

Microgenetik Analysis of Students' Strategy Changes in Determining Grouped Data Quartiles

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ABSTRACT

Students often experience difficulties in understanding grouped data quartiles because they tend to apply procedures without comprehending the relationships among quartile positions, cumulative frequencies, and quartile formulas. This study aimed to analyze students' strategy changes in determining grouped data quartiles through a microgenetic approach. This research employed a qualitative method using a task-based microgenetic study approach. The study was conducted at SMA Negeri 4 Jayapura during the second semester of the 2025/2026 academic year. A total of 41 students participated in a pretest to identify their initial abilities, from which three students representing high (S1), medium (S2), and low (S3) ability levels were selected through purposive sampling. Data were collected through a diagnostic pretest, graded microgenetic tasks, observations, and semi-structured interviews. Data were analyzed microgenetically by identifying problem-solving episodes, strategies, strategy changes, and critical moments. The findings revealed that students' strategies developed through four stages: understanding quartile positions, using cumulative frequencies, determining quartile classes, and applying quartile formulas conceptually. Strategy changes occurred when students understood the role of cumulative frequencies in determining quartile positions and classes. It can be concluded that understanding cumulative frequencies served as a critical moment that promoted strategy changes from procedural use toward conceptual understanding in determining grouped data quartiles.

Informasi Artikel

Kata Kunci:

Kuartil data kelompok; mikrogenetik; perubahan strategi; statistika; task-based microgenetic study.

ABSTRAK

Peserta didik masih mengalami kesulitan dalam memahami konsep kuartil data kelompok karena cenderung menggunakan prosedur tanpa memahami hubungan antara posisi kuartil, frekuensi kumulatif, dan rumus kuartil. Penelitian ini bertujuan untuk menganalisis perubahan strategi peserta didik dalam menentukan kuartil data kelompok melalui pendekatan mikrogenetik. Penelitian ini merupakan penelitian kualitatif dengan pendekatan task-based microgenetic study. Penelitian dilaksanakan di SMA Negeri 4 Jayapura pada semester genap Tahun Ajaran 2025/2026. Sebanyak 41 peserta didik mengikuti pretest untuk mengidentifikasi kemampuan awal, kemudian dipilih tiga subjek yang mewakili kategori kemampuan tinggi (S1), sedang (S2), dan rendah (S3) menggunakan teknik purposive sampling. Data diperoleh melalui pretest, soal mikrogenetik bertingkat, observasi, dan wawancara semi-terstruktur. Data dianalisis secara mikrogenetik dengan mengidentifikasi episode penyelesaian soal, perubahan strategi, dan critical moment. Hasil penelitian menunjukkan bahwa strategi peserta didik berkembang dari pemahaman posisi kuartil menuju penggunaan frekuensi kumulatif, penentuan kelas kuartil, dan penggunaan rumus kuartil secara konseptual. Perubahan strategi terjadi ketika peserta didik memahami fungsi frekuensi kumulatif dalam menentukan posisi dan kelas kuartil. Disimpulkan bahwa pemahaman terhadap frekuensi kumulatif berperan sebagai titik kritis (critical moment) yang mendorong perubahan strategi peserta didik dari penggunaan prosedur menuju pemahaman konseptual dalam menentukan kuartil data kelompok.

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1. Introduction

In statistics education, students are expected not only to perform calculations but also to understand the meaning of data obtained from a distribution. Statistics learning plays a significant role in helping students understand, process, and interpret data commonly encountered in everyday life (Kaur et al., 2025). One statistical topic taught at the senior high school level is grouped data quartiles. Grouped data quartiles require not only procedural competence but also conceptual understanding of data distributions, data positions, and cumulative frequencies (Cahani et al., 2021). In mathematics learning, conceptual understanding is important because students are expected to explain the processes underlying their solutions (Ansari et al., 2021; Cahani et al., 2021).

Good statistical conceptual understanding also supports students' data literacy when dealing with various data-based forms of information in the current digital era. Therefore, statistics learning, particularly grouped data quartiles, requires serious attention from mathematics teachers. Meaningful mathematics learning requires connections between mathematical concepts and students' learning experiences. (Yeni D. Fonataba et al., 2023) showed that using contexts familiar to students can support the development of mathematical conceptual understanding in a more meaningful way. With adequate understanding, students are expected to interpret data more accurately in various real-life situations (Noviafta Widya, 2022).

