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Exploring Preservice Mathematics Teachers' Statistical Literacy: A Mixed-Methods Study with Phenomenological Insights

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Abstract

Statistical literacy is increasingly recognized as a fundamental competence for preservice mathematics teachers because it enables individuals to interpret data, reason under uncertainty, critically evaluate statistical information, and make informed judgments in diverse contexts. Despite its importance, research on statistical literacy has largely emphasized quantitative measurement of achievement, providing limited insight into how preservice teachers experience, interpret, and construct statistical meaning throughout their learning processes. This study explored preservice mathematics teachers' statistical literacy by integrating quantitative performance data with qualitative interpretations of lived learning experiences through a sequential explanatory mixed-methods design informed by hermeneutic phenomenology. The participants were 36 preservice mathematics teachers enrolled in a statistics course at Universitas PGRI Silampari. Quantitative data were collected using a statistical literacy assessment measuring procedural competence, data interpretation, and contextual reasoning, while qualitative data were obtained through reflective questionnaires and semi-structured interviews. Descriptive statistical analysis and iterative thematic interpretation were employed to examine the data. The findings indicated that although most participants demonstrated satisfactory procedural competence, many encountered difficulties in interpreting statistical information, justifying conclusions, and connecting statistical results to meaningful real-world contexts. Qualitative evidence further revealed that participants' understandings of statistics were strongly shaped by prior instructional experiences that emphasized formula application over interpretation and reasoning. These findings suggest that the development of statistical literacy involves not only procedural proficiency but also interpretative reasoning, reflective meaning-making, self-confidence, and engagement with contextualized learning experiences, highlighting the need for instructional approaches that support deeper statistical understanding in teacher education.

Keywords: Statistical literacy, interpretative reasoning, preservice mathematics teachers, hermeneutic phenomenology, mixed-methods research

Introduction

Statistical literacy has become an increasingly important competence in contemporary data-rich societies, where individuals are expected to interpret information critically, evaluate statistical claims, and make evidence-based decisions across educational, social, economic, and professional contexts. For mathematics teachers, statistical literacy extends beyond the ability to understand statistical information; it encompasses the capacity to support students in reasoning about uncertainty, variability, risk, and data-based arguments in ways that are both mathematically rigorous and contextually meaningful. As data increasingly shape public discourse and decision-making, the development of statistical literacy among preservice mathematics teachers has emerged as a central concern within statistics education research (Gal, 2002; Gould, 2017; Bakker & Derry, 2014).

Despite its recognized importance, a growing body of evidence suggests that the development of statistical literacy remains challenging. Findings from the Programme for International Student Assessment (PISA) indicate that students frequently encounter difficulties when interpreting data representations, reasoning under conditions of uncertainty, and drawing meaningful conclusions from statistical information (OECD, 2019). Similar challenges have been documented among preservice mathematics teachers, who often demonstrate competence in carrying out statistical procedures while experiencing difficulties in interpreting statistical results, explaining graphical representations, and connecting quantitative findings to contextual situations (Callingham & Watson, 2017; Garfield & Ben-Zvi, 2008). Within the Indonesian context, previous studies likewise report that statistics instruction continues to emphasize procedural mastery and formula application, often at the expense of reflective interpretation, critical evaluation, and contextual reasoning (Rohimah et al., 2026).

Although these studies consistently identify limitations in learners' interpretative reasoning, much of the existing literature has examined statistical literacy through relatively fragmented perspectives. Quantitative investigations have predominantly focused on measuring achievement levels, procedural competence, or statistical performance through tests and survey instruments. While such approaches are valuable for identifying patterns of competence, they offer limited insight into how learners experience statistical learning and construct meaning from statistical ideas. Conversely, qualitative studies have provided richer accounts of students' reasoning processes, classroom interactions, and learning experiences, yet these investigations are often disconnected from measurable indicators of statistical competence. Consequently, the relationship between observable statistical performance and the interpretative processes through which learners make sense of statistical concepts remains insufficiently understood.

