



Indonesian grade 11 students' conceptual difficulties with measures of central tendency: An nvivo-assisted qualitative study of representativeness, visualization, and decision making

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Abstract

Background: Conceptual understanding is essential in statistics learning, especially measures of central tendency, because it supports students' ability to represent, interpret, and make data-based decisions.

Aims: This study identifies patterns of students' conceptual difficulties in measures of central tendency across basic concepts, data visualization, data interpretation, and decision making.

Methods: A qualitative descriptive case study involved 33 eleventh-grade students from a public senior high school. Data came from a written test and semi-structured interviews with six purposively selected students. Responses were analyzed using NVivo-assisted inductive open coding. Trustworthiness was supported through data-source triangulation, peer debriefing, and an audit trail.

Result: Twenty-two initial codes were synthesized into four themes: understanding basic concepts, data visualization, data interpretation, and Application and decision making. Difficulties were most prominent in viewing central tendency as a representative value, constructing histograms and line plots, and justifying contextual decisions. Common misconceptions included computing the mean as "total frequency ÷ number of categories" and treating histogram tasks as table rewriting rather than graph construction. Overall, the pattern suggests a plausible progression linking conceptual understanding with representational and interpretive demands.

Conclusion: Students' difficulties are interrelated and conceptually driven; instruction should emphasize representativeness, multiple representations, and evidence-based reasoning.

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INTRODUCTION

Measures of central tendency (mean, median, and mode) are central ideas in secondary statistics because they serve as *representative values* that summarize a dataset and support interpretation and decision making in real contexts. However, students frequently treat these measures as merely computational procedures rather than as tools for representing and reasoning about data. Empirical studies have shown that students often struggle to explain what the mean, median, or mode *represents*, to select an appropriate measure for a given context, and to justify decisions using statistical (Aydn & Ay, 2025; Akar & Işıksal Bostan, 2025; Landtblom & Sumpter, 2025). These difficulties are compounded when tasks require moving across representations (tables, histograms, bar charts, line plots) and interpreting visual information to draw conclusions (Binali et al., 2024; Rao et al., 2025).

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From the perspective of mathematics learning, conceptual understanding is essential because it enables students not only to carry out procedures but also to grasp meaning, purpose, and conceptual connections. The relationship between conceptual understanding and procedural knowledge is mutually reinforcing: conceptual understanding supports flexible use of procedures, while procedures can deepen concepts when accompanied by reflection (Rittle-Johnson & Siegler, 2021). In contrast, instruction that overemphasizes procedures without conceptual grounding tends to produce shallow understanding and increases conceptual errors (Barumbun & Kharisma, 2022). Conceptual understanding also underpins higher-level thinking, including reasoning, non-routine problem solving, and evidence-based decision making, all of which are central to statistical literacy (Fielding & Makar, 2022; Jäder & Johansson, 2025).

In statistics learning, conceptual understanding becomes particularly crucial because students must integrate quantitative reasoning, visual representation, and contextual interpretation to make data-based decisions (Mulligan et al., 2024). Measures of central tendency require students to connect computations to the idea of “typical/representative value,” interpret how that value relates to distributional features, and select an appropriate measure depending on context (Akar & Işıksal Bostan, 2025; Landtblom & Sumpter, 2025). Yet many students experience misconceptions and weak statistical reasoning that lead them to treat mean, median, and mode mechanistically rather than as representative summaries of data (Maryati & Priatna, 2018; Gunadi et al., 2022). In addition, students often encounter difficulties with data visualization and interpretation, such as constructing or reading histograms and line plots, which limits their ability to draw conclusions and justify decisions in contextual problems (Binali et al., 2024; Subali et al., 2025). Cognitive and affective factors (e.g., attitudes toward statistics and statistics anxiety) may further influence the quality of students’ statistical understanding (Saidi & Siew, 2022; Ismail et al., 2022).

To guide the analysis in this study, we adopt a conceptual lens that integrates three closely related components of statistical understanding: (1) representativeness (understanding measures of central tendency as representative values rather than formulas), (2) representational competence (coordinating numerical, tabular, and graphical representations of data), and (3) statistical reasoning for decision making (interpreting results and using them to justify conclusions in context). This lens is consistent with prior work emphasizing that students may compute correctly yet still struggle to interpret results or use them as a basis for data-driven decisions, especially when the task demands movement across representations (Schuchardt & Schunn, 2016; Lemieux & Chapman, 2025; Rao et al., 2025). Accordingly, the present study organizes students’ difficulties across four analytic dimensions, basic concepts (representativeness), data visualization, data interpretation, and Application and decision making, which are examined through inductive coding.

Although prior studies have contributed important insights into students’ difficulties in statistics, many have emphasized quantitative indicators such as error rates, test scores, or closed-ended assessments, with comparatively fewer providing in-depth accounts of how these difficulties are formed within students’ thinking processes (Mahfudhoh & Kurniasari, 2025). Quantitative-only approaches may offer limited explanations of how students construct, connect, and represent measures of central tendency across learning contexts (Jäder & Johansson, 2025; De Zeeuw et al., 2013). Therefore, several scholars recommend qualitative or mixed-methods approaches to examine students’ reasoning processes more (Kelle & Buchholtz, 2015; Sasidharan & Kareem, 2023). However, software-assisted qualitative analysis in mathematics education remains relatively limited, even though tools such as NVivo can support systematic coding, transparent data management, and visualization of conceptual relationships (Allsop et al., 2022; Saputri et al., 2025). This situation points to a research gap: the need for in-depth qualitative studies that map patterns of students’ conceptual difficulties in measures of central tendency using transparent, technology-supported analytic procedures.

Based on this background, the present study aims to identify and analyze patterns of students' conceptual difficulties in understanding measures of central tendency. Specifically, the study examines difficulties in understanding basic concepts (representativeness), visualizing data, interpreting results, and applying measures of central tendency in decision making. Using a qualitative descriptive case study supported by NVivo for data management and coding, the study seeks to generate a systematic mapping of students' conceptual difficulty patterns that can inform more effective statistics instruction.