Although grouped data quartiles have been taught in schools, many students still experience difficulties in developing a deep understanding of the concept. Students often have difficulty determining data positions and reading cumulative frequencies (Cahani et al., 2021; Febrilia, 2020). This condition indicates that some students remain oriented toward directly applying procedures or formulas without understanding the relationships among the underlying concepts (Meidianti et al., 2022). Consequently, students often experience difficulties when confronted with problems presented in different forms or contexts, which may lead to errors during problem solving (Luqmanul Hakim & Yasmadi, 2021)

This phenomenon indicates that mathematics instruction still tends to emphasize final answers and the direct application of procedures. Conceptual understanding in statistics, however, needs to be developed through thinking processes that evolve gradually through learning experiences and active student engagement in solving mathematical problems (Barumbun & Kharisma, 2022)).

(Cahani et al., 2021) reported that students' statistical conceptual understanding remained relatively low, particularly in interpreting data and using statistical representations appropriately. (Rahayu et al., 2021) found that students frequently experienced difficulties in determining measures of position because they had not understood the relationship between data position and frequency distributions. (Febrilia, 2020) likewise showed that many statistical errors were triggered by students' tendency to apply procedures mechanically without adequate conceptual understanding.

Previous studies have identified various difficulties in

understanding grouped data quartiles. These difficulties are evident not only in the use of solution procedures but also in students' conceptual understanding of the underlying statistical concepts. (Mardhotillah et al., 2025) reported that students continued to experience obstacles in understanding statistical concepts and connecting statistical representations with their mathematical meanings.

Although previous research has examined errors and students' ability levels in statistics, studies specifically investigating how students' strategies change while learning grouped data quartiles remain limited.

One approach that can be used to examine the development of students' understanding in detail is the microgenetic approach. In studies of mathematical cognitive development, microgenetic approaches have been used to identify changes in strategies and the development of understanding in detail during problem solving. A microgenetic approach focuses on intensive observation of strategy changes, developing understanding, and the emergence of misconceptions during learning (Robert S. Siegler and Kevin Crowley, 1991). Through this approach, researchers can observe how students' ways of thinking change while solving a problem, from an initial condition of limited understanding toward more stable understanding (Chen, 2021). Thus, the approach does not merely examine learning outcomes but emphasizes the detailed process through which understanding changes.

The microgenetic approach is closely related to constructivist theory, which views knowledge as being actively constructed by learners through experience. In mathematics learning, students do not immediately receive concepts in a complete form; rather, they construct understanding through exploration, errors, reflection, and strategy refinement (Robert S. Siegler and Kevin Crowley, 1991).

In addition, Siegler's overlapping waves theory explains that students' strategy development does not proceed linearly. Instead, multiple strategies may occur simultaneously, with more effective strategies gradually becoming more dominant as a result of experience (Siegler, 2003). Such strategy variability is an important indicator of developing understanding because it reflects ongoing adaptation and restructuring of knowledge (Eldstål-Ahrens et al., 2024).

The novelty of this study lies in mapping the trajectory of students' strategy changes in determining grouped data quartiles, from limited initial understanding to conceptual understanding. The study also identifies the critical moment that triggers strategy changes during statistical problem solving.

In addition, microgenetic research in mathematics education has generally focused on arithmetic, fractions, proportional reasoning, and algebra (George & Voutsina, 2021; Lundberg, 2022; Voutsina et al., 2019).

In contrast, grouped data quartiles are a statistical topic that frequently generates misconceptions concerning quartile positions, cumulative frequencies, and the use of quartile formulas. Therefore, a research gap remains regarding how students move from less appropriate strategies toward more conceptual strategies while learning statistics.

Based on this background, the study is important because understanding the development of students' thinking can help teachers identify misconceptions, learning difficulties, and changes in students' strategies during statistics learning. Therefore, this study aimed to analyze students' strategy changes in determining grouped data quartiles through a microgenetic approach. Theoretically, the study is expected to enrich microgenetic research in mathematics education, particularly in statistics and the development of students' strategies for understanding grouped data quartiles. Practically, the findings can serve as a basis for teachers to identify students' misconceptions and design statistics instruction that is more oriented toward developing conceptual understanding.