This limitation reflects a broader conceptual issue within statistical literacy research. Statistical literacy is widely understood as more than the ability to execute computational procedures or apply statistical formulas correctly. Rather, it involves interpreting data critically,

evaluating statistical information within context, engaging in reflective judgment, and constructing meaningful understandings of data-based phenomena (Gal, 2002). From this perspective, statistical literacy is fundamentally interpretative in nature because statistical information acquires meaning only when individuals relate numerical representations to contextual situations, prior knowledge, and reasoned judgments. Nevertheless, many empirical studies continue to operationalize statistical literacy primarily through procedural achievement, thereby underrepresenting the interpretative and meaning-making dimensions that are central to statistical understanding. As a result, limited attention has been given to understanding how preservice teachers move beyond formula-oriented learning toward deeper forms of statistical reasoning and interpretation.

Addressing this gap requires methodological approaches capable of connecting measurable competence with learners lived experiences of statistical learning. Mixed-methods research, particularly sequential explanatory designs, offers a valuable framework for integrating quantitative evidence with qualitative interpretation and thereby generating a more comprehensive understanding of complex educational phenomena (Creswell & Plano Clark, 2018). However, the application of mixed methods in statistics education has frequently positioned qualitative findings merely as supplementary explanations for quantitative outcomes. Such applications often lack an explicit interpretative framework capable of illuminating how learners experience, internalize, and assign meaning to statistical ideas. Consequently, the explanatory potential of mixed-methods research remains only partially realized.

To address this limitation, the present study integrates a sequential explanatory mixed-methods design with a hermeneutic-phenomenological perspective. Hermeneutic phenomenology conceptualizes learning as an interpretative process through which individuals construct meaning based on prior understandings, reflection, and engagement with lived experiences (van Manen, 2016). Within the context of statistical literacy, this perspective provides a theoretical lens for examining how preservice mathematics teachers experience statistical concepts, interpret uncertainty, negotiate the meaning of data representations, and develop understandings that extend beyond procedural performance. The integration of mixed methods and hermeneutic phenomenology therefore represents not merely a methodological combination but an epistemological effort to bridge observable statistical competence and the lived interpretative experiences through which such competence is developed and understood.

Accordingly, this study aims to explore preservice mathematics teachers' statistical literacy by integrating quantitative evidence of statistical performance with qualitative accounts of learning experiences and meaning-making processes. The study contributes to the literature in three significant ways. First, it advances the conceptualization of statistical literacy by foregrounding interpretative meaning-making as a central dimension of statistical competence. Second, it demonstrates the methodological potential of integrating sequential explanatory mixed methods with hermeneutic phenomenology in statistics education research. Third, it offers practical insights for the design of reflective, contextually grounded, and meaning-oriented statistics learning environments within mathematics teacher education programs.

Methods

This study employed a sequential explanatory mixed-methods design to investigate preservice mathematics teachers' statistical literacy as both a measurable competence and an interpretative learning experience. The selection of this design was based on the premise that statistical literacy cannot be adequately understood through quantitative measurement alone. Quantitative evidence was required to identify patterns of competence and areas of difficulty, whereas qualitative inquiry was necessary to illuminate how participants interpreted statistical ideas, experienced conceptual challenges, and constructed meaning through statistical learning processes. Accordingly, the qualitative phase was designed as an interpretative extension of the quantitative findings rather than merely a supplementary stage of data collection (Creswell & Clark, 2018).

The study was further informed by a hermeneutic-phenomenological perspective. Hermeneutic phenomenology conceptualizes understanding as an interpretative process shaped by prior experiences, reflection, and contextual meaning-making (van Manen, 2016). This perspective was particularly relevant because statistical literacy encompasses not only procedural competence but also the ability to interpret, evaluate, and reflect critically on statistical information. Consequently, the qualitative phase focused on exploring how participants experienced statistical learning and how statistical meaning was constructed through engagement with data, uncertainty, and contextual situations.