METHOD

Research Design

This study employed a qualitative descriptive case study design to examine patterns of eleventh-grade students' conceptual difficulties in measures of central tendency. The case was bounded as one Grade 11 mathematics class in a public senior high school in Majalengka Regency, Indonesia, taught by a single mathematics teacher. Data were collected in a single day after classroom instruction on measures of central tendency had been completed. This class was selected as an information-rich case because students had recently learned the target topic and demonstrated varied responses on the written test, enabling in-depth exploration of contrasting conceptual difficulties. A qualitative approach was used to capture students' reasoning processes and explanations that were not fully observable from written answers alone (Ograjenšek & Gal, 2016).

Participant

The participants in this study consisted of 33 eleventh-grade students at a public senior high school in Majalengka Regency in the 2024/2025 academic year. Access to the site and data collection were approved by the school and the class mathematics teacher. Participation was voluntary, and students provided informed assent prior to completing the written test and interviews. To protect confidentiality, all data were anonymized using participant codes, and identifying information was removed from notes and reporting. Purposive sampling was chosen because it allows researchers to recruit participants who are most relevant and information-rich in line with the study's objectives, particularly in qualitative research that emphasizes depth of understanding rather than the generalizability of findings (Ahmad & Wilkins, 2025). All participants had completed instruction on measures of central tendency under the applicable curriculum. For follow-up interviews, six students were purposively selected using maximum variation based on written-test performance to represent contrasting levels of conceptual understanding (e.g., high, medium, and low performance). This strategy aligns with the principle of purposive sampling, which emphasizes selecting informative cases to capture the variation of the phenomenon under investigation comprehensively (Ahmad & Wilkins, 2025).

Instrument

Data were collected using two instruments: a written test and semi-structured interviews. The written test consisted of six main questions with ten sub-items (Items 1, 2, 3a–3b, 4a–4b, 5a–5b, and 6a–6b) aligned with four dimensions of conceptual understanding: basic concepts (data type and measures of central tendency as representative values), data visualization, data interpretation, and Application and decision making. The test was administered in one session lasting three class periods. Prior to administration, the items were reviewed and refined through expert feedback from the research supervisor and a statistics/mathematics education course lecturer to ensure clarity and alignment with the intended dimensions. The test blueprint and original items are provided in Appendix A–B, and the analytic scoring rubric summary is provided in Appendix C.

Semi-structured interviews were conducted with six purposively selected students to elicit explanations for their written-test responses and to clarify sources of difficulty across the same

dimensions. Interviews were conducted in Indonesian and typically lasted 10–15 minutes. With students' permission, the researcher took detailed notes during each interview and expanded them immediately afterward; all interview records were anonymized using participant codes. A standardized interview guide and core prompts were used consistently across participants, with follow-up probes adapted to students' responses. The interview protocol (sample questions and prompts linked to the test items) is provided in Appendix D. Interview notes were triangulated with written-test data by linking each interview account to the corresponding test item(s) to corroborate and elaborate coding interpretations.

Data Analysis

Data analysis was conducted qualitatively with NVivo used as a tool for data management and retrieval, not as an automated analytic agent. Students' written-test responses and interview notes were converted into digital text and imported into NVivo for integrated analysis. The primary coding unit was a meaningful segment of a response linked to each test sub-item or interview prompt. Analysis began with inductive open coding to label meaning units that reflected conceptual understanding and difficulty patterns. An initial codebook was developed iteratively by defining each code and documenting inclusion/exclusion criteria with brief exemplar excerpts; the codebook was refined through repeated comparison across cases and data sources. Codes were then clustered into higher-order categories and synthesized into the four themes reported (basic concepts, data visualization, data interpretation, and Application and decision making). NVivo was used to support transparent organization of coded segments and to generate visualizations to assist interpretation. Coding was conducted by the first author, and theme development was reviewed through peer debriefing with the supervisor to discuss code definitions, resolve ambiguities, and confirm thematic boundaries. An audit trail was maintained throughout the analysis, enhancing transparency and trustworthiness. Integration of written-test and interview notes also supported data-source triangulation (Meydan & Akkaş, 2024).

RESULTS AND DISCUSSION

Results

The research findings were derived from qualitative analysis of students' written-test responses and interview notes using an inductive open-coding approach supported by NVivo for data organization. The analysis generated 22 initial codes representing recurring patterns of conceptual difficulty in measures of central tendency. These codes were grouped based on shared meaning and synthesized into four themes: (1) Understanding Basic Concepts, (2) Data Visualization, (3) Data Interpretation, and (4) Application and Decision Making. These themes capture interrelated aspects of students' conceptual understanding spanning definition, representation, interpretation, and contextual justification. To provide transparency of the analytic procedure, the coding pipeline is summarized in Table 1.

Table 1. Coding pipeline and example excerpt-to-theme mapping

Step	What the researchers did (decision rules)	Output / artifact	Worked example (excerpt → code → theme)
Data preparation	Collected written-test responses (Items 1–6b) and interview notes, anonymized participants (S01...); converted to digital text for NVivo organization.	Clean dataset; anonymized IDs; NVivo project file	
Define coding unit	Used meaningful segments as coding units (a sentence/phrase/explanation	Unit-of-analysis rule for coding	Example unit: "10 ÷ 5 = 2" (one solution step)

	or a distinct solution step) linked to each test sub-item		
Inductive open coding	Assigned a short descriptive label to each meaning unit. Decision rule: code captures the difficulty/misconception shown, not just the topic	Initial open codes (22) + codebook draft	Excerpt (S07, Item 6): "1+3+3+2+1=10; 10 ÷ 5 = 2" → Code: "mean computed as frequency ÷ categories" → Theme: Application and decision making
Codebook refinement	Compared coded segments across students/items; merged similar codes; clarified code definitions and inclusion/exclusion criteria; recorded changes in analytic memos (audit trail).	Revised codebook + memos	Excerpt (S03, Item 3a): listing intervals only (no axes/bars) → Code: "histogram treated as table rewriting" → Theme: Data visualization
Theme synthesis	Grouped codes into higher-order categories using conceptual similarity, resulting in four themes (basic concepts, visualization, interpretation, Application and decision making).	4 themes + code-theme map	Excerpt (S02, Item 2): "Median: salah satu ukuran pemusatan data" → Code: "label-only definition" → Theme: Understanding basic concepts
Transparency & checking	Used NVivo to organize coded excerpts and track code-theme relationships; maintained an audit trail (codebook versions + memos). Evidence excerpts are reported in Table 3 to "show the work."	NVivo outputs (maps) + audit trail + evidence table	
Inductive open coding	Assigned a short descriptive label to each meaning unit. Decision rule: code captures the difficulty/misconception shown, not just the topic	Initial open codes (22) + codebook draft	Excerpt (S07, Item 6): "1+3+3+2+1=10; 10 ÷ 5 = 2" → Code: "mean computed as frequency ÷ categories" → Theme: Application and decision making

Table 1 summarizes the coding pipeline and the decision rules used to move from raw student responses to codes and themes, including illustrative excerpt-to-theme mappings. The distribution of codes across themes is presented in Table 2, and representative coded excerpts supporting each theme are provided in Table 3.