2. Method

2.1. Research Design

This study employed a qualitative method with a task-based microgenetic study approach. The approach was intended to identify students' strategy changes in detail while they solved problems involving grouped data quartiles. The study was conducted at SMA Negeri 4 Jayapura during the second semester of the 2025/2026 academic year, with data collection carried out in May 2026.

All data-collection activities were integrated into one intensive interaction session on the same day. The session lasted approximately 90 minutes. Integrating all stages into a single session was intended to maintain consistency in the participants' cognitive conditions during the transition process.

The research procedure consisted of four stages. First, a pretest was administered to all students to identify their initial understanding of grouped data quartiles. Second, research subjects were selected based on the pretest results. Third, individual microgenetic tasks were administered. The tasks consisted of six graded steps: calculating the total number of data points, determining the quartile position, constructing the cumulative frequency, determining the quartile class, calculating the quartile value, and completing a transfer problem. During task completion, the researcher observed the strategies used by students and recorded changes occurring at each stage. Fourth, semi-structured interviews were conducted to confirm the strategies and changes in understanding that emerged during task completion.

2.2. Participants, Instruments, Data Collection, and Data Analysis

The participants were 41 tenth-grade students in class 10-G at SMA Negeri 4 Jayapura who had studied statistics, particularly grouped data quartiles. All students completed a pretest to identify their initial ability before the research subjects were selected.

Based on the pretest results, students were classified into high, medium, and low ability categories. The categories were based on pretest scores: high (80–100), medium (60–79), and low (≤ 60).

The intervals were aligned with commonly used assessment criteria in secondary mathematics education and with

previous mathematics education research used to select subjects representing variations in ability (Agnielia Mulyadi et al., 2022).

This classification was intended to obtain variation in students' abilities so that differences in strategy-development trajectories could be identified. The practice of grouping students into high, medium, and low categories has also been used in mathematics education research for selecting subjects in qualitative studies (Alfisyahra et al., 2021; Nilam Sari & Galih Adirakasiwi, 2025).

Three research subjects were then selected through purposive sampling. Subjects were selected based on good communication skills, willingness to participate in the entire research process, and the ability to explain their thinking during problem solving.

One student was selected from each ability category: one high-ability student (S1), one medium-ability student (S2), and one low-ability student (S3).

The research instruments consisted of a diagnostic pretest, microgenetic task sheets, an observation guide, and a semi-structured interview guide. The pretest was used to identify students' initial abilities. The microgenetic task sheet consisted of graded problems designed to allow variations in strategies and changes in understanding to emerge during grouped data quartile problem solving. The observation guide was used to record students' activities, solution strategies, and behavioral changes while completing the microgenetic tasks. The interview guide explored students' reasons and considerations when selecting particular strategies.

The data sources consisted of primary and supporting data. The primary data came from students' solutions to the microgenetic tasks, whereas supporting data were obtained from observations and interviews.

Research data included pretest results, students' written responses, observations during task completion, and interview results. All student activities during task completion were video-recorded and subsequently transcribed. Data validity was ensured through technique triangulation by comparing written work, observation results, and interview results.

Data were analyzed microgenetically in four stages. First, the written work, observation notes, and interview transcripts were examined to identify the strategies used by students. Second, the problem-solving process was divided into episodes corresponding to the stages of solving grouped data quartile problems. Third, the strategies emerging in each episode and the changes in strategies throughout problem solving were identified. Fourth, critical moments were determined, namely points at which substantial strategy or understanding changes occurred. The analysis results were presented as descriptions of strategy development among students in the high-, medium-, and low-ability categories.

3. Result and Discussion

3.1. Pretest Results and Selection of Research Subjects

A pretest was administered to all students to determine their initial ability to calculate grouped data quartiles. Based on the pretest results, students were grouped into high, medium, and low ability categories. The distribution is presented in Table 1.