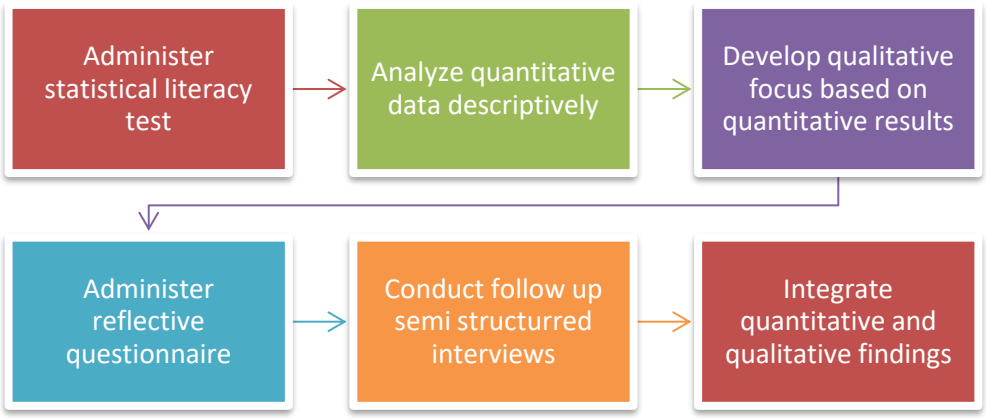

Figure 1. Research Procedure

The overall analytical framework is illustrated in Figure 1. As shown in the figure, the study began with the administration of a statistical literacy assessment to examine participants' levels of statistical competence. Quantitative findings were subsequently analyzed to identify patterns of performance, particularly the relationship between procedural competence and interpretative reasoning. These findings informed the development of the qualitative inquiry, enabling a deeper exploration of the experiences and meanings underlying participants' statistical performance. Rather than representing discrete stages, the research procedure

constituted an integrated analytical process linking observable outcomes with lived learning experiences.

Participants and Context

The participants consisted of 36 preservice mathematics teachers enrolled in a statistics course within the mathematics teacher education program at Universitas PGRI Silampari. Participants were selected purposively because they had completed foundational coursework in statistics and were therefore able to reflect meaningfully on their experiences of learning statistical concepts. Although the sample was relatively small and context-specific, its size was appropriate for the interpretative depth sought within hermeneutic-phenomenological inquiry. Accordingly, the findings are intended to provide analytical and contextual insights rather than statistical generalizations to broader populations.

Instruments and Data Collection

Two primary instruments were employed in this study: a statistical literacy test and a reflective experience questionnaire. The statistical literacy test was developed based on Gal's (2002) conceptualization of statistical literacy, emphasizing three dimensions: interpretation of statistical information, reasoning under uncertainty, and contextual evaluation of data representations. The instrument consisted of ten open-ended items that integrated procedural and interpretative tasks. Rather than focusing exclusively on computation, the items required participants to explain statistical meanings, interpret graphical representations, justify conclusions, and relate statistical results to contextual situations. For example, one item presented comparative rainfall data and required participants not only to identify trends but also to explain their implications within a meaningful context. Responses were evaluated using an analytic rubric ranging from 0 to 4, with higher scores indicating accurate computation accompanied by coherent interpretation and contextual justification.

The second instrument was a reflective experience questionnaire administered following the quantitative phase. The questionnaire contained both Likert-scale statements and open-ended reflective prompts designed to capture participants' perceptions of statistical learning, interpretative challenges, and experiences of meaning-making in statistics. To further elaborate emerging themes identified from the quantitative findings and questionnaire responses, semi-structured interviews were subsequently conducted with selected participants. These interviews provided opportunities to explore participants' experiences, interpretations, and reflections in greater depth.

Prior to implementation, both instruments underwent a rigorous validation process. Content validity was evaluated by three experts in mathematics education and statistics education, who examined construct alignment, contextual relevance, linguistic clarity, and representation of interpretative dimensions of statistical literacy. Revisions were subsequently made based on expert recommendations, particularly regarding item wording and contextual appropriateness. A pilot study involving 20 preservice mathematics teachers outside the main participant group was conducted to assess readability and internal consistency. The statistical

literacy test yielded a Cronbach's alpha coefficient of $\alpha = 0.82$, while the questionnaire produced a reliability coefficient of $\alpha = 0.79$, indicating satisfactory reliability for exploratory educational research.

Data Integration

Integration between the quantitative and qualitative phases occurred throughout the study. First, quantitative findings informed the focus of the qualitative inquiry, particularly regarding the observed discrepancy between procedural success and interpretative reasoning. Second, qualitative evidence was used to explain why such discrepancies emerged by examining participants' prior learning experiences, reflective processes, and contextual understandings of statistical concepts. Finally, integration occurred during interpretation, where quantitative performance patterns and qualitative experiential narratives were considered collectively to develop a comprehensive understanding of statistical literacy as both a cognitive and interpretative phenomenon.

Data Analysis

Quantitative data were analyzed descriptively using mean scores, percentage distributions, and category classifications to identify participants' levels of statistical literacy. These analyses provided an overview of participants' procedural competence, interpretative reasoning, and contextual understanding.

