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Hots Assessment: Case Of Students' Performance On Understanding Of Statistical Graph

Adri Nofrianto[1], Elfa Rafulta[2], Mira Amelia Amri[3]
[12] , STKIP YDB Lubuk Alung, Indonesia; adrinofrianto@gmail.com, elfarafulta10@gmail.com
[3] State University of Jakarta, Indonesia; miraamelia@unj.ac.id

* WhatsApp Number

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Abstract

The study purpose is to assess senior high school students' ability on Higher Order Thinking Skills (HOTS) and understanding of statistical graph by using HOTS based statistical graph problems. The students were given two statistical graph problems. This research utilizes mixed-method research approach. It involves 42 senior high school students. The test result was analyzed based on two categories which are students' performance on solving HOTS based problem and students' understanding of statistical graph. The result suggested that (a) students that have good evaluation have higher rate of success on creating new version of graph based on their analysis; (b) students understanding of graph reading and graph interpretation is considered moderate and the main reason is students understanding of the graph properties itself; (c) Students found that constructing new graph is easier than evaluating graph; (d) Histogram chart is more difficult to construct by the students

Keywords HOTS Assessment, Statistics, Graph, Student Understanding

INTRODUCTION

Graph understanding has become one of the essential skills needed by students in the 21st century. Data and graphs appear in everyday life and in every corner of our society, from news media to scientific publications, making graphical literacy a fundamental competency for informed citizenship (Aoyama, 2007; Marchy & Juandi, 2023). The ability to interpret, evaluate, and create graphical representations is not merely an academic skill but a prerequisite for navigating the data-driven information environments that characterize modern society (Budgett & Rose, 2017; Koga, 2025).

Research has consistently demonstrated that student mastery of graph understanding significantly supports their learning across multiple disciplines. For instance, student understanding of natural science is strongly related to their mastery of graph comprehension

(Roslina et al., 2020). Graphs serve as cognitive tools that mediate between concrete data and abstract concepts, facilitating knowledge construction in fields ranging from mathematics and science to economics and social sciences (Lewandowsky & Spence, 1989; Shah & Hoeffner, 2002).

Numerous studies have been conducted in assessing students' understanding of statistical graphs. However, it is difficult to find research that utilized Higher Order Thinking Skills (HOTS) based problems to assess students' understanding of graphs. Existing research has employed various approaches: questionnaires to assess participants' understanding of statistical graphs (Samuel et al., 2019), true and false sets of graph questions (Radulović et al., 2022), and spreadsheets to develop and assess students' understanding of statistical graphs (Wu & Wong, 2007). Despite these valuable contributions, the field lacks comprehensive investigation into how students apply higher-order thinking when engaging with statistical graphs.

On the other hand, Higher Order Thinking Skills (HOTS) have emerged as a critical competency in 21st-century education, receiving substantial attention in educational research over the recent decade. Numerous studies focus on developing students' HOTS (Huang et al., 2023; Nadarajan et al., 2023; Nofrianto et al., 2016; Sekwena, 2023), recognizing that the ability to analyze, evaluate, and create is essential for success in complex, information-rich environments. Research on assessing students' HOTS in mathematical concepts can be found across many subjects and countries (Gradini et al., 2022; Moyo et al., 2022), reflecting a global commitment to fostering higher-order cognitive capabilities. Specifically, studies examining students' evaluation skills (C5) in solving statistics problems have been conducted (Afalah Asman et al., 2024), highlighting the importance of understanding how students apply higher-order thinking in statistical contexts.

The theoretical framework for this study is grounded in the revision of Bloom's Taxonomy (Anderson et al., 2023), which identifies six levels of cognitive processing: remembering, understanding, applying, analyzing, evaluating, and creating. The evaluation level (Level 5) involves making judgments based on criteria and standards, while the creating level (Level 6) entails putting elements together to form a coherent whole or reorganizing elements into a new pattern or structure. These higher-order levels are particularly relevant to graph comprehension, as they require students to move beyond simple data extraction to critical assessment and innovative representation.