Table 2. Distribution of Codes and Patterns of Findings by Theme

Main Theme	Number of Codes	Operational Definition (What Counts Under This Theme)	Main Pattern Indicated
Understanding Basic Concepts	6	Codes capturing difficulties in defining/understanding data types (ungrouped vs grouped) and measures of central tendency as representative values (e.g., label-only definitions, procedural-only explanations, misconceptions about "representative value").	Errors predominantly related to conceptual meaning of central tendency and basic statistical terms.
Data Visualization	7	Codes capturing difficulties in constructing appropriate representations (histogram, bar chart, line plot), including choosing the correct representation, setting axes/scales, and mapping frequencies/intervals correctly.	Highest difficulty in histograms and line plots; frequent confusion between tables and graphs.

Data Interpretation	4	Codes capturing difficulties in reading and explaining meaning from a given or self-constructed representation, including identifying trends/most frequent values and supporting claims with evidence from the graph/data.	Variation in students' ability to make evidence-based interpretations.
Application and Decision Making	5	Codes capturing difficulties in computing/choosing mean/median/mode and using results to justify a contextual decision, including misapplication of mean as a benchmark and weak/no justification.	A gap between performing calculations and using results for decision making and justification.
Total	22 codes		

The distribution of codes in Table 2 shows that students' conceptual difficulties are not evenly distributed, with greater intensity in the areas of data visualization and understanding basic concepts. To enhance transparency, representative coded excerpts from students' written-test responses are presented in Table 3.

Table 3. Theme evidence table (representative coded excerpts and interpretations)

Theme	Representative code	Exemplar excerpt (student work)	Interpretation
Understanding Basic Concepts	Misconception about grouped vs ungrouped data	S1 (Item 1): " <i>Kelompok: ... data yang menyimpulkan data kelompok... Tunggak: ... data orang tersebut/orang itu sendiri.</i> " (Grouped: data summarizing a group; Ungrouped: data about the person.)	The student defines data types based on <i>who</i> the data describe rather than how the data are organized (grouped by intervals vs listed individually), indicating a conceptual mismatch.
Understanding Basic Concepts	Central tendency explained procedurally; incomplete definitions	S2 (Item 2): " <i>Mean... menjumlahkan seluruh nilai data, kemudian membaginya dengan banyaknya data... Median: salah satu ukuran pemusatan data. Modus: salah satu ukuran pemusatan data.</i> " (Mean: sum divided by number of data; Median/Mode: stated without meaning.)	The student relies on a procedural rule for the mean and provides label-only definitions for median/mode, suggesting rote knowledge and limited understanding of central tendency as a representative value.
Data Visualization	Histogram treated as rewriting table	S3 (Item 3a): Student lists class intervals and frequencies (e.g., "4-5: 8; 6-7: 10; ...; 10-11: 5") without drawing axes/bars.	The student treats the histogram task as copying interval-frequency information rather than producing a graphical representation, indicating limited representational competence.
Data Visualization	Bar chart replaced by frequency table	S4 (Item 4a): Student draws a two-column frequency table ("Nilai kesulitan"-"Frekuensi") instead of a bar chart.	The student conflates tabular and graphical representations, showing difficulty translating data into a bar chart format.
Data Visualization	Line plot confused with a continuous line graph	S5 (Item 5a): Student draws a connected up-down line across values (95, 90, 85, ...), resembling a continuous graph.	The student interprets a line plot as a continuous line graph rather than discrete points/frequencies, reflecting a misconception about the representation's defining features.

Application and decision making	Decision without statistical justification	S6 (Item 6b): <i>"Perlu mengurangi karena melebihi dari 10 hari."</i> (Needs to reduce because it exceeds 10 days.)	The decision is not linked to comparing daily spending to the mean threshold or identifying specific days, indicating weak evidence-based justification.
Application and decision making	Mean computation error (dividing by number of categories)	S7 (Item 6): <i>"1+3+3+2+1=10"</i> then <i>"10 ÷ 5 = 2"</i> .	The student divides total frequency by the number of categories, showing a conceptual/procedural error in computing or applying the mean.