Qualitative data derived from reflective questionnaires and semi-structured interviews were analyzed thematically through a hermeneutic interpretative process. Consistent with van Manen's (2016) conception of the hermeneutic circle, the analysis involved iterative movement between individual experiential accounts and broader contextual understandings. Rather than treating participants' statements as isolated units of information, the analysis sought to uncover underlying structures of meaning associated with learning statistics.

To operationalize the hermeneutic-phenomenological approach, the researchers engaged in repeated readings of the data, reflective writing, thematic interpretation, and dialogical comparison across participants' narratives. Initial coding focused on significant experiential statements related to interpretation, uncertainty, contextual reasoning, and reflective understanding. These codes were subsequently examined recursively to generate broader thematic structures that illuminated participants' experiences of developing statistical literacy.

Trustworthiness and Reflexivity

Because hermeneutic phenomenology acknowledges the interpretative role of the researcher, issues of reflexivity and interpretative credibility were addressed throughout the analytical process. Researcher reflexivity was maintained through analytic memo writing those documented assumptions, interpretative decisions, and thematic development. Peer debriefing among members of the research team was conducted to critically examine emerging interpretations and reduce the influence of individual bias. Furthermore, triangulation across statistical literacy test results, reflective questionnaires, and interview data enhanced the

consistency and credibility of the findings. Representative participant quotations were retained during the interpretative process to preserve the connection between thematic interpretations and participants lived experiences. Through this integrated methodological approach, statistical literacy was examined not merely as procedural achievement but as an interpretative and experiential process shaped by reflection, prior learning experiences, and contextual engagement with statistical meaning.

Results and Discussion

The quantitative findings indicated that preservice mathematics teachers demonstrated a moderate level of statistical literacy, with an overall mean score of M = 67.4 (SD = 8.2). However, the significance of this finding lies not primarily in the average score itself but in the pattern of statistical engagement reflected in participants' responses. Although most participants successfully completed routine computational tasks, they frequently encountered difficulties when required to interpret statistical information, justify conclusions, and connect numerical results to meaningful contextual situations. This finding supports the argument advanced by Ben-Zvi & Garfield (2004) that statistical literacy should be understood as a multidimensional construct involving interpretation, reasoning, and meaning-making rather than computational proficiency alone.

As shown in Figure 2, 66.7% (n = 24) of participants were categorized as demonstrating moderate statistical literacy, whereas 19.4% (n = 7) were classified within the low category and only 13.9% (n = 5) achieved a high level of statistical literacy. These categories should not be interpreted merely as achievement classifications but as qualitatively different profiles of engagement with statistical ideas.

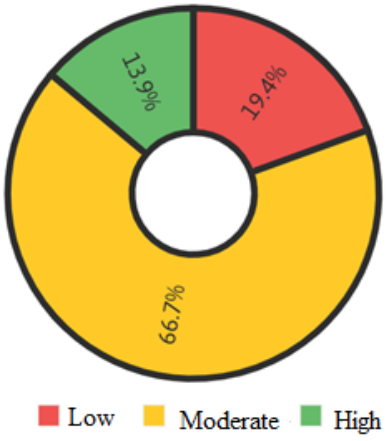

Figure 2. Statistical literacy level category of prospective mathematics teachers

Participants in the low category exhibited fragmented understandings characterized by limited procedural control and minimal interpretative reasoning. Those in the moderate category were generally able to execute routine statistical procedures correctly but experienced

difficulty explaining the meaning of statistical outcomes or relating them to contextual situations. In contrast, participants in the high category demonstrated integrated forms of statistical reasoning in which procedural accuracy was accompanied by contextual awareness, reflective interpretation, and critical evaluation of data. Such patterns are consistent with perspectives that conceptualize statistical literacy as a developmental progression from procedural decoding toward interpretative and critical engagement with data (Sharma, 2017). To clarify the meaning of each level of statistical literacy, participants' performance profiles were categorised as shown in Table 1.

Table 1. Categorization of Preservice Mathematics Teachers' Statistical Literacy Levels.