The intersection of HOTS and statistical graph comprehension represents a significant gap in the current literature. Studies on graph comprehension have primarily focused on students' ability to read and interpret graphs at basic levels, often neglecting the evaluation and creation dimensions (Aoyama, 2007; Ozmen et al., 2020). Furthermore, research on HOTS in mathematics has rarely employed statistical graph problems as the assessment medium, leaving a critical gap in understanding how students apply higher-order thinking skills to graphical representations of data.

Recent systematic reviews have identified persistent challenges in students' statistical graph comprehension. Boels et al. (2023) found that secondary school students frequently exhibit systematic errors when interpreting histograms and case-value plots, often over-applying strategies learned from simpler graph types. Similarly, Okan et al., (2016) demonstrated that individuals with low graph literacy rely heavily on misleading spatial-to-conceptual mappings, failing to override intuitive but incorrect interpretations when these conflict with formal graphical conventions. These findings underscore the need for assessment approaches that specifically target higher-order cognitive processes in graph comprehension.

The cognitive processes underlying graph comprehension are complex and multifaceted. Research employing eye-tracking methodologies has revealed that high graph literacy is associated with longer fixation times on relevant conventional features, whereas low-literacy individuals tend to focus on unproductive local data views (Schreiter & Vogel, 2025). Gestalt principles of perceptual organization significantly influence how students group graphical features and interpret data, often hindering comprehension when graph formats conflict with task-specific requirements (Ali & Peebles, 2013). These findings suggest that effective graph assessment must account for both bottom-up perceptual processes and top-down conceptual knowledge.

Instructional interventions have shown promise in addressing these cognitive barriers. Dotplot scaffolding and schema training have been demonstrated to improve student accuracy by fostering readiness for complex interpretation tasks (Boels et al., 2023; Kang et al., 2021). Technology-enhanced learning environments, including interactive visualizations and AI-driven tools, facilitate deeper engagement by allowing students to move from procedural calculation toward authentic data investigation (Pham et al., 2024; Subali et al., 2025). These findings highlight the potential for targeted assessment strategies that leverage both cognitive insights and technological affordances.

Based on this extensive research context, this article will discuss the use of statistical graph problems to evaluate students' HOTS and students' understanding of graphs. The study aims to contribute to the theoretical development of statistical education by providing empirical evidence on how students engage with higher-order thinking tasks involving statistical graphs. Additionally, it seeks to offer practical insights for educators and curriculum designers seeking to enhance graph literacy and foster critical reasoning in statistics education.

METHODS

This study employs a mixed-method research approach, combining quantitative and qualitative analyses to provide a comprehensive understanding of students' performance on HOTS-based statistical graph problems. The mixed-method design is particularly appropriate for this study as it allows for both the measurement of performance patterns and the exploration of underlying cognitive processes and difficulties (Cresswell, 2014).

Forty-two third-grade senior high school students were involved as participants in this study. The participants were selected from a senior high school in West Sumatra, Indonesia, using purposive sampling to ensure they had received instruction on statistical graphs as part of their mathematics curriculum. The sample consisted of students with diverse mathematical abilities, reflecting the typical heterogeneity found in Indonesian senior high school classrooms.

The participants were given two graph problems which were categorized as Level 5 (evaluation) and Level 6 (creating) according to the revised Bloom's Taxonomy (Anderson et al., 2023). The first question assessed students' skills in identifying errors in a given graph, formulating the correct answer, and drawing a corrected version of the graph. This problem targeted evaluation skills, requiring students to assess the accuracy of graphical features, identify inconsistencies or inaccuracies, and justify their judgments based on graphical conventions.

The second question assessed students' ability to compare two graphs, formulate the features of the graphs, and choose the best graph representation. This problem targeted creating skills, requiring students to synthesize information from multiple sources, generate a reasoned decision based on the given data, and produce a new graphical representation that accommodated the features of both original graphs.