Table 1. Distribution of Students' Ability Based on Pretest Results

Category	Number of Students
High (80–100)	26
Medium (60–79)	3
Low (≤ 60)	12
Total	41

The distribution shows that most students had mastered the basic procedures for grouped data quartiles, although some still experienced conceptual difficulties. Three research subjects were subsequently selected through purposive sampling: S1 (high), S2 (medium), and S3 (low). Their characteristics are presented in Table 2.

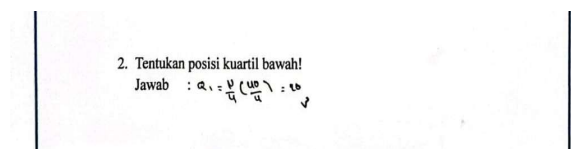
Table 2. Characteristics of Research Subjects

Subject	Pretest Score	Category
26	90	High
3	70	Medium
12	50	Low

The selection of subjects based on cognitive ability was intended to obtain diverse patterns of strategy change during problem solving. Variation in students' initial abilities provided an opportunity to examine the characteristics of strategy development across different ability levels.

3.2. Initial Phase : Formula-Based Strategies and Initial Understanding

In the task requiring students to determine the quartile position, S3 was identified as a experiencing a conceptual difficulty in differentiating a statistical position indicator from the absolute quartile value. Based on the written response, S3 directly concluded that the lower quartile was 10.



In the post-task interview, S3 explained: "I immediately divided by four because the lower quartile is one fourth of the data."

When asked about the meaning of the value 10 obtained from $n/4$, S3 stated : "It is the value of the lower quartile".

The misconception appears to have arisen because the student was able to perform the calculation procedure but did not yet understand the statistical meaning of the resulting value. This is consistent with (Casas del Rosal et al., 2024) , who reported that students often have difficulty connecting statistical procedures with their underlying conceptual interpretations. Consequently, a calculation that actually represents a data position may be

interpreted as the statistical value being sought. (Nuraini & Imami, 2025) similarly explained that mathematical conceptual understanding includes not only the ability to understand relationships among concepts and explain the reasons behind a solution procedure.

Table 3. Students' Initial Strategies for Determining Quartile Position

Subject	Initial Strategy
S1	Correctly determines the quartile position
S2	Determines the position but does not yet understand its meaning
S3	Regards the quartile position as the quartile value

From a constructivist perspective, this indicates that S3's understanding remained at a procedural level. Thus, the student was able to apply $n/4$ but did not understand that the result represents the position of the quartile within the data distribution. The misconception emerged because the student focused more on the calculated result than on the conceptual meaning of the symbols and operations used. This finding is consistent with (Cahani et al., 2021), who found that students' statistical errors are often caused by dominant procedural use without adequate conceptual understanding. This misconception became the starting point for strategy change in the subsequent stage.

3.3. Strategy Change Through the Use of Cumulative Frequency

Strategy changes began to emerge when students were asked to construct the cumulative frequency. At this stage, S2 still attempted to determine the quartile solely from the position formula. However, after completing the cumulative-frequency column, the strategy began to change.

3. Lengkapi tabel frekuensi kumulatif.

Interval Nilai	Frekuensi (f)	Frekuensi Kumulatif (FK)
40-49	4	4
50-59	6	10
60-69	10	20
70-79	12	32
80-89	8	40

Observation during task completion showed that S2 initially had difficulty determining the location of the 10th data point in the frequency-distribution table. After completing the cumulative-frequency column, S2 began to realize that the data position could be identified through cumulative frequency, leading to a change in strategy. This was reinforced by the interview:

Researcher: "What is the function of cumulative frequency?"
S2 : "To determine the quartile class, so I can see which class the 10th data point belongs to."

Triangulation of the written work, observation, and interview showed that cumulative frequency became important

4. Tentukan
Jawab

information that helped S2 determine the quartile class. The change indicates a shift in attention from formula use toward understanding the structure of the data distribution.