Level of Statistical Literacy	Operational Criteria	Empirical Characteristics
Low	Limited procedural accuracy and weak interpretative reasoning	Participants struggled with basic statistical procedures and were unable to interpret tables, graphs, or statistical results meaningfully.
Moderate	Adequate procedural accuracy with inconsistent interpretative reasoning	Participants were generally able to perform routine statistical computations correctly but showed recurring difficulties in interpreting data, reasoning under uncertainty, and explaining results in context. Understanding was primarily formula-driven and only partially connected to meaning-making processes.
High	Strong procedural accuracy and consistent interpretative reasoning	Participants demonstrated accurate statistical computations and were able to interpret data representations, justify conclusions, and reason under uncertainty. Their responses reflected contextual awareness, reflective engagement, and conceptual understanding.

The Tension Between Procedural Competence and Interpretative Reasoning

A more detailed examination of participants' responses revealed a substantial discrepancy between procedural competence and interpretative reasoning. Approximately 84% of participants successfully completed routine computational tasks, including calculations of measures of central tendency and basic data representations. By contrast, only 38%

demonstrated the ability to interpret statistical results meaningfully, explain the significance of data representations, or justify conclusions within real-world contexts.

Importantly, this discrepancy represents more than a difference in performance levels; it reflects fundamentally different ways of understanding statistics. Many participants approached statistical tasks primarily as exercises in formula application rather than opportunities to reason about uncertainty, context, and meaning. For example, several participants accurately calculated averages and percentages yet struggled to explain the implications of those values for the situations described in the tasks. Statistical knowledge therefore appeared to function largely as procedural technique rather than as a resource for interpretation and judgment. This finding resonates with Ziegler & Garfield's (2018) observation that students frequently learn statistical procedures without developing corresponding statistical reasoning.

The qualitative findings provided further insight into this pattern. Participants consistently described their previous experiences of learning statistics as heavily focused on formulas, computational accuracy, and obtaining correct answers. One participant remarked:

> "I usually focus on remembering formulas because statistics problems are often about getting the correct answer quickly, not explaining the meaning."

From a hermeneutic-phenomenological perspective, this statement reveals more than an instructional preference; it reflects how participants had come to understand the nature of statistics itself. Statistics was experienced not as an interpretative practice concerned with understanding data but as a procedural activity governed by rules and formulas. Consequently, opportunities to construct statistical meaning through reflection, contextual interpretation, and discussion appeared limited.

Interestingly, this procedural orientation was not universal. A smaller group of participants described learning experiences involving classroom discussion, contextual examples, and opportunities to explain statistical conclusions. These participants tended to demonstrate stronger interpretative reasoning and greater contextual awareness. This variation suggests that statistical literacy development is influenced not only by individual cognitive abilities but also by the pedagogical environments through which learners encounter statistical ideas.

Statistical Literacy as an Experiential and Interpretative Process

One of the most significant findings emerging from the integration of quantitative and qualitative evidence was the distinction between statistical performance and statistical understanding. Several participants who obtained relatively high-test scores expressed uncertainty when asked to explain statistical meanings verbally. Conversely, some participants with only moderate quantitative performance demonstrated considerable reflective awareness regarding the limitations and contextual nature of statistical interpretation.

These findings suggest that statistical literacy cannot be fully represented through performance scores alone. Observable achievement and interpretative understanding do not

necessarily develop in parallel. From a hermeneutic perspective, understanding emerges through ongoing processes of interpretation in which individuals relate statistical information to prior experiences, contextual knowledge, and reflective judgment (van Manen, 2016). Consequently, statistical literacy should be viewed not merely as a measurable outcome but as an evolving interpretative practice through which learners construct meaning from data.

This interpretation extends the conceptualization proposed by Gal (2002), who argues that statistical literacy encompasses the ability to interpret, evaluate, and communicate statistical information. The present findings further suggest that these capacities are inseparable from learners' experiences of engaging with statistical ideas. In this sense, statistical literacy is not solely cognitive but also experiential, shaped by how learners encounter, interpret, and make sense of statistical situations.

The Role of Self-Efficacy in Statistical Interpretation

Beyond cognitive performance, the findings revealed a meaningful relationship between self-efficacy and statistical literacy. A moderately strong positive correlation was identified between participants' self-confidence and statistical literacy scores ($r = 0.62$, $p < 0.01$). Participants reporting higher levels of self-efficacy achieved higher average scores ($M = 74.2$) than those reporting lower levels of self-efficacy ($M = 61.5$).

Figure 3 further illustrates this pattern. Most participants acknowledged that interpreting statistical meaning was substantially more difficult than performing statistical calculations. Approximately 58.3% agreed and 16.7% strongly agreed that interpreting statistical results posted significant challenges, whereas no participants strongly disagreed. These perceptions suggest that statistical activity was generally experienced as procedurally manageable but interpretatively demanding.

