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Exploring Students' Lived Experiences of Statistical Literacy in a Mathematical Statistics Course: A Phenomenological Narrative Study

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ABSTRACT

Background. The rapid development of information technology and the increasing use of data across various domains require students to be able to understand and critically interpret statistical information. Statistical literacy has become an essential competency in higher education, particularly in contexts that demand data analysis and interpretation of research findings. However, previous studies indicate that students still experience difficulties in understanding statistical concepts and interpreting statistical information appropriately.

Purpose. This study aims to explore the statistical literacy of mathematics education students after completing a mathematical statistics course, with a particular focus on how they experience and construct meaning of statistical concepts.

Method. This study employed a qualitative approach with a phenomenological design to examine students' lived experiences in learning statistics. The participants were mathematics education students who had completed a mathematical statistics course. Data were collected through a statistical literacy test consisting of 15 items used as an elicitation tool, followed by semi-structured interviews to explore students' meaning-making processes. Data were analyzed using thematic analysis to identify patterns in how students understand and interpret statistical concepts and information.

Results. The findings reveal that students' statistical literacy is predominantly characterized by procedural understanding, where students are able to execute statistical procedures but struggle to interpret results and critically evaluate research findings. More importantly, the study identifies a pattern of understanding conceptualized as surface statistical thinking, in which students rely on mechanical procedures, exhibit limited knowledge transfer, and demonstrate fragmented conceptual understanding. These findings highlight that students' difficulties are not merely related to ability levels, but are rooted in how they experience and make sense of statistics learning.

Conclusion. This study contributes theoretically by proposing surface statistical thinking as a phenomenological construct that explains the gap between procedural performance and conceptual understanding in statistical literacy. Therefore, statistics instruction in higher education should be designed to promote conceptual understanding through contextual, reflective, and data-driven learning, while integrating data literacy and critical thinking to better prepare students for the demands of the data-driven and artificial intelligence era.

KEYWORDS

Mathematics Education Students, Statistical Literacy, Statistics Learning, Phenomenology

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INTRODUCTION

The rapid advancement of digital technology and the increasing use of data across various domains of life have positioned statistical literacy as an essential competency in modern society. Data-driven information is now presented in multiple forms, such as graphs, tables, and statistical reports, which are widely used in decision-making processes in education, healthcare, economics, and public policy. In this context, the ability to understand and critically evaluate statistical information has become a crucial component of 21st-century literacy. Gal (2002) defines statistical literacy as the ability to interpret, evaluate, and communicate statistical information critically across diverse contexts. This perspective is reinforced by Garfield and Ben-Zvi (2007), who emphasize that statistical literacy involves conceptual understanding, critical thinking about data, and the ability to use data to support decision-making. Other studies also highlight that the ability to critically interpret data forms an integral part of quantitative literacy in an information-based society (Sharma, 2017; Watson & Callingham, 2003). More recent developments indicate that statistical literacy is no longer a standalone competence but is increasingly integrated with data literacy and data-driven thinking in the era of artificial intelligence and data science (Bauder & Cave, 2025; Biehler et al., 2025; Phadke et al., 2024; Ridgway et al., 2022).

In the field of mathematics education, statistics plays a significant role in fostering analytical and interpretative thinking skills related to data. The teaching of statistics is not merely aimed at procedural computation but also at developing students' ability to critically understand data and make evidence-based decisions. Ben-Zvi and Garfield (2004) argue that effective statistics education should promote statistical thinking, which includes understanding data collection processes, data analysis, and critical interpretation of results. Similarly, Franklin et al. (2007) assert that statistical literacy is a primary goal of statistics education, as it enables students to make sense of quantitative information encountered in everyday life. Other studies have identified the development of statistical literacy as a key focus in mathematics education due to the growing demand for data analysis skills across disciplines (Groth, 2012; Ridgway et al., 2022). However, recent research indicates that instructional practices in statistics often remain focused on procedural aspects rather than on fostering conceptual understanding and statistical reasoning (Córdova-Espinoza et al., 2024; Hasanah et al., 2024).