Students' responses were analyzed quantitatively and qualitatively. The quantitative data was used to determine students' ability to solve the given problems, calculating percentages of correct responses and identifying patterns in performance across the two problem types. The qualitative data, collected by analyzing students' written work, was utilized to gain deeper understanding of students' strengths and weaknesses when solving HOTS-based statistical graph problems. This analysis focused on identifying specific errors, misconceptions, and reasoning processes that characterized students' approaches to the tasks.

The analysis framework drew upon established hierarchies of graph comprehension (Aoyama, 2007; Curcio, 1981) and the cognitive process dimensions of the revised Bloom's Taxonomy (Anderson et al., 2023). Students' responses were categorized according to their level of graph understanding: graph reading (extracting information), graph interpretation (understanding relationships), graph construction (creating representations), and graph evaluation (assessing and judging representations) (Wu, 2004). This multi-dimensional analysis allowed for a nuanced understanding of how HOTS demands interact with specific aspects of graph comprehension.

RESULTS AND DISCUSSION

We analyzed the data based on two categories. The first category is students' performance on solving HOTS problems, examining their ability to engage with evaluation and creation level thinking skills. The second category discusses students' Understanding of Statistical Graph (USG), encompassing graph reading, graph interpretation, graph construction, and graph evaluation (Wu, 2004). The findings are discussed in relation to the existing literature on graph comprehension and higher-order thinking, highlighting both consistencies with previous research and novel insights from this study.

Students' Performance on Solving HOTS Problems

The results of the data analysis indicate that students' achievement in solving

HOTS problems is concerning, with less than 50% of students able to solve the problems correctly. For the evaluation question, only 48% of the 42 students could provide proper answers. The percentage of students who could answer the creating problem dropped significantly to 36%. These numbers represent students categorized as being able to solve the problem when they could provide at least 75% correct answers, a stringent criterion that reflects the high demands of HOTS tasks.

Table 1: Students' Performance on HOTS-Based Statistical Graph Problems

Problem Type	N	Students Able to Solve (≥75% correct)	Percentage
Evaluation (Level 5)	42	20	48%
Creation (Level 6)	42	15	36%

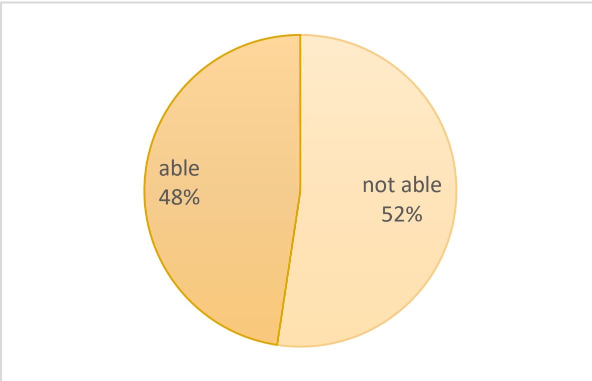

Figure 1: Percentage of Students Able to Answer the Evaluation Level Problem

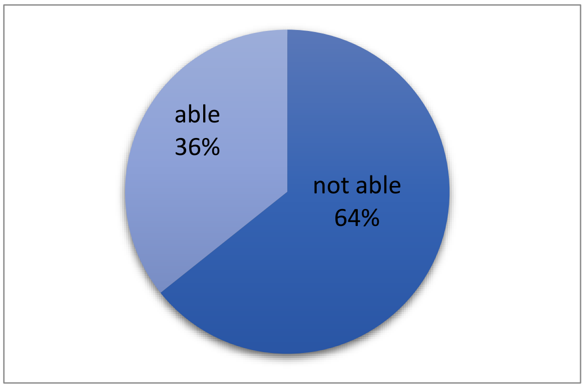

Figure 2: Percentage of Students Able to Answer the Creating Level Problem

This result is lower compared with students' performance in solving combinatorics HOTS problems, in which 55% of students could answer evaluation level problems and 47% could answer creating level problems (Fatahillah et al., 2021). The lower performance in this study suggests that statistical graph problems may present unique cognitive challenges that are distinct from those encountered in pure mathematical problem-solving. This finding aligns with research indicating that graph comprehension involves specialized cognitive processes that are not necessarily developed through general mathematical instruction (Boels et al., 2023; Shah & Hoeffner, 2002).