Table 4. Strategy Changes Through the Use of Cumulative Frequency

Subject	Before	After
S1	Uses a formula	Uses a cumulative frequency to determine position
S2	Uncertain	Understands the function of cumulative frequency
S3	Guesses	Begins to use cumulative frequency

Understanding cumulative frequency became an important point in students' strategy development. At this stage, students began to establish a relationship between quartile position and the data distribution. From a microgenetic perspective, a change in students' attention toward particular elements of a task can be viewed as an indicator of progress in the development of competence. In cognitive-developmental theory, this change can be viewed as accommodation, namely an adjustment of a knowledge structure that previously could not adequately explain new information. The shift indicates that statistical development depends not only on computational ability but also on the ability to connect different available data representations.

3.4.. Strategy Change Through the Use of Cumulative Frequency

When determining the quartile class, the three subjects showed different patterns. S1 could immediately determine the quartile class based on cumulative frequency. S2 examined several intervals before determining the quartile class, whereas S3 used a different strategy.

Figure 3. Written Work of the Low-Ability Student (S3)

In the interview, S3 stated that initially the student selected the class with the largest frequency because the quartile was assumed to be located in the class containing the largest number of data points. However, after examining the cumulative frequency, S3 changed the answer. Triangulation of the written work, observation, and interview showed that, after attending to cumulative frequency, S3's strategy changed into one that considered the position of the data within the frequency distribution.

Table 5. Strategy Changes in Determining the Quartile Class

Subject	Initial Strategy	Final Strategy
S1	Based on cumulative	Based on cumulative

	frequency	frequency
S2	Checks several intervals	Based on cumulative frequency
S3	Largest frequency	Based on cumulative frequency

The strategy change observed in S3 reflects the characteristics of Siegler's Overlapping Waves theory. The theory explains that students do not immediately abandon an old strategy when a new strategy is acquired; instead, several strategies may be used simultaneously before the more effective strategy becomes dominant. Initially, S3 used an intuitive strategy by selecting the class with the largest frequency. After obtaining more relevant information from the cumulative frequency, the intuition-based strategy was replaced by a strategy more consistent with statistical concepts. This demonstrates that strategy development occurs gradually and dynamically.

3.5 Strategy Changes in Applying the Quartile Formula

In the final stage, students used the grouped-data quartile formula. Based on written work and interviews, S1 was able to use the quartile formula correctly and explain the meaning of each component. S2 was able to perform the calculation correctly but remained uncertain about several components of the formula. S3 could substitute numbers into the formula but did not yet understand the meaning of each symbol used.

5. Hitung nilai kuartil bawah!
Jawab : $Q_1 = \left(\frac{n}{4} - F \right) \times p$
 $L = 49,5$ $F = 4$ $p = 10$
 $n = 40$ F_6
 $= 49,5 + \left(\frac{10-4}{6} \right) \times 10$
 $= 49,5 + 10 = 59,5$

Figure 4. Written Work of the Low-Ability Student (S3)

When asked about the solution procedure, S3 stated: "I just put the numbers into the formula." When asked where the value of F in the quartile formula came from, the following exchange occurred:

Researcher: "Where did you obtain the value of F in the quartile formula?"

S3: "From the frequency table, but I forgot which frequency."

Triangulation of the written work, observation, and interview showed that S3 was able to carry out the substitution procedure in the quartile formula but did not understand the function of each component. This indicates that procedural mastery was not yet fully accompanied by conceptual understanding of the grouped-data quartile formula.

Table 6. Understanding of the Components of the Quartile Formula

Component	S1	S2	S3
Tb (lower class boundary)	✓	✓	✓
F (cumulative frequency)	✓	✓	–
f (class frequency)	✓	✓	✓
p (class width)	✓	–	–

This finding is consistent with the distinction between conceptual and procedural understanding, which indicates that students' ability to use formula components procedurally does not necessarily imply conceptual understanding. S3 was able to substitute values into the formula but did not understand the function of components such as cumulative frequency and class width. The finding reinforces the view that strategy development occurs gradually alongside improvements in the quality of understanding. From a constructivist perspective, conceptual understanding develops when students can connect symbols, procedures, and mathematical meanings within an integrated knowledge structure.

3.6 Trajectory of Students' Strategy Changes

Microgenetic analysis showed that students' strategy changes occurred through four main stages.