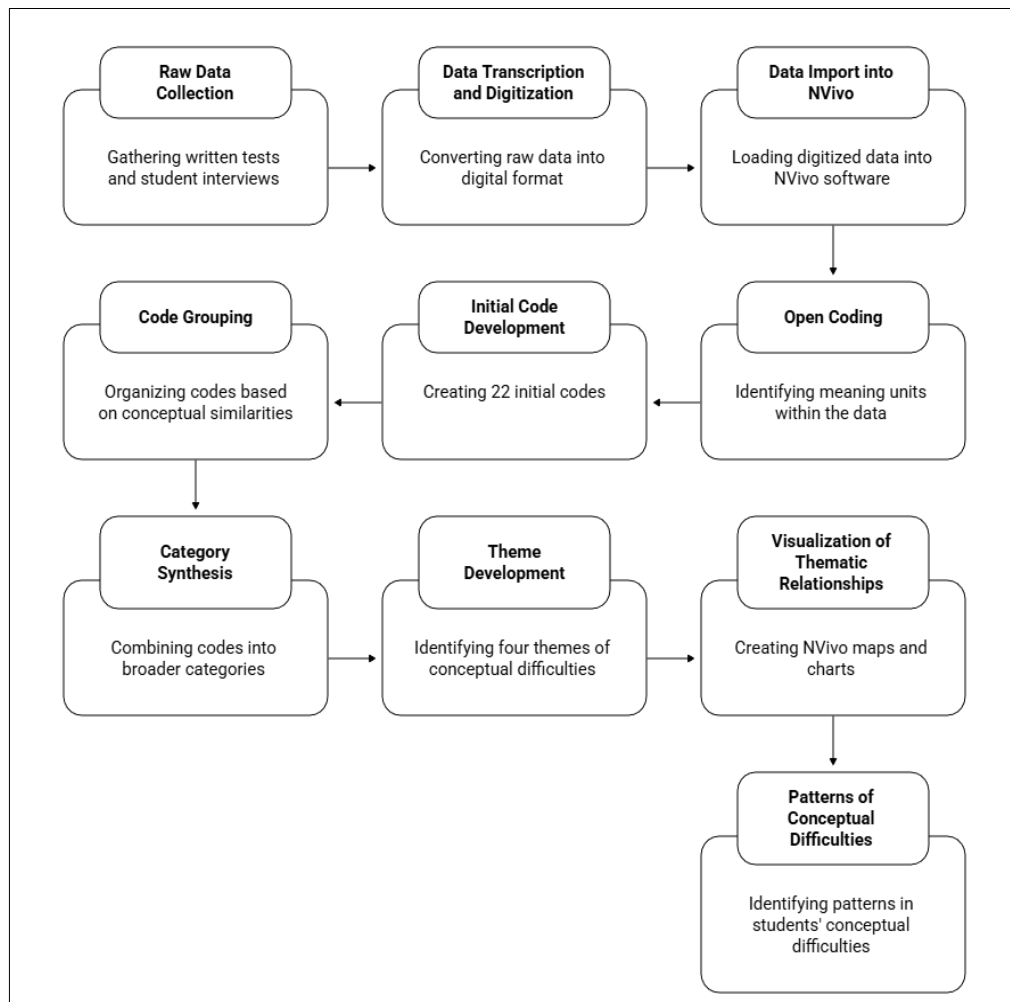


Figure 1. Qualitative Data Analysis Process

The diagram summarizes the analytic pipeline from raw written-test responses and interview notes to theme development: data transcription/digitization, import into NVivo for data management, segmentation into meaning units, inductive open coding (resulting in 22 initial codes), code grouping and category synthesis, and theme development into four themes. NVivo was used to organize coded segments and to generate thematic maps/charts for visualization; all coding and interpretation decisions were made by the researchers. The figure is provided to increase transparency and traceability of the analytic procedure and to clarify the decision points that produced the final themes.

Understanding Basic Concepts

The theme of understanding basic concepts represents students' initial ability to grasp fundamental statistical concepts, particularly the definitions of ungrouped and grouped data and the meaning of measures of central tendency. This theme emerged as one of the main themes from the coding synthesis because it indicates significant patterns of conceptual difficulty and serves as a foundation for subsequent stages of understanding.

1.1. Definitions of Ungrouped and Grouped Data

The coding visualization related to students' ability to define ungrouped and grouped data is presented in Figure 2. The visualization indicates that most students 29 out of 33 were able to correctly define ungrouped and grouped data. However, four students still demonstrated conceptual errors in distinguishing between the two types of data. These findings suggest that although students' understanding of data classification is relatively strong, this basic conceptual understanding is not yet evenly distributed across all students. Next, the coding visualization related to students' ability to define measures of central tendency is presented in Figure 3. This visualization reveals a different pattern from that found for data classification. Of the 33 students, only 15 (45.45%) were able to correctly define measures of central tendency, whereas 18 (54.55%) still made errors in explaining the concept. The dominance of the error category indicates that measures of central tendency are more difficult for students to understand than the definitions of ungrouped and grouped data.

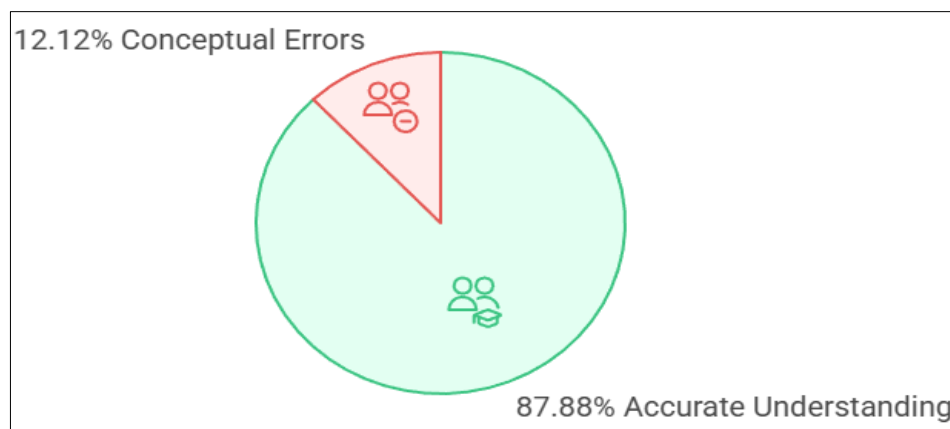


Figure 2. Visualization of Coding Results on Students' Basic Conceptual Understanding: Definitions of Ungrouped and Grouped Data

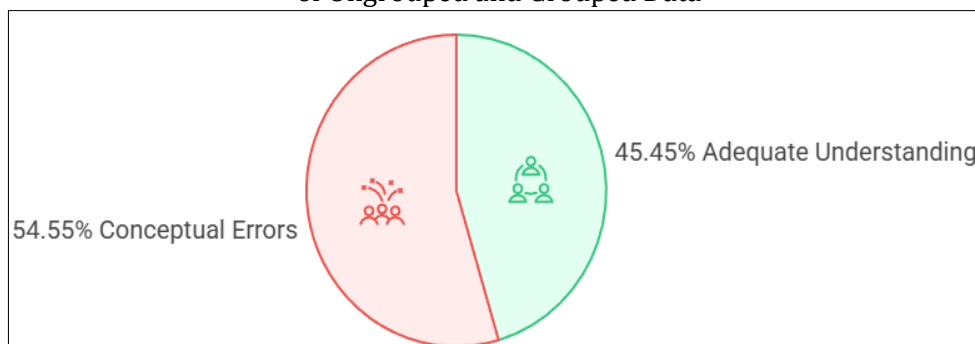


Figure 3. Visualization of Coding Results on Students' Basic Conceptual Understanding: Definition of Measures of Central Tendency

The errors observed in students' understanding of measures of central tendency were not merely related to unfamiliarity with terminology, but also to limitations in interpreting central tendency as a representative value of a dataset. Some students tended to describe computational procedures without demonstrating a conceptual understanding of the roles of the mean, median, and

mode. This pattern indicates that, at the basic conceptual understanding stage, students face greater challenges in defining measures of central tendency conceptually.