Most participants encountered difficulties in finding the errors in the given problem. Students' failure to spot inaccuracies in the graph indicates they lack the skills to assess, examine details, and comprehend the problem as a whole. This finding is consistent with research by Ozmen et al. (2020), who found that middle school students often remained at literal reading levels and struggled with critical evaluation. Similarly, (García-García et al., 2020) reported that secondary school students frequently failed to progress beyond comparative reading to evaluative reasoning.

The ability of students to make judgments on how to formulate the correct answer can be considered relatively good. Among the 20 students who successfully detected the errors, 16 students (80%) could provide the correct version of the graph. This suggests that once students overcome the initial barrier of error identification, they possess the skills necessary to construct corrected representations. This finding supports the hierarchical nature of graph comprehension identified by (Aoyama, 2007), where evaluation skills may be prerequisite to creation skills, and students who master evaluation are more likely to succeed at creation tasks.

Students' performance in solving Level 6 problems was lower than their performance in Level 5 problems. Students found it difficult to generate a reasonable decision based on the given data. Formulating a new graph that accommodated the two graphs in the second question became a challenging task for them. Most students could not solve the second problem completely, indicating that the cognitive demands of synthesis and creation exceed those of evaluation for many students.

This difficulty with creation tasks is consistent with findings from the broader HOTS literature. (Aoyama & Stephens, 2003) noted that the "creation of dimensionally new information" remains a complex construct that is particularly challenging for students to master. Similarly,Rahayu et al. (2021) found that university students struggled most with creating-level tasks in mathematical statistics, suggesting that difficulty with creation is not limited to secondary school contexts.

The systematic literature review by Ruf et al. (2023) identified that construction and interpretation skills within K-12 STEM education contexts often remain at lower levels, with students failing to demonstrate the integrative reasoning required for complex tasks. This finding provides a broader context for understanding the difficulties observed in this study, suggesting that the challenges that students face are not idiosyncratic but reflect systemic issues in statistics education.

Students' Understanding of Statistical Graphs

Students' failure in identifying errors in the first problem was strongly related to their ability in graph reading and graph interpretation. Graph reading and graph interpretation require the reader to understand the properties of graphs, including scales, axes, labels, and the conventions that govern different graph types. Students' inability to identify that the scale of the graph was inaccurate indicates that their understanding in reading graphs is moderate at best.

The ability to infer the scale that is used on one or two graphs is one of the indicators in assessing students' understanding of graph interpretation. It is symptomatic that the participants' level of graph interpretation is low, since only 48% of participants were able to identify the error. This result is consistent with findings from Amin et al. (2020), who found that South Sulawesi students' interpretation of graphs was categorized as low. Similarly, Kurnia et al. (2024) reported that Indonesian high school students across grades 9 and 12 demonstrated limited critical thinking and decision-making skills in statistical literacy tasks.

Table 2: Students' Understanding of Statistical Graph Components

USG Component	Performance Indicator	Student Performance
Graph Reading	Ability to read scales, labels, and values	Moderate (students could read basic information but missed nuanced features)
Graph Interpretation	Ability to understand relationships and infer meaning	Low (only 48% could identify scale errors)
Graph Construction	Ability to create new graphs from data	Higher than evaluation (75% of those who passed the first hurdle succeeded)
Graph Evaluation	Ability to assess graphs for accuracy and appropriateness	Low (only 48% could identify errors)

The graph construction task seemed to be easier compared to graph evaluation. Students' responses for both questions related to constructing new graphs showed that more than 75% of students who passed the first hurdle of each question gained success in drawing the new graph. This finding is intriguing and somewhat counterintuitive, as one might expect evaluation (which involves recognition of errors) to be easier than construction (which involves generating novel representations).

However, this pattern is consistent with research by (Boels et al., 2023), who found that engaging with dotplot items created readiness for learning and improved subsequent histogram interpretation strategies. The act of construction may serve as a scaffold for understanding, allowing students to develop mental models of graphical conventions that facilitate both evaluation and interpretation. This suggests that construction tasks may have pedagogical value beyond their assessment function.