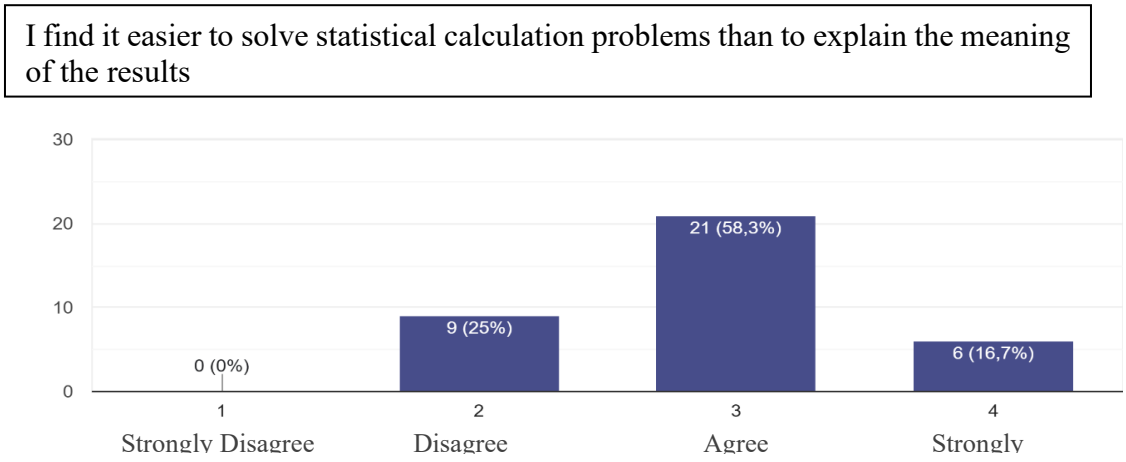

Figure 3. Participants' Perceptions of Difficulty in Interpreting Statistical Results

Qualitative evidence indicates that this challenge was closely associated with uncertainty and hesitation during meaning-making processes. Several participants reported feeling

confident when applying formulas but uncertain when required to justify interpretations or explain statistical conclusions. As one participant stated:

> "I can calculate the answer, but I am often unsure how to explain what the numbers actually mean."

This finding highlights the affective dimension of statistical literacy. Interpretative reasoning requires not only conceptual knowledge but also confidence in making judgments under conditions of uncertainty. Thus, statistical literacy development involves dispositions, beliefs, and self-confidence alongside procedural and conceptual competence.

Prior Learning Experiences and the Construction of Statistical Meaning

The origins of procedural dominance became increasingly evident through participants' reflections on previous learning experiences. Questionnaire data indicated that 72% of participants perceived their prior statistics education as predominantly procedural and formula-oriented, whereas only 41% reported regular engagement in interpretative discussion and reflection. Interview data further revealed that many participants' earliest encounters with statistics were confined to calculating descriptive measures and constructing tables or graphs. One participant explained:

> "I only know statistics as calculating the mean and median, or creating tables and diagrams from given data. I do not yet understand its meaning or real-world application."

This account illustrates how learners' understandings of statistics are shaped through pedagogical experiences. The issue appears not simply to be insufficient conceptual knowledge but a broader educational culture that privileges procedural accuracy over interpretation and reflection. Consequently, participants often perceived statistics as a collection of techniques rather than a means of understanding data-based phenomena.