An example of students' conceptual errors in defining ungrouped and grouped data is shown in Figure 4. In one written response, a student stated that "grouped data are data that summarize everything in that group, whereas ungrouped data are data about the person themselves." This response indicates that the student did not understand the difference in the format and structure of the data, but instead interpreted the concept based on the subject (who the data describe) rather than its mathematical characteristics. This interpretation is supported by interview notes, in which one student indicated that they distinguished ungrouped and grouped data based on the number of people rather than on how the data are organized (paraphrased from interview notes).

This suggests that some students have not yet developed an accurate conceptual understanding of the distinction between ungrouped and grouped data as a difference in how data are presented and grouped.

1	kelompok : yaitu sebuah data yang menyimpulkan data kelompok atau semua yang ada di kelompok itu
	terpisah : yaitu sebuah data yang menyimpulkan data orang tersebut atau orang itu sendiri.

Figure 4. Example of Students' Conceptual Errors in Defining Ungrouped and Grouped Data

Next, an example of students' conceptual errors in defining measures of central tendency is shown in Figure 5. An analysis of the students' written work in the figure indicates that some students understood the procedure for calculating the mean but had not developed a complete conceptual understanding of the meaning of measures of central tendency. The student described the mean as an average obtained by summing all data values and dividing by the number of data points, yet did not explain the function of the mean as a representative value of a dataset.

In addition, students' understanding of the median and mode appeared more limited. Students only wrote that the median and mode are "one of the measures of central tendency," without providing further explanation of how to determine them or the role each measure plays. This response pattern suggests that students tend to recognize terms and formulas by rote, but are not yet able to connect them to the underlying conceptual meaning. This finding is consistent with the coding visualization in Figure 3, which shows the dominance of conceptual errors in students' understanding of measures of central tendency at the basic conceptual understanding stage.

2	Mean : Rata-rata, merupakan wakil kumpulan data.
	Mean dapat dihitung dengan menjumlahkan
	Seluruh nilai data, kemudian membaginya
	dengan banyaknya data
	Median : Salah satu ukuran pemusatan data
	Modus : Salah satu ukuran pemusatan data

Figure 5. Example of Students' Conceptual Errors in Defining Measures of Central Tendency

1.2. Definition and Interpretation of Measures of Central Tendency

In contrast to the definitions of ungrouped and grouped data, more dominant difficulties emerged in students' understanding of measures of central tendency. The coding visualization in Figure 3 shows that only 15 students were able to define measures of central tendency accurately, whereas the remaining 18 students still demonstrated misconceptions. Analysis of students' responses indicates that some students could describe the procedural steps for calculating the mean,

but did not yet understand its meaning as a representative value of a dataset. An example of such a response is presented in Figure 5, where the student explains the procedure for calculating the mean without linking it to the mean's role in representing the data.

Meanwhile, students' understanding of the median and mode appeared more limited. Some students only wrote that the median and mode are "one of the measures of central tendency" without providing further explanation of their meaning or how they work, as shown in Figure 5. This response pattern suggests that students' understanding in this area remains based on rote memorization and has not yet developed into a complete conceptual understanding. This interpretation is supported by interview notes indicating that at least one student could recall formulas for the mean, median, and mode but reported difficulty explaining what these measures mean conceptually (paraphrased from interview notes).

This reinforces that students tend to master procedural aspects but are not yet able to explain the conceptual meaning of measures of central tendency. Overall, the theme of basic conceptual understanding indicates that students are relatively more capable of understanding data classification than of making sense of measures of central tendency. The conceptual difficulties primarily appear as limited understanding of central tendency as a representative value and a tendency to rely on procedural memorization. These difficulties also appear linked to challenges observed in students' work on representation, interpretation, and contextual justification tasks.

Data Visualization

The data visualisation theme represents students' ability to represent statistical data in various visual forms, including histograms, bar charts, and line plots. This theme emerged as one of the main themes from the coding synthesis, as it reveals prominent patterns of conceptual difficulty, particularly in students' ability to translate numerical data into appropriate visual representations. The NVivo-based coding visualisation of students' data visualisation skills is presented in Figure 6. The visualisation shows variations in students' performance across different types of data representations. With respect to histogram construction, the analysis indicates that 14 out of 33 students (42.42%) were able to construct histograms correctly. However, 6 students (18.18%) demonstrated partial errors in histogram construction, while 13 students (39.39%) were unable to construct histograms at all. This distribution suggests that more than half of the students experienced difficulties in accurately representing data in histogram form.

In contrast, students demonstrated relatively better performance in constructing bar charts. The results show that 19 students (57.58%) were able to construct bar charts correctly, whereas 3 students (9.09%) made partial errors and 11 students (33.33%) were unable to construct bar charts as required. Although bar charts were generally better understood, the presence of a substantial proportion of students who experienced difficulties indicates that students' data visualisation skills are not yet evenly developed. The greatest difficulty was observed in line plot construction. Only 8 students (24.24%) were able to construct line plots correctly, while 12 students (36.36%) made errors in their construction, and 13 students (39.39%) were unable to construct line plots. The relatively balanced proportions between error and inability categories indicate that line plots constitute the most challenging form of data visualisation for students. Overall, the pattern shown in Figure 6 demonstrates that students' difficulties in data visualisation are most pronounced in histogram and line plot representations, whereas bar charts are relatively easier for students to understand and construct.

