the principle of* maximum variation sampling (Patton, 2002), with two students selected from each of the Process, Object, and Schema stages, as presented in Table 3.

No.	Participant	Gender	APOS Stage
1	WA	Female	Process
2	GD	Female	Process
3	AP	Female	Object
4	GM	Female	Object
5	JP	Male	Schema
6	FR	Male	Schema

Time Triangulation Results

To obtain valid and consistent data regarding the APOS stages attained by each subject for each question, time triangulation was conducted by comparing the results of the w*ritten test,* Think *Aloud 1,* and Think Aloud 2. All subjects met the characteristics of the Action stage across the three instruments; therefore, the subsequent discussion focuses on the Process, Object, and Schema stages. A summary of each subject's APOS stage tendencies for each question is presented in Table 4.

Table 4. Results of Time Triangulation of Students' Conceptual Understanding Based on APOS Stages

Subject	Question	WT	Think Aloud 1	Think Aloud 2	Tendency APOS
WA	1	Schema	Schema	Schema	Schema
	2	Schema	Schema	Schema	Schema
	3	Process	Process	Schema	Process
GD	1	Schema	Schema	Schema	Schema
	2	Schema	Schema	Schema	Schema
	3	Process	Process	Schema	Process
AP	1	Schema	Schema	Schema	Schema
	2	Schema	Schema	Schema	Schema
	3	Object	Object	Schema	Object
GM	1	Schema	Schema	Schema	Schema
	2	Schema	Schema	Schema	Schema
	3	Object	Object	Schema	Object
JP	1	Schema	Schema	Schema	Schema
	2	Schema	Schema	Schema	Schema
	3	Schema	Schema	Schema	Schema
FR	1	Schema	Schema	Schema	Schema
	2	Schema	Schema	Schema	Schema
	3	Schema	Schema	Schema	Schema

Table 4 shows that, for Questions 1 and 2, all subjects consistently reached the Schema stage across all three instruments. This consistency indicates that the six subjects had genuinely attained conceptual understanding of both questions rather than merely memorizing solution procedures. In contrast, Question 3 was more complex and contextual: subjects WA and GD reached only the Process stage on the written test and Think *Aloud 1;* subjects AP and GM reached only the Object stage on both instruments; whereas subjects JP and FR consistently reached the Schema stage from the outset. *In Think* Aloud 2, subjects WA, GD, AP, and GM demonstrated improvement, reaching the Schema stage. This improvement is presumed to have occurred because the nervousness and lack of confidence experi*enced by* the subjects during Think Aloud 1 had diminished by the second session, allowing them to express more freely the relationships among concepts that they had actually understood. This was also supported by the opportunity to reconsider their answers, as the same questions were administered across all three instruments. These findings are consistent with those of Napitupulu and Panjaitan (2023), who similarly found that their research subjects' ability to recheck solutions was not evident in the written test but emerged only when the subjects were interviewed, during which they stated that they had rechecked their work by verifying the correctness of their completed answers.

DISCUSSION

Students' Conceptual Understanding at the Action Stage

The analysis of the six research subjects showed that all met the indicators of the Action stage: they were able to identify the given and requested data, determine class midpoints, multiply frequency by the class midpoint, and correctly apply the grouped-data mean formula. This was confirmed through written responses and the results of Think A*loud 1 and* Think *Aloud 2,* and no substantial difficulties were identified at this stage. These findings differ from those of Ferdian et al. (2020) on the Pythagorean Theorem, who found that most students remained at the Action stage because they had not yet been able to relate procedures to broader concepts. This difference indicates that grouped-data mean material may be relatively easier for Grade X students to understand procedurally than geometry material, which requires visualization and proof.

Students' Conceptual Understanding at the Process Stage

All subjects also met the indicators of the Process stage: they were able not only to calculate the grouped-data mean but also to explain why the mean value was located within a particular interval by relating it to the frequency distribution of the data. Consistent with APOS theory, this stage is characterized by the ability to reflect on and explain procedures along with their underlying rationale. These findings support those of Lestari (2018), who reported a 57.41% increase in students' understanding from the Action to the Process stage in sequences and series, and are consistent with Anggraini (2024), who found that students studying geometric transformations had generally reached the Process stage, although not all were able to relate it to more complex concepts. This ability to explain procedures independently was also highlighted in the study (dkk., 2022) involving preservice mathematics teachers, which found that subjects with high representational ability could accurately construct solution steps even though they did not necessarily succeed in completing them to reach a final solution, indicating that strong procedural ability is not always directly associated with success in solving a problem comprehensively.