At the higher education level, statistical literacy is a critical competence for university students, particularly in relation to research and scientific data analysis. Students are expected to understand statistical concepts, conduct appropriate data analyses, and critically interpret results within academic research contexts. Gould (2017) highlights that statistical literacy is essential in the era of big data, where students are required not only to understand statistical concepts but also to apply data in solving real-world problems. Chance et al. (2007) further argue that statistical literacy encompasses both conceptual understanding and the ability to use data to support scientific arguments. Zieffler et al. (2008) emphasize the importance of contextual understanding in interpreting data for informed decision-making, while Engel (2017) identifies statistical literacy as a core competency in higher education. More recent studies also demonstrate that statistical literacy is closely linked to students' abilities in scientific reasoning and data-based argumentation (Berndt et al., 2021; Phadke et al., 2024).

Students enrolled in mathematics education programs play a strategic role in the development of statistical literacy, as they are future teachers who will teach statistical concepts at the school level. Therefore, a strong understanding of statistical literacy is essential for these prospective teachers. Ben-Zvi and Garfield (2004) argue that pre-service mathematics teachers must possess deep conceptual knowledge of statistics to teach it effectively. Groth (2012) also emphasizes that teachers' statistical literacy significantly influences the quality of statistics instruction in schools. Sharma (2017) further highlights that pre-service teachers should be capable of interpreting data and explaining statistical concepts contextually. Recent studies suggest that statistical literacy among pre-service teachers is not only related to conceptual knowledge but also to their ability to reflect on their own learning experiences in statistics (Addison et al., 2025; Guven et al., 2021).

Despite its importance, numerous studies indicate that students' statistical literacy remains relatively low. Garfield and Ben-Zvi (2007) found that many students tend to focus on computational procedures without understanding the underlying concepts of data analysis. Watson (2013) reports that students often struggle to interpret statistical information presented in graphical or tabular forms. Similarly, Zieffler et al. (2008) reveal that students frequently make errors when drawing conclusions from data due to insufficient conceptual understanding. Sharma (2017) also identifies limited conceptual knowledge and lack of experience in data analysis as key factors contributing to low statistical literacy. These findings point to a fundamental tension between procedural proficiency and conceptual understanding, where students may perform calculations correctly but fail to meaningfully interpret the results. Recent studies further confirm that this gap remains a major challenge in contemporary statistics education (Biehler et al., 2025; Koga, 2025).

In addition to low levels of statistical literacy, students often exhibit negative perceptions toward statistics. Many perceive statistics as a difficult and abstract subject, which negatively affects their learning motivation. Chance et al. (2007) identify statistics anxiety as a significant factor influencing students' performance. Gould (2017) also notes that such anxiety can hinder learning processes and conceptual understanding. Groth (2012) argues that instructional approaches overly focused on procedural computation may exacerbate these negative perceptions. Engel (2017) further suggests that a lack of contextualization in teaching can make it difficult for students to see the relevance of statistical concepts in real-life situations. Recent research indicates that less meaningful learning experiences contribute significantly to the development of these negative perceptions (Addison et al., 2025; Córdova-Espinoza et al., 2024).

Previous studies have examined statistical literacy across different educational levels using various research approaches. Watson and Callingham (2003) developed a hierarchical model of statistical literacy to assess students' abilities. Sharma (2017) employed quantitative methods to measure students' statistical literacy through test instruments. Garfield and Ben-Zvi (2007) investigated the development of statistical literacy through analyses of students' conceptual understanding. While quantitative approaches provide valuable insights into students' performance levels, they tend to focus primarily on learning outcomes and often fail to capture the meaning-making processes experienced by students during learning.