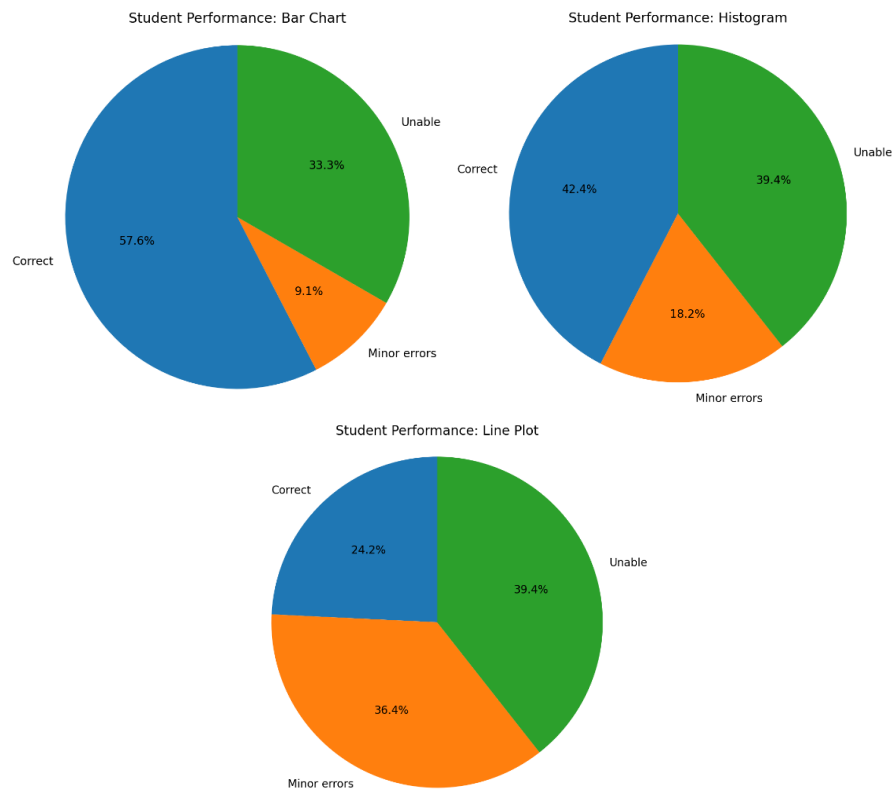


Figure 6. Students' performance in constructing bar charts, histograms, and line plots

To clarify the nature of the difficulties experienced by students, samples of students' responses are presented in Figures 7, 8, and 9. An example of a student's error in drawing a histogram is shown in Figure 7. In this response, the student merely rewrote the class intervals and frequencies provided in the question, without proceeding to the steps of constructing a frequency table or drawing the histogram. This response pattern indicates that the student has not yet developed a comprehensive understanding of the histogram-construction procedure, particularly the relationship among the raw data, the frequency table, and the resulting visual representation.

<input type="checkbox"/>	3. a	$u-5 = 8$
<input type="checkbox"/>		$6-7 = 10$
<input type="checkbox"/>		$8-9 = 7$
<input type="checkbox"/>		$10-11 = 5$

Figure 7. Example of a Student Response Demonstrating an Inability to Draw a Histogram

Next, an example of an error in visualizing data using a bar chart is presented in Figure 8. In this artifact, the student only provided the data in the form of a frequency table without constructing the bar chart as required by the task. This indicates that the student has not yet understood the difference in function between a frequency table and a bar chart as a visual representation of data.

<input type="checkbox"/>			
<input checked="" type="checkbox"/>	4. A.	nilai kesulitan	frekuensi
<input type="checkbox"/>		1	0
<input type="checkbox"/>		2	3
<input type="checkbox"/>		3	8
<input type="checkbox"/>		4	7
<input type="checkbox"/>		5	2
<input type="checkbox"/>			
<input type="checkbox"/>			

Figure 8. Example of a Student Response Demonstrating an Inability to Draw a Bar Chart

A more conceptual error is evident in the line-plot visualization, as shown in Figure 9. In this figure, the student produced a curved graph resembling a function graph rather than a line plot. This response suggests that the student has not yet understood the defining characteristics of a line plot as a representation of discrete data, displayed as points on a number line according to their frequencies, without connecting the points with a continuous line.

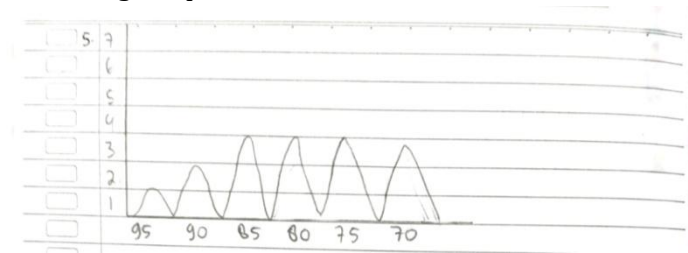


Figure 9. Example of a Student's Answer Who Is Unable to Draw a Line Plot

Overall, the findings within the data visualization theme indicate that students' difficulties are not limited to the technical aspects of drawing but also reflect constraints in their conceptual understanding of the purposes and defining features of each form of data representation. These recurring patterns suggest that students' understanding of data visualization remains partial and largely procedural, and has not yet been fully integrated with the underlying statistical meaning. Difficulties at the visualization stage may consequently affect students' ability to interpret data and to apply measures of central tendency in subsequent learning.

Data Interpretation

The data interpretation theme reflects students' ability to read, comprehend, and derive meaning from information presented in the form of data. This theme emerged as one of the key themes in the coding synthesis results, as it highlights variations in students' ability to connect the data to appropriate conclusions.

The coding-visualization results related to students' data-interpretation ability are presented in Figure 10. The visualization indicates that most students were able to interpret the data effectively. Nevertheless, a number of students still experienced difficulties and were unable to provide accurate interpretations. These findings suggest that although data-interpretation ability is generally strong among the majority of students, this understanding is not yet evenly distributed across the entire cohort.

The presence of a group of students who were unable to provide accurate interpretations indicates that some students still face challenges in understanding the meaning of the data and relating it to the context of the problem. This condition highlights the need for further attention and instructional support particularly for students who continue to struggle so that their ability to interpret data can be strengthened

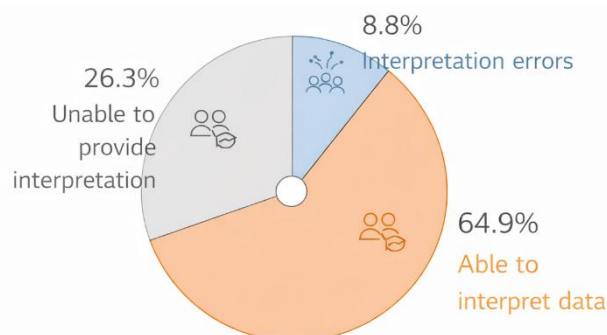


Figure 10. Coding Visualization of Students' Data Interpretation Ability

Figures 11 and 12 illustrate differences in students' ability to interpret data. Figure 11 presents an example of a student response that demonstrates an inability to interpret the data accurately, as indicated by a general explanation that does not clearly link the data to the conclusion drawn. In contrast, Figure 12 shows an example of a student response that successfully interprets the data, evidenced by a clear explanation of the relationship between the data, the average values, and logical reasoning that supports the conclusion.