Several explanations may account for this finding. First, construction tasks may engage different cognitive processes than evaluation tasks. Construction requires students to apply procedural knowledge of how graphs should be structured, while evaluation requires students to compare existing representations against internal standards. Second, construction tasks may be more structured and directive than evaluation tasks, with clearer expectations of what constitutes a correct response. Third, students may have had more exposure to constructing graphs than to evaluating them in their previous instruction, reflecting a common emphasis on production over critique in statistics education.

However, students' task in evaluating the bar graph in the first question and the histogram graph in the second question had low rates of success. Students found that histograms were more difficult to analyze and construct. This finding aligns with extensive research on the particular challenges posed by histograms. Boels et al. (2025) found that about half of the histogram tasks were solved using correct interpretation strategies by students, with many incorrectly applying distribution features relevant only to histograms when comparing case-value plots. Similarly, Lee & Meletiou-Mavrotheris (2003) identified specific difficulties in learning histograms in introductory statistics, including confusion with bar charts and challenges understanding the concept of distribution.

The within-the-bar bias identified by Kang et al. (2021) provides a specific cognitive mechanism for histogram difficulties. This bias occurs when students conflate the average estimation point with the bar-tip in mean bar graphs, leading to systematic misinterpretations. Kerns & Wilmer (2021) further documented the "Bar-Tip Limit error," observed in about one in five persons across diverse samples, involving conflation of mean bar graphs with count bar graphs. These cognitive biases likely contribute to the difficulties observed in this study.

The semiotic complexity of histograms may also explain students' difficulties. Anam (2025) investigated the complexity of high school students' semiotic graphics in solving statistical problems, finding that cognitive styles such as field dependence significantly influence the complexity of graphical representations students can successfully construct. Histograms require students to understand concepts of binning, frequency density, and distribution shape that are not present in bar charts, adding layers of conceptual complexity.

Furthermore, research by Mathai et al. (2025)revealed that comprehension of bar graphs with nominal data was easier than line graphs requiring integration, suggesting that interpretation from spatial to symbolic representations poses significant challenges for students. Histograms, like line graphs, require students to move between conventions, graphical elements, and the underlying data structure, demanding a level of representational fluency that many students have not developed.

Cognitive Processes in Graph Comprehension

The findings of this study contribute to a growing understanding of the cognitive processes involved in statistical graph comprehension. Research using eye-tracking and machine learning has provided insights into the micro-level cognitive strategies students employ when interpreting (Boels et al., 2023; Schreiter & Vogel, 2025). These studies reveal that students frequently switch between multiple perceptual strategies, often relying on "local" views of data rather than perceiving global distribution features.

This pattern is evident in the current study's findings. Students who successfully identified graph errors demonstrated the ability to attend to conventional features such as scale markings and axis labels, while those who failed tended to focus on superficial features such as bar heights and colours. This distinction is consistent with the finding by (Okan et al., 2016) that high graph literacy individuals spend more time viewing relevant conventional features, whereas less literate individuals rely on real-world spatial mappings rather than formal graphical conventions.

Table 3: Comparison of High and Low Performers' Cognitive Strategies

Strategy Type	High Performers	Low Performers
Attention Focus	Focused on conventional features (scales, axes, labels)	Focused on superficial features (bar heights, colors)
Error Detection	Systematically checked all graphical elements	Failed to detect scale and property errors
Reasoning Process	Used analytic reasoning to identify and justify errors	Relied on intuitive spatial mappings
Construction Approach	Applied correct conventions in new graphs	Made procedural errors in graph construction

The role of Gestalt principles in graph comprehension is also relevant. (Peebles & Cheng, 2001) demonstrated that Gestalt principles of perceptual organization significantly influence how users group graphical features and interpret data. The principle of similarity, for example, may lead students to group bars of similar colour or pattern, potentially overriding the intended categorical structure of the graph. In this study, students' tendency to focus on visual properties such as bar height rather than scales and labels may reflect the operation of Gestalt principles that emphasize perceptual grouping over conventional analysis.