Table 7. Trajectory of Strategy Changes

Stage	S1	S2	S3
Stage 1	P2	P1	P0
Stage 2	P3	P2	P1
Stage 3	P3	P2	P2
Stage 4	P3	P3	P2

Notes:

P0 = does not understand; P1 = partially understands; P2 = understands the procedure; P3 = understands the concept.

The P0 – P3 categories were developed by the

researchers to describe levels of developing understanding identified during the microgenetic analysis. The classification was based on indicators of understanding emerging from written work, observation, and interviews.

In this study, P0 indicates that the student did not understand the concept being learned; P1 indicates partial understanding; P2 indicates the ability to use the solution procedure; and P3 indicates conceptual understanding, characterized by the ability to explain relationships among concepts and the reasons for using particular procedures. The use of these developmental categories is consistent with the view that cognitive change in microgenetic studies occurs gradually, from limited understanding toward more stable and conceptual understanding.

Unlike S2 and S3, S1 demonstrated relatively strong initial understanding. Nevertheless, strategy development still occurred when S1 began to integrate understanding of quartile positions, cumulative frequencies, and the components of the quartile formula more comprehensively. This finding indicates that strategy development does not occur only among students experiencing misconceptions; it can also occur among students with high initial ability through refinement and strengthening of conceptual understanding.

The combined data from written work, observations, and interviews consistently showed that students' strategy development proceeded gradually from limited understanding toward conceptual understanding. The changes were evident in students' ability to identify quartile positions, use cumulative frequency, determine quartile classes, and understand the meaning of each component in the grouped-data quartile formula.

The findings are consistent with (Eldstål-Ahrens et al., 2024), who reported that students' mathematical strategy development occurs through gradual transitions and does not necessarily follow a uniform pattern across individuals. The similarity is reflected in the diversity of developmental trajectories influenced by students' prior knowledge and learning experiences.

This study extends those findings into statistics, specifically grouped data quartiles, which have rarely been examined using a microgenetic approach.

The trajectory in Table 7 shows that students' strategy shifts did not occur uniformly but varied according to their initial level of understanding. S1 showed relatively rapid development because the student understood quartile position and cumulative frequency from the beginning.

In contrast, S3 required more adjustment because the student initially regarded $n/4$ as the quartile value and selected the class with the largest frequency as the quartile class. For S3, the strategy of selecting the class with the largest frequency continued to be used even after cumulative-frequency information had been provided. This indicates the simultaneous use of two strategies, as described by Overlapping Waves theory.

The diversity of developmental trajectories among S1, S2, and S3 reflects the role of prior learning experiences and

existing knowledge structures in shaping statistical understanding.

From a microgenetic perspective, the movement from P0 to P3 does not merely represent increased ability to solve problems; it also indicates a fundamental reorganization of how students understand grouped data quartiles.

Therefore, the developmental trajectory mapped in this study can serve as a conceptual basis for understanding the stages through which students construct understanding of measures of position, particularly grouped data quartiles.

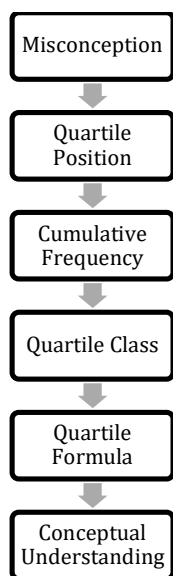


Figure 5. Diagram of the Strategy-Change Trajectory

The diagram indicates that strategy development moves from a misconception concerning quartile position toward a deeper understanding of the meaning of each component in the quartile formula. The trajectory suggests that cumulative frequency occupies a strategic position as a bridge connecting students' understanding of quartile position with their ability to determine the quartile value accurately.

3.7 Main Findings

1. Students' strategy changes occurred gradually through four developmental stages.
2. Understanding cumulative frequency became a critical moment that triggered strategy changes.
3. The most dominant misconception was the tendency to regard $n/4$ as the quartile value rather than the quartile position.

Based on the analysis of S1, S2, and S3, students' strategy development was evident in changes in how they determined quartile positions, used cumulative frequency, determined quartile classes, and applied the quartile formula conceptually.