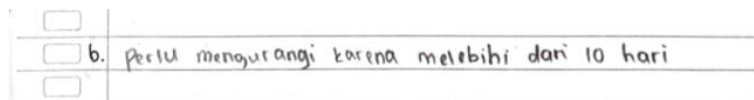


Figure 11. Example of a student response that demonstrates an inability to accurately interpret data

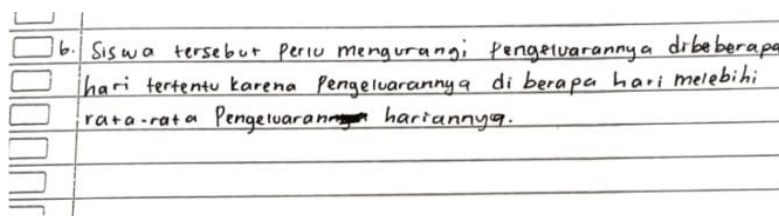


Figure 12. Example of a student response that demonstrates the ability to accurately interpret data

Application of Measures of Central Tendency

The theme of applying measures of central tendency represents students' ability to use the concepts of the mean, median, and mode to solve problems, as well as to employ the resulting calculations as a basis for decision-making. This theme emerged as one of the key themes in the coding synthesis because it captures the extent to which students not only understand the concepts, but are also able to apply them procedurally and within context.

1.1. Calculating Measures of Central Tendency

The coding-visualization results regarding students' ability to calculate measures of central tendency are presented in Figure 13. The visualization shows that the difference between students who were able and unable to calculate measures of central tendency is relatively small. Based on the analysis, 14 students solved the central-tendency calculation items correctly, 4 students made computational errors, 2 students provided correct answers but did not show their solution steps, and 13 students were unable to complete the central-tendency calculation tasks. These findings indicate that students' procedural competence in calculating measures of central tendency is not yet evenly developed, underscoring the need for reinforcement through more effective instructional approaches.

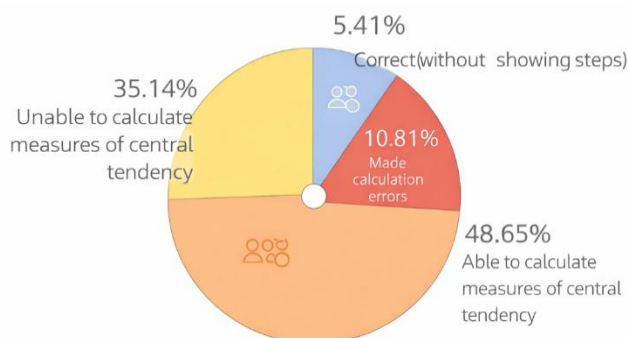


Figure 13. Students' Ability to Calculate Measures of Central Tendency

1.2. Making Decisions Based on Calculation Results

Next, the coding-visualization results related to students' ability to make decisions based on measures of central tendency are presented in Figure 14. The visualization indicates that most students were not yet able to use their calculation results as a basis for decision-making. The analysis shows that 18 students were unable to draw a decision from the results of their calculations, whereas 15 students were able to make appropriate decisions. The predominance of the "unable" category suggests that students face substantial difficulty in applying central-tendency results to decision-making contexts; therefore, this aspect warrants focused attention in subsequent instruction.

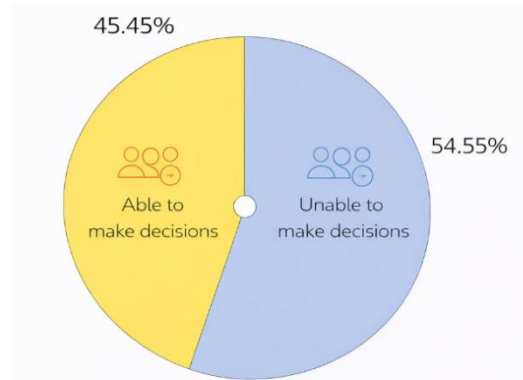


Figure 14. Students' Ability to Make Decisions Based on Measures of Central Tendency Results

1.3. Examples of Errors in Calculating Measures of Central Tendency

An example of a student response that contains an error in calculating measures of central tendency is presented in Figure 15. Based on the analysis, the student correctly determined the frequency of each value and obtained a total frequency of 10. However, the student then divided the total frequency by the number of categories ($10 \div 5 = 2$), producing a result that does not represent the correct mean. This error indicates that the student has not yet understood the procedure for computing the mean as the weighted average—namely, the sum of each data value multiplied by its frequency, divided by the total frequency. Therefore, the mistake reflects not only an arithmetic miscalculation but also a conceptual misunderstanding of the meaning and purpose of the steps involved in calculating the mean.

6	40, 50, 60, 50, 70, 60, 50, 80, 70, 60.
	40 = 1 1+3+3+2+1 = 10
	50 = 3 10 ÷ 5 = 2
	60 = 3
	70 = 2
	80 = 1

Figure 15. Example of a Student Response Containing Errors in Calculating Measures of Central Tendency

Discussion

This discussion is grounded in a qualitative thematic analysis of students' written-test responses and interview notes. In addition to thematic interpretation, we report simple descriptive counts/percentages to indicate the *salience* of particular difficulties across participants and tasks. These frequency indicators are used to highlight which codes appeared more often in the dataset and to support transparent reporting; they are not intended for statistical inference or generalization beyond the case. The findings suggest an interrelated pattern of students' difficulties in learning measures of central tendency. These difficulties are not limited to computation; they are closely

associated with students' conceptual understanding, representational competence, and their ability to justify decisions using data. Across the four themes (basic concepts, visualization, interpretation, and Application and decision making), recurring difficulties often co-occurred within students' work, indicating conceptual links among these aspects of statistical understanding.

At the conceptual-understanding stage, most students were able to distinguish between ungrouped (single) data and grouped data reasonably well. However, more substantial difficulties emerged when students were asked to define measures of central tendency. Many students tended to describe the mean, median, and mode procedurally as formulas or calculation steps—without understanding their meaning as representative values of a dataset (Mokros & Russell, 1995). This finding reinforces theoretical perspectives on the imbalance between procedural knowledge and conceptual understanding, where mastery of procedures without meaning tends to produce shallow and inflexible understanding (Star, 2005).