The interaction between bottom-up perceptual processing and top-down conceptual knowledge is central to graph comprehension (Freedman & Shah, 2002; Shah, 2002). High graph literacy is characterized by the ability to integrate both types of processing, using top-down knowledge to guide bottom-up attention to task-relevant features. Low graph literacy, in contrast, is characterized by over-reliance on bottom-up perceptual cues, leading to systematic errors when these cues conflict with conventional graphical meaning. The difficulties observed in this study suggest that many students have not developed the integrated processing required for effective graph comprehension.

Theoretical Implications

The findings of this study have several theoretical implications. First, they support the hierarchical conceptualization of statistical graph comprehension proposed by Aoyama (2007) and Curcio (1981). Students' performance clearly differentiated between levels, with evaluation and creation demanding higher cognitive engagement than reading and interpretation. However, the finding that students performed better on construction than evaluation suggests that the hierarchy may be more complex than a simple linear progression, with different cognitive demands at each level.

Second, the results challenge the assumption that higher-order thinking skills develop linearly with grade level or instruction. Despite being third-grade high school students who had received instruction on statistics, many participants remained at non-critical interpretation levels, consistent with findings by Kurnia et al. (2024)). This suggests that developmental and instructional factors interact in complex ways to influence the acquisition of graph literacy.

Third, the findings extend cognitive load and dual-coding theories by demonstrating that semiotic complexity plays a crucial role in advanced statistical reasoning (Anam, 2025; Jain & Mitra, 2025). Histograms, with their greater semiotic complexity, posed more significant challenges than bar graphs, suggesting that the cognitive load imposed by graph type is a significant determinant of performance. This finding aligns with the information reduction framework proposed by Okan et al., (2016), which posits that skill acquisition leads to more efficient attention allocation to task-relevant features.

Fourth, the study provides empirical support for the conceptual change theory of graph comprehension. AsBaker et al. (2001) have argued, systematic errors in graph interpretation often arise from the failure to adapt previously learned foundational concepts to new graphical representations. Students in this study appeared to over-apply strategies learned from bar charts to histograms, leading to systematic errors in evaluation and construction. This suggests that robust statistical reasoning requires conceptual change rather than simple skill accumulation.

Practical Implications

The findings of this study have several practical implications for educators and curriculum designers. First, instructional design should prioritize the development of meta-representational competencies, moving beyond simple graph reading to foster understanding of how different graphical formats represent measures of centre and variability (Chang et al., 2024; Mhlolo, 2015) Students need explicit instruction on the properties and conventions of different graph types, including the specific features that distinguish histograms from bar charts.

Second, educators should implement targeted scaffolding for evaluation and creation tasks. The finding that students performed better on construction than evaluation suggests that assessment and instruction should balance both types of tasks. Dotplot scaffolding, as demonstrated by Boels et al. 2023), can build readiness for learning and facilitate the transition from concrete data representations to more abstract histograms. Schema training, as advocated by Lieb & Pickhardt, (2025), can help students develop mental models that support interpretation of complex visualizations.

Third, graphical design in educational materials should be optimized to reduce cognitive load. The finding that histograms were more difficult to construct and evaluate suggests that teachers should provide additional support for these more complex graph types. Design modifications such as clear labeling, consistent scaling, and the use of color-coded features can help students overcome perceptual biases (Ali & Peebles, 2013). Using real-world data contexts may also enhance engagement and comprehension by connecting abstract representations to meaningful phenomena (Dorigon et al., 2023; Gardner et al., 2024).

Fourth, assessment frameworks should move beyond simple identification tasks to include items that demand inference, critical evaluation, and the identification of misleading graphical representations (Kiili et al., 2021; Villa-Esparza et al., 2023). The difficulties students experienced in this study suggest that standard assessment practices may underestimate the challenges of graph comprehension by not adequately testing higher-order skills. Item Response Theory (IRT) models and eye-tracking analysis may provide more precise measurement of student reasoning (Boels et al., 2025; Subali et al., 2025).