In this regard, qualitative approaches are essential for gaining deeper insights into students' learning experiences. Gal (2002) emphasizes that statistical literacy involves not only cognitive abilities but also individuals' experiences in interpreting and using statistical information. Creswell and Creswell (2018) explain that phenomenological research aims to explore individuals' lived experiences of a particular phenomenon. This approach enables researchers to understand how individuals construct meaning from their experiences within specific contexts. In educational research, phenomenology can be used to explore students' learning experiences in depth (Manen, 2016; Stolz, 2020). Therefore, this approach is particularly relevant for uncovering the essence of students' experiences in developing statistical understanding.

Several studies in the Indonesian context indicate that students' statistical literacy still requires considerable attention. Andriatna and Kurniawati (2021) found that most pre-service mathematics teachers exhibit low to moderate levels of statistical literacy. Similarly, (Lukman et al.,

2022) suggest that improving students' statistical literacy requires contextual and data-driven instructional approaches. Setiawan and Sukoco (2021) emphasize the need for innovative teaching strategies to enhance students' conceptual understanding of statistics. However, these studies primarily focus on learning outcomes and do not explicitly examine how students experience and make sense of statistical learning processes.

Although numerous studies have investigated students' statistical literacy, most have relied on quantitative approaches that emphasize measurement of ability. Research that explores students' lived experiences in understanding statistical concepts remains limited, particularly within the context of mathematics education students. Furthermore, existing approaches have not sufficiently captured the dimension of lived experience how students perceive, interpret, and construct meaning from statistical concepts in real learning situations. As a result, current understandings of statistical literacy tend to remain superficial and do not fully address the essential aspects of students' learning experiences.

Based on these considerations, this study aims to explore students' experiences of statistical literacy through a phenomenological approach. Specifically, this study seeks to answer the following research questions: how mathematics education students experience statistical literacy in statistics courses, how they construct meaning of statistical concepts during the learning process, and how the tension between procedural and conceptual understanding emerges in their learning experiences. This study is expected to provide deeper insights into the essence of statistical literacy from the perspective of students' lived experiences and to contribute to the development of more meaningful statistics instruction in higher education.

RESEARCH METHODOLOGY

This study employed a qualitative approach with a phenomenological design to explore students' experiences in developing statistical literacy after completing a mathematical statistics course. Epistemologically, the study is grounded in hermeneutic (interpretive) phenomenology, which seeks to understand and interpret the meaning of students' lived experiences in learning statistics (Manen, 2016; Stolz, 2020). This approach was selected because the study does not merely aim to describe experiences, but also to interpret how students construct meaning around statistical concepts within an academic context. To support this phenomenological inquiry, the study adopted a qualitatively dominant design supplemented by limited quantitative data, where a test instrument was used as an elicitation tool to stimulate deeper reflections during interviews.

The participants were undergraduate students enrolled in a mathematics education program at a university in Indonesia who had completed a mathematical statistics course. Participants were selected through purposive sampling based on the following criteria: (1) having completed the mathematical statistics course, (2) having experience in applying data analysis in assignments or research, and (3) willingness to participate voluntarily. A total of 23 students participated in the statistical literacy test. From this group, 12 participants were selected for in-depth interviews based on variation in test results, gender, and academic background to capture diverse experiences. The participants represented different academic stages, including those who had recently completed the course, those currently working on their undergraduate thesis, and those who had completed their thesis defense. This variation was intended to provide a more comprehensive understanding of students' experiences related to statistical literacy. The number of interview participants was determined based on the principle of data saturation, where no substantial new information emerged and recurring patterns were observed (Creswell & Creswell, 2018; Moustakas, 1994).