These conceptual limitations became more evident at the data-visualization stage. Although bar charts were relatively easier for students to understand, difficulties increased markedly for histograms and line plots (Lian et al., 2022). Many students were unable to construct a complete histogram or to draw a line plot in accordance with its defining characteristics; some even produced graphs resembling continuous function graphs (Ayeh, 2025); Boels et al., 2025). From the perspective of representation theory in mathematics education, these results indicate weak representational competence namely, the ability to meaningfully connect numerical data, frequency tables, and graphical representations (Edelsbrunner et al., 2023). Visual representations appear to be viewed as final products rather than as tools for understanding and reasoning about data (Zentgraf & Prediger, 2024).

Difficulties in data visualization have direct implications for data-interpretation skills (Pozdniakov et al., 2024). While many students were able to interpret data correctly, a subgroup failed to derive meaning from graphical representations (Binali et al., 2024). This suggests that students have not fully developed the ability to use visual representations as a basis for statistical reasoning (Franconeri et al., 2021). Theoretically, data interpretation requires the integration of conceptual understanding, visual representation, and problem context (Groth & Choi, 2023). When any of these components is weak, the interpretation process becomes suboptimal (Thomanek et al., 2025). At the application stage, students' difficulties became increasingly complex (Cazorla et al., 2023). Some students were able to compute measures of central tendency but failed to apply the results to decision-making (Rosidah & Ikram, 2021). Procedural errors such as dividing the total frequency by the number of categories indicate that students have not yet understood the concept of the average at a conceptual level (Svensson & Holmqvist, 2021). Moreover, the large number of students who were unable to make decisions based on their calculations points to a gap between computational skill and statistical reasoning (Landtblom, 2023). Theoretically, data-based decision-making is a complex component of statistical literacy, supported by conceptual, representational, and interpretive competencies developed in earlier stages (Kurnia et al., 2024).

These quantitative findings are further supported by student interview notes. Most students reported that statistics is a difficult topic, primarily due to insufficient understanding of basic concepts (Zin et al., 2023). Reliance on textbooks as the only learning resource, limited variation in instructional methods, time constraints, and low learning motivation further intensified the difficulties students experienced (Li & Wang, 2024; Niki, 2024; Xiong, 2025). Students' efforts to learn from alternative sources, such as online instructional videos, suggest a need for more accessible conceptual and visual explanations (Greeves & Oz, 2024). This indicates that classroom instruction has not yet fully met students' needs in developing conceptual understanding and representational competence (Schoenherr et al., 2024). Overall, this study indicates that students' difficulties in measures of central tendency are interrelated. Weak conceptual understanding of central tendency

as a representative value often co-occurred with difficulties in constructing and interpreting representations, and with challenges in using results to justify decisions in contextual problems. Rather than implying a time-ordered developmental sequence, the pattern is best interpreted as a set of conceptually connected difficulties that can constrain students' statistical reasoning. Therefore, instruction should integrate conceptual meaning, multiple representations, and opportunities to interpret and justify decisions based on data, not merely procedural computation.

Implications

The findings indicate that instruction on measures of central tendency should not be limited to procedural calculation, but should also address conceptual understanding and representational competence. Students' difficulties were associated with limited understanding of representative value, inappropriate selection of statistical measures, and weak interpretation of tables and graphs. These results suggest the importance of explicitly teaching the meaning and appropriate use of the mean, median, and mode, particularly in relation to dataset characteristics such as outliers and distribution shape. The study also highlights the need for structured support in constructing and interpreting statistical representations. Common errors in graphing tasks suggest that students require guidance in transforming frequency tables into accurate visual displays through correct labeling, scaling, and plotting. In addition, interpretation tasks should emphasize evidence-based reasoning so that students learn to justify conclusions using numerical and graphical features of the data. The misconceptions documented in students' work may further inform the design of targeted instructional interventions. Using typical errors as the basis for brief corrective activities may support the development of stronger conceptual understanding, more accurate representation skills, and more robust statistical reasoning.

Limitations

This study has several limitations. The participants were drawn from a single eleventh-grade class in one public senior high school; thus, the findings are context-specific and not intended for broad generalization. The study also focused only on measures of central tendency and did not examine other statistical topics that may involve different conceptual demands. In addition, although the instrument was reviewed through expert feedback, it was not formally piloted or psychometrically validated, which limits the strength of the validity evidence. The qualitative coding was conducted primarily by a single coder, thereby constraining claims regarding coding reliability. Finally, researcher positionality may have influenced data interpretation, despite the use of analytic memos and an audit trail to support transparency.

Suggestions

Future studies should involve participants from multiple schools and educational levels to examine the transferability of the findings across contexts. Research may also extend to other statistical topics, including variability and inferential statistics. Methodological improvements are likewise needed, particularly through formal pilot testing, stronger validation procedures, and intercoder checking. In addition, mixed-methods and intervention-based studies would be valuable for examining how instructional strategies focused on conceptual understanding, representation, and data-based reasoning may address the difficulties identified in this study.

CONCLUSION

This study concludes that students' difficulties in understanding measures of central tendency are not merely procedural; rather, they are primarily associated with limitations in conceptual understanding and statistical representational competence. Although some students were able to compute measures of central tendency, many did not yet understand the meanings of the mean, median, and mode as representative values of a dataset. The findings suggest an

interrelated pattern of difficulties across basic concepts, data visualization, data interpretation, and Application and decision making. Rather than indicating a time-ordered developmental sequence, these difficulties appear conceptually connected: limited understanding of foundational concepts is often associated with challenges in constructing and interpreting representations and in using statistical results to justify decisions in contextual problems. Through NVivo-assisted qualitative analysis, this study systematically identified patterns of students' conceptual difficulties. Overall, the results underscore the importance of statistics instruction that emphasizes conceptual meaning, the use of multiple data representations, and the development of evidence-based interpretation and decision-making skills. With a more integrated and conceptually oriented instructional approach, students' statistical understanding is expected to develop in a more meaningful and sustainable manner.

AUTHOR CONTRIBUTIONS STATEMENT

PI : Designed the study, collected and analyzed the data, and drafted the manuscript.
 MG : Contributed to the research design, provided critical feedback, supervised the research process, and revised the manuscript.

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