Fifth, professional development for teachers is essential to address the current reliance on literal-level instruction and to equip educators with research-based methods for fostering critical statistical literacy (Bustamante-Valdés et al., 2024; Sandoval et al., 2020). Teachers need support in developing instructional strategies that target evaluation and creation skills, not just reading and interpretation. This includes learning to design HOTS-based problems, provide effective feedback, and scaffold student reasoning.

Limitations and Future Research Directions

Several limitations of this study should be acknowledged. First, the sample size of 42 students from a single school limits generalizability. Future research should involve larger, more diverse samples across multiple schools and regions. Second, the study relied on written responses and did not include think-aloud protocols or eye-tracking, which could provide deeper insights into cognitive processes. Third, the study did not include a control group or pre-test, limiting causal inferences about factors contributing to student difficulties.

The literature review identified several gaps that future research should address. Longitudinal research is needed to track how conceptual difficulties with histograms and bar charts evolve over years of schooling (Lian et al., 2022; Schreiter & Vogel, 2025). Cross-cultural studies using identical assessment instruments could examine global patterns of statistical literacy (Marchy & Juandi, 2023; Olande, 2014). Research on the generalizability of instructional interventions across diverse academic disciplines and graph types would inform the development of robust, scalable pedagogical tools (Boels et al., 2023; Cooper, 2018).

Furthermore, future research should investigate the specific interaction between individual differences (such as working memory and math anxiety) and the cognitive load imposed by varying graphical formats (Okan et al., 2016; Peebles & Cheng, 2001). Understanding how cognitive and affective factors interact with perceptual mechanisms will allow for the customization of instructional strategies for diverse learners. Research on metacognitive strategies and their role in overriding perceptual biases would also be valuable (Chang et al., 2024).

Finally, research on the role of technology in graph comprehension is needed. While technology-based tools facilitate deeper engagement, the specific cognitive processes that distinguish technology-aided learning from traditional methods remain poorly defined (Chang et al., 2024; Meletiou-Mavrotheri & Stylianou, 2003). Studies contrasting eye-tracking patterns and strategy shifts in students using dynamical software versus traditional methods would inform the effective integration of technology into statistics curricula.

CONCLUSION

The following main conclusions can be drawn from this study. First, students with good evaluation skills have a higher rate of success in creating new versions of graphs based on their analysis, supporting a hierarchical relationship between these higher-order thinking levels. Among students who successfully identified errors in the given graphs, 80% could construct correct versions, suggesting that developing evaluation competence may be a prerequisite for successful creation tasks. Second, students' understanding of graph reading and graph interpretation is considered moderate, with the main reason being students' understanding of graph properties themselves. Only 48% of students could identify scale errors and other inaccuracies, indicating that many students lack the foundational knowledge of graph conventions necessary for higher-order reasoning. Third, students found that constructing new graphs is easier than evaluating graphs, with more than 75% of students who overcame initial hurdles succeeding in construction tasks, while evaluation tasks had lower success rates. This suggests that construction tasks may be more accessible than evaluation tasks, perhaps due to their more directive nature or students' greater familiarity with construction activities. Fourth, histogram charts are more difficult for students to construct, consistent with extensive research on the cognitive challenges posed by histograms, including the semiotic complexity of concepts such as binning, frequency density, and distribution shape.

These findings indicate that teachers should focus their attention on students' understanding of graph properties and evaluating graphs. Explicit instruction on graphical conventions, particularly those distinguishing histograms from bar charts, is essential. Professional development should equip teachers to design assessment tasks that target evaluation and creation skills, moving beyond literal reading to foster critical statistical reasoning. Assessment practices should include items that demand inference, critical evaluation, and the identification of misleading representations. Ultimately, fostering graph literacy requires moving beyond procedural instruction to develop meta-representational competencies that enable students to critically evaluate and reconstruct the underlying data structures of complex visualizations. By integrating insights from cognitive psychology, educational research, and instructional design, educators can help students develop the higher-order thinking skills necessary for informed citizenship in an increasingly data-driven world.

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