The research instruments consisted of a statistical literacy test and a semi-structured interview guide. The test included 15 items designed to identify students' understanding of statistical concepts, data interpretation, and evaluation of statistical information. The items covered various aspects, including parameter definitions, instrument validity, sampling techniques, data analysis procedures, assumption testing, interpretation of results, and ethical issues such as plagiarism. Example questions included: "What is a parameter?", "What is the difference between linear regression and analysis of variance?", and "Why is instrument validation necessary?". The instrument was developed based on the context of statistics instruction and was not intended as the primary measurement tool, but rather as a stimulus to elicit initial responses that were further explored during interviews. Content validity was established through expert judgment by two lecturers specializing in mathematics education and statistics. A pilot test was conducted with students outside the research participants to ensure clarity and comprehensibility of the items. Reliability was not assessed statistically, as the instrument was not used as a primary quantitative measure, but was instead evaluated based on the consistency of student responses and its alignment with the goals of phenomenological exploration.

Data collection was conducted in several stages. The first stage involved administering a statistical literacy test online using Google Forms, where all participants completed the instrument independently. The second stage involved selecting interview participants based on test results to ensure variation in levels of understanding. The third stage consisted of conducting semi-structured interviews online, each lasting approximately 30-60 minutes. The interviews aimed to explore students' experiences in understanding statistical concepts, the challenges they encountered, and how they constructed meaning from statistics learning within the context of academic research. All interviews were audio-recorded and transcribed verbatim. During this process, the researcher applied the principle of bracketing by reflecting on and temporarily suspending prior assumptions about students' statistical literacy to ensure that interpretations were grounded in participants' experiences (Moustakas, 1994).

Data analysis was carried out using reflexive thematic analysis (Braun & Clarke, 2006), integrated with a hermeneutic phenomenological perspective. The analysis followed several stages: (1) familiarization with the data through repeated reading of interview transcripts, (2) initial coding to identify meaningful units related to students' experiences, (3) grouping codes into categories based on shared meanings, (4) developing overarching themes that represent patterns of experience, and (5) interpreting these themes within a phenomenological framework to uncover the essence of the experience. To enhance the credibility of the analysis, coding was conducted collaboratively with a peer coder, followed by discussions to reach agreement (inter-coder agreement). Additionally, an audit trail was maintained to document the entire analytical process, from raw data to the development of final themes.

The trustworthiness of the data was ensured through several techniques, including triangulation, member checking, and peer debriefing. Triangulation was conducted by comparing data obtained from the test and interviews to examine consistency in students' understanding. Member checking involved asking participants to verify the interpretations of their interview responses to ensure alignment with their intended meanings. Peer debriefing was carried out through discussions with fellow researchers to examine the consistency and logic of data interpretation. These strategies were employed to enhance the credibility, dependability, and confirmability of the study (Creswell & Creswell, 2018; Morrison et al., 2020).

Ethical considerations were carefully addressed throughout the study. The research was conducted at a university in Indonesia, specifically within a mathematics education program, with formal permission obtained from the head of the program. The researcher adhered to ethical standards in both data collection and analysis processes. All participants were informed about the purpose of the study, research procedures, and their rights as participants through an informed consent process prior to data collection. Confidentiality was strictly maintained by assigning codes or initials to participants and by omitting explicit references to the program or institution in the reporting of findings. All data were securely stored in protected digital storage and were used solely for academic purposes.

Despite careful methodological design, several limitations should be acknowledged. The use of a test within a phenomenological study may introduce epistemological tension if treated as a primary measurement tool. Therefore, in this study, the test was used solely as an elicitation instrument to enrich the exploration of students' experiences. Additionally, while the relatively small number of interview participants allowed for in-depth analysis, it limits the generalizability of the findings. Accordingly, this study prioritizes an in-depth understanding of the essence of students' experiences rather than population-level generalization.