The findings are consistent with (George & Voutsina,

2021), who showed that mathematical strategy changes occur through gradual transitions and do not necessarily follow the same developmental pattern for every student. The similarity lies in the variation of developmental trajectories influenced by individual prior knowledge and learning experiences. However, this study extends those findings to the statistical context of grouped data quartiles, which has been relatively rarely examined using a microgenetic approach. In addition, the study identifies cumulative frequency as a critical moment that plays an important role in promoting strategy change.

The finding that cumulative frequency functions as a critical moment is also consistent with (Finesilver, 2022), who emphasized that changes in mathematical understanding can be observed through important moments that trigger the reorganization of students' representations and strategies during task completion. In this study, cumulative frequency became an important point that helped students connect quartile position with the data distribution, enabling them to determine the quartile class more accurately. This indicates that strategy change is influenced not only by procedural ability but also by students' ability to make meaning from information represented in a data display.

From a theoretical perspective, the observed strategy changes suggest that the development of statistical understanding is not primarily triggered by mastery of a new formula but by changes in how students interpret data representations. Cumulative frequency functions as key information because it helps students connect quartile position with the data distribution. Once this relationship begins to be understood, students can reorganize strategies that were previously procedural into more conceptual strategies. Thus, strategy development in statistics represents a process of knowledge reorganization rather than merely the addition of new procedures.

These findings support the microgenetic perspective, which views cognitive development as a process of change that can be observed directly as students interact with tasks. The results show that conceptual understanding of cumulative frequency plays an important role in promoting strategy reorganization and the development of grouped-data quartile understanding.

The main contribution of this study lies in identifying the trajectory of students' strategy changes in determining grouped data quartiles and revealing cumulative frequency as a critical moment that promotes the reorganization of statistical understanding. This extends the application of microgenetic approaches to statistics, a domain that has been relatively less studied than other areas of mathematics.

Therefore, statistics instruction should not emphasize formula use alone but should provide opportunities for students to understand the relationships among data position, cumulative frequency, and the meaning of each component in the quartile formula.

4. Conclusion and Suggestions

Based on the microgenetic analysis, students' strategy changes in determining grouped data quartiles occurred through four developmental stages: understanding quartile position, using

cumulative frequency, determining the quartile class, and using the grouped-data quartile formula conceptually. The findings show that students' strategy development proceeds gradually from procedural understanding toward conceptual understanding.

Cumulative frequency was identified as a critical moment that played an important role in reorganizing students' understanding. When students began to understand the function of cumulative frequency in determining quartile positions and classes, their strategies changed toward more conceptual understanding. Conversely, the misconceptions that emerged indicate that some students remained focused on procedural use without understanding the relationship between quartile position and cumulative frequency.

The results confirm that students' understanding does not develop immediately but through a series of strategy changes that can be observed during problem solving.

Theoretically, this study contributes by mapping the trajectory of students' strategy changes in determining grouped data quartiles and identifying cumulative frequency as a critical moment in the development of statistical understanding. The findings extend microgenetic research in mathematics education, particularly in statistics, which has been studied less frequently than arithmetic, fractions, and algebra.

This study has several limitations. First, the research involved only three students representing high-, medium-, and low-ability categories, so the findings cannot represent the full range of strategies that may occur in a larger population. Second, because the microgenetic observation was conducted in a single sequence of activities, the study could not capture students' strategy development over a longer period. Third, the study focused specifically on grouped data quartiles, so the findings may not be generalizable to other statistical topics.

Based on these findings, mathematics teachers are encouraged to design learning activities that help students explore the relationships among quartile position, cumulative frequency, and data distribution before introducing the grouped-data quartile formula. The findings indicate that cumulative frequency functions as a critical moment that helps students reorganize their understanding. Therefore, cumulative-frequency tables can be used as a medium for discussion and conceptual exploration to reduce the misconception that $n/4$ is the quartile value. In addition, graded tasks that allow students to reflect on their solution strategies may help them develop deeper understanding of grouped data quartiles.

Future research should involve a more diverse number of subjects and longer observation periods so that students' developmental trajectories can be examined more comprehensively. Future studies may also investigate whether cumulative frequency functions as a critical moment in other statistical topics, such as deciles, percentiles, or measures of dispersion. Longer observation periods may likewise provide a more comprehensive picture of students' strategy-development trajectories.

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