Students' Conceptual Understanding at the Object Stage

Students at the Object stage were able to understand that changes in frequency within an interval would affect the mean because they influenced the total frequency and the sum of frequency–midpoint products. Two participants who had reached *only the* Object stage on Question 3 during Think Aloud 1 successfully reached the Schema stage *during* Think Aloud 2 after their nervousness and lack of confidence had diminished. These findings indicate that students' conceptual understanding may be more optimally elicited when they feel more comfortable explaining their thought processes, consistent with the findings of Ramadoni and Hafizh (2023) in Grade X Statistics, which found that students' average conceptual understanding reached only 38.75%, with the primary difficulty occurring in conceptual rather than merely procedural aspects. The role of affective factors is further supported by the findings of Panjaitan dkk. (2024) among prospective mathematics teachers, which showed that self-efficacy also affects students' interest and academic achievement in mastering mathematics, with

students who have high self-confidence tending to be more confident in completing complex mathematical tasks. The differences in achievement in this study also indicate that affective factors, such as confidence during interviews, play a role in the elicitation of students' conceptual understanding, consistent with the view that knowledge construction occurs through active interaction between individuals and their learning situations, including the interview situation itself.

Students' Conceptual Understanding at the Schema Stage

At this highest stage, all participants were able to connect the concept of the grouped-data mean with other mathematical concepts, such as probability, the mean of ungrouped data, linear equations in one variable, and systems of linear equations in two variables, and to solve contextual and nonroutine problems comprehensively. Two participants consistently remained at the Schema stage across all questions and instruments from the beginning of the study, demonstrating the most mature conceptual understanding among the participants, whereas the other four participants consistently reached the Schema stage on Question 3 only a*fter Think* Aloud 2. Students' difficulties in connecting concepts in these more complex word problems are consistent with the findings of Musa dkk. (2024) on sequences and series, which reported that students tend to experience difficulty connecting mathematical concepts when confronted with contextual word problems. These findings are also consistent with the results of Lestari (2018), which reported that the percentage of understanding at the Schema stage reached 96.29%, substantially higher than at the preceding **S**tages, as well as with the study by Anggraini (2024), which showed that students categorized as having high understanding tend to be at the Schema stage. However, these findings differ from those of Ferdian dkk. (2020), who found that only a small proportion of students were able to reach the Schema stage in the Pythagorean Theorem topic. This difference indicates that attainment of the Schema stage is strongly influenced by the characteristics of the material and students' opportunities to integrate various relevant concepts, as emphasized in APOS theory, in which a schema constitutes an integrated organization of Actions, Processes, and Objects that forms a coherent pattern of thought in problem solving.

Conclusion

Based on the results of the analysis using APOS theory, students' conceptual understanding of grouped-data mean material in Grade X at SMA Negeri 1 Jayapura can be explained through four developmental stages. At the Action and Process stages, all participants demonstrated good and consistent mastery across the three data-collection instruments. At the Object stage, most participants were able to understand the relationship between changes in frequency and changes in the mean, although two participants reached this stage consistently only during the *second Think* Aloud.

At the Schema stage, the highest stage, nearly all participants consistently reached this stage on the written test for Questions 1 and 2, whereas for the more complex and contextual Question 3, four participants consistently reached the Schema stage only during the second *Think* Aloud, while the other two participants had consistently been at the Schema stage from the beginning of the study across all questions. These differences in achievement were influenced more by students' nervousness and lack of confidence during the interviews than by instability in conceptual understanding itself.

Thus, it can be concluded that students' conceptual understanding of grouped-data mean material in Grade X at SMA Negeri 1 Jayapura varied from the Object stage to the Schema stage, with the most evident variation appearing in the solution of more complex contextual questions.

Recommendations

Based on these conclusions, future studies examining similar topics are recommended to use Think Aloud techniques and more in-depth interviews to identify students' thought processes at each APOS stage more clearly and to consider the characteristics and difficulty levels of the questions used, as these also affect students' attainment of APOS stages. Teachers are recommended to design instruction that focuses not only on the use of formulas but also on conceptual understanding of the grouped-data mean by providing varied contextual questions so that students become accustomed to connecting various mathematical concepts and are able to reach the Schema stage.

Students are encouraged to be more active in understanding the concepts underlying grouped-data mean calculations and to become accustomed to working on varied contextual questions so that their ability to connect various mathematical concepts and solve problems systematically can continue to develop.

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