RESULT AND DISCUSSION

The findings of this study illustrate the level of statistical literacy among mathematics education students after completing a mathematical statistics course. The analysis was based on the results of a statistical literacy test consisting of 15 items, as well as interviews aimed at exploring students' experiences in understanding statistical concepts. In this study, statistical literacy was analyzed across three levels of competence: basic, intermediate, and advanced. This classification aligns with established frameworks suggesting that statistical understanding develops progressively, from basic conceptual recognition to the ability to critically evaluate statistical information (Ben-Zvi & Garfield, 2004; Gal, 2002; J. Watson & Callingham, 2003). Moreover, statistical literacy is not only associated with conceptual understanding but also with the ability to use data to make rational decisions in various contexts (Bailey & McCulloch, 2023; Phadke et al., 2024), and it is increasingly viewed as part of data literacy in the era of artificial intelligence, which requires critical interpretation and evaluation of data (Bauder & Cave, 2025; Biehler et al., 2025).

To provide an overview of students' statistical literacy, a summary of test results is presented in Table 1. The table displays the distribution of students' responses across various indicators of statistical literacy, including conceptual, procedural, and evaluative aspects. The results indicate that the percentage of correct responses is generally higher for procedural indicators, such as instrument validity (82.61%) and data analysis application (82.61%), compared to indicators requiring deeper conceptual and evaluative understanding, such as distinguishing between regression and ANOVA (39.13%) and evaluating the quality of research references (13.04%). These findings suggest that students are more capable of completing procedure-based tasks than of understanding statistical meaning at a deeper level.

Table 1. Distribution of Students' Correct, Partially Correct, and Incorrect Responses Across Statistical Literacy Competencies

No	Competency	Correct Answers (%)	Correct Answers with Inaccurate Reasoning (%)	Incorrect Answers (%)
1	Searching for research literature	69.57	13.04	17.38
2	Concept of parameters	39.13	39.13	21.74
3	Instrument validity	82.61	17.39	0
4	Sampling techniques	43.48	52.17	4.35
5	Instrument validity	21.74	78.26	0
6	Assumption testing for statistical analysis	69.57	13.04	17.39
7	Use of census in research	43.48	30.43	26.09
8	Importance of instrument validation	0	78.26	21.74
9	Regression vs. ANOVA	39.13	0	60.87
10	Invalid instrument items	13.04	43.48	43.48
11	Application of data analysis	82.61	13.04	4.35
12	Quality of research references	13.04	43.48	43.48
13	Drawing research conclusions	47.83	39.13	13.04
14	Research success indicators	8.70	60.87	30.43
15	Plagiarism	0	95.65	4.35

Overall, Table 1 indicates that students' statistical literacy varies across different levels of competence. Students tend to perform better on tasks related to basic statistical concepts than on those requiring complex data analysis and interpretation. This condition suggests that students' understanding of statistics remains predominantly procedural. These findings are consistent with previous studies indicating that students are often able to perform statistical calculations but struggle to interpret the meaning of data analysis results (Berndt et al., 2021; Garfield & Ben-Zvi, 2007).

However, interview findings reveal that this condition is not merely a matter of limited ability, but rather reflects how students experience statistics learning. One participant stated:

"I usually just follow the steps, as long as the result is correct." (Res 5)

This statement indicates that students tend to perceive statistics as a set of mechanical procedures. Another participant expressed:

"If the problem is slightly different from the example, I get confused about which method to use." (Res 3)

These findings point to limitations in knowledge transfer, suggesting that students' understanding has not yet reached a conceptual level.

Based on these results, this study proposes an interpretive model termed *surface statistical thinking*, referring to a condition in which students are able to execute statistical procedures but lack a deep conceptual understanding of the data they analyze. This model is characterized by three main features: (1) dominance of procedural understanding, (2) limited ability to transfer knowledge, and (3) weak evaluative capacity toward data. This concept extends previous research by offering a phenomenological perspective on students' experiences in learning statistics.

Figure 1 presents the distribution of students' responses to questions related to basic statistical literacy competencies. The figure shows that most students were able to correctly answer basic-level questions, particularly those related to instrument validity and sampling techniques. However, this ability is not accompanied by adequate conceptual understanding. Thus, the findings indicate that students are at the stage of concept recognition rather than deep understanding.