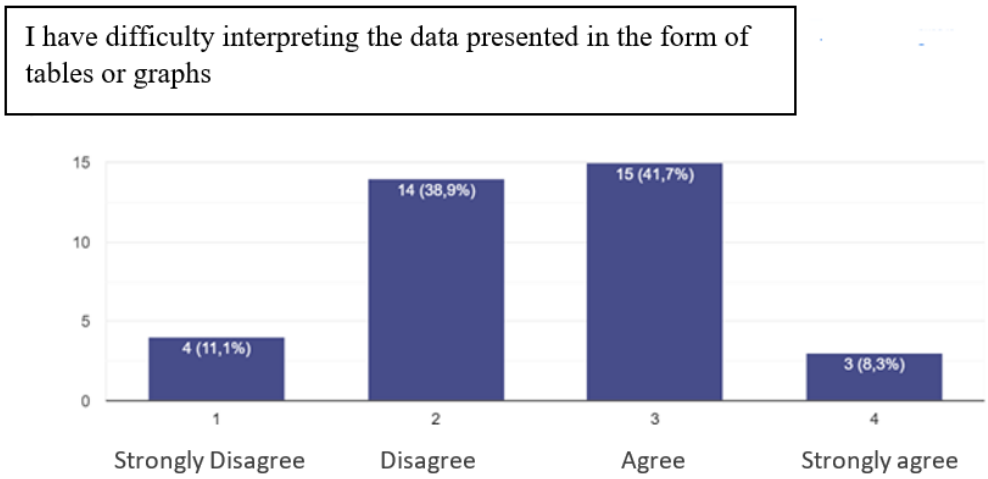

Figure 4. Ability to interpret data in the form of tables and graphs

Difficulties with data interpretation further reinforce this conclusion. As shown in Figure 4, a substantial proportion of participants reported challenges when interpreting information presented in tables and graphs. Such findings are consistent with previous studies demonstrating that procedural approaches to statistics instruction frequently constrain opportunities for reflective thinking, critical evaluation, and contextual reasoning (Machromah & Musthofa, 2023; Masfingatin & Suprapto, 2020).

Implications for Statistics Education

Taken together, the findings suggest that statistical literacy is fundamentally multidimensional, encompassing procedural competence, interpretative reasoning, contextual judgment, reflective understanding, and affective dispositions. The substantial discrepancy between procedural success (84%) and interpretative competence (38%) indicates that current approaches to statistics education may support computational proficiency without necessarily fostering meaningful statistical understanding.

From both national and international perspectives, these findings underscore the need for a pedagogical shift from procedure-centered instruction toward learning environments that emphasize interpretation, reflection, discussion, and contextual meaning-making. Such environments should encourage learners not only to calculate statistical results but also to question, justify, communicate, and evaluate those results within authentic contexts. For preservice mathematics teachers in particular, the development of statistical literacy requires opportunities to experience statistics as an interpretative practice through which data become meaningful rather than merely calculable.

Viewed through a hermeneutic-phenomenological lens, statistical literacy emerges not simply as a set of skills but as a way of engaging with data through interpretation, reflection, and contextual understanding. The central challenge identified in this study was therefore not participants' inability to perform statistical procedures but their difficulty in transforming procedural activity into meaningful statistical interpretation. This insight extends previous research by demonstrating that such interpretative limitations are shaped not only by conceptual knowledge but also by the educational experiences through which learners come to understand what statistics is and what it means to do statistics.

Conclusion

This study demonstrates that preservice mathematics teachers' statistical literacy extends beyond procedural competence and should be understood as an interpretative process of constructing meaning from data. Although most participants demonstrated satisfactory performance in routine statistical calculations, both quantitative and qualitative findings

revealed persistent difficulties in interpreting statistical information, contextualizing results, and critically evaluating data-based conclusions. The findings further suggest that the discrepancy between procedural performance and interpretative understanding is closely associated with prior learning experiences that emphasized formula application and answer accuracy rather than reflection, contextual reasoning, and meaning-making. Consequently, statistical literacy emerged not merely as a technical ability but as a multidimensional competence involving procedural proficiency, interpretative reasoning, reflective engagement, and contextual judgment.

The study contributes to statistical literacy research by extending prevailing conceptions of statistical competence beyond computational achievement toward a more interpretative and experiential perspective. Through the integration of sequential explanatory mixed methods and hermeneutic phenomenology, the study revealed dimensions of statistical literacy that were not fully visible through quantitative assessment alone, particularly the tensions between observable performance and participants' lived experiences of understanding statistics. These findings highlight the value of combining measurable evidence with interpretative inquiry to obtain a more comprehensive understanding of how statistical literacy develops among preservice mathematics teachers.

The findings also have important implications for mathematics teacher education. Statistics instruction should move beyond formula-centered approaches and provide greater opportunities for contextual interpretation, reflective discussion, and meaningful engagement with data. Such learning experiences may support the development of both interpretative reasoning and confidence in making data-based judgments. Nevertheless, the findings should be interpreted in light of the study's context-specific sample and interpretative methodology. Future research may extend this work by examining statistical literacy across diverse educational settings and by investigating instructional interventions that more effectively connect procedural competence with interpretative understanding and contextual reasoning.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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