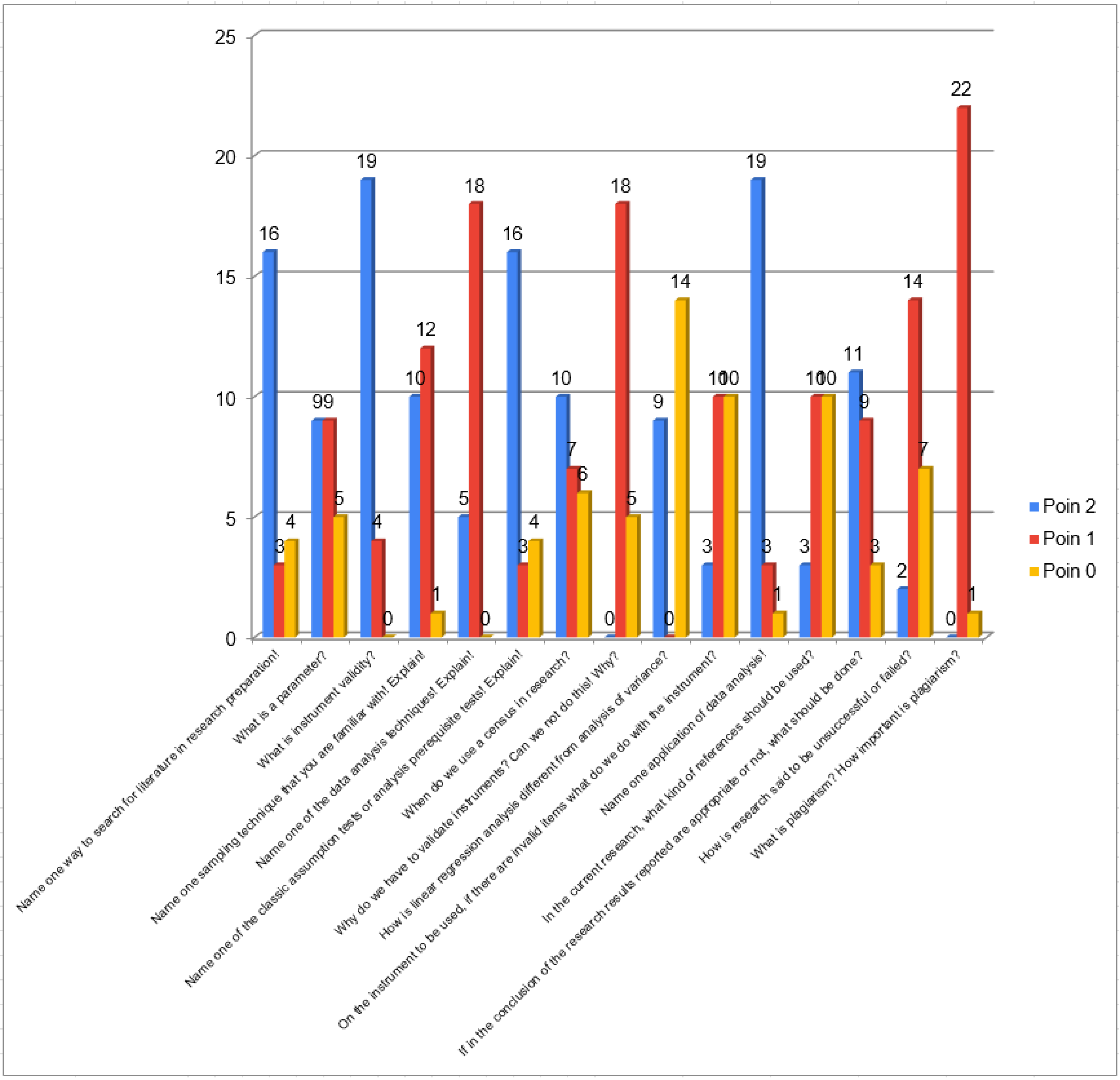

Figure 1. Description of Students' Statistical Literacy Ability

Interview data further reveal that students have limited ability to evaluate data sources and statistical information. Some participants reported frequently using less credible references, indicating that statistical literacy is closely related to information literacy and data literacy (Bauder & Cave, 2025), which require the ability to critically assess the quality of data sources.

At the intermediate level, students are expected to perform statistical analyses and explain the reasoning behind their results. However, the findings show that many students still struggle to understand more complex statistical concepts. For instance, in questions regarding the difference between linear regression and analysis of variance, more than half of the students provided incorrect or incomplete responses.

One participant noted:

"I know regression is about relationships, but compared to ANOVA, I don't really understand the difference." (Res 10)

This finding indicates fragmentation in conceptual understanding. From the perspective of cognitive load theory, this condition may arise when students experience excessive cognitive load due to instruction that emphasizes procedures without providing a clear conceptual structure (Sweller, 2011). As a result, students find it difficult to integrate various statistical concepts coherently.

From a constructivist perspective, this also suggests that students have not yet developed meaningful understanding through their learning experiences. Recent studies indicate that project-based and context-rich learning approaches can enhance students' conceptual understanding in statistics (Córdova-Espinoza et al., 2024).

At the advanced level, students are expected to critically evaluate research findings. However, the results show that this ability remains limited, as reflected in the low percentage of correct responses related to evaluating reference quality and research validity.

One participant stated:

"When I read research, I usually just accept the results." (Res 12)

This finding suggests that students lack adequate evaluative skills. In the context of modern data literacy, such skills are essential, as students are required not only to understand data but also to critically assess its validity and reliability (Biehler et al., 2025; Phadke et al., 2024).

Figure 2 illustrates the overall distribution of students' responses across different aspects of statistical literacy measured in this study. The figure shows that most students fall within the low to moderate levels of competence. This indicates that the statistics instruction experienced by students has not yet fully supported the development of comprehensive statistical literacy.

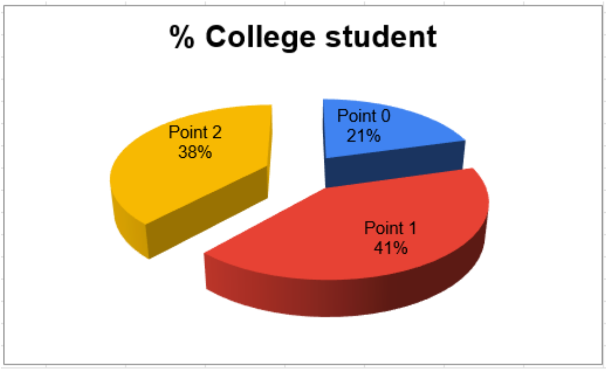

Figure 2. Percentage of Students' Statistical Literacy Responses

The findings also reveal that students' perceptions of statistics influence their level of statistical literacy. Some students still perceive statistics as a difficult and abstract subject, which leads them to adopt learning strategies focused primarily on memorizing procedures.

In light of recent developments, statistical literacy is increasingly viewed not as a standalone competence, but as part of broader data literacy and AI literacy. Recent studies suggest that data literacy encompasses the ability to understand, analyze, evaluate, and communicate data critically across contexts (Wang et al., 2025). Furthermore, the integration of technologies such as artificial intelligence has been shown to enhance students' conceptual understanding and critical thinking in statistics (Hariyanti et al., 2025).

However, the findings of this study indicate that students are still at an early stage in developing these competencies. This suggests a gap between the demands of data-driven learning in the modern era and students' actual learning experiences. Therefore, these findings reinforce the need to reconstruct statistics instruction to be more contextual, data-driven, and supportive of conceptual understanding.

Overall, the results indicate that the statistical literacy of mathematics education students is still dominated by procedural understanding, conceptualized in this study as *surface statistical thinking*. This finding not only confirms previous research but also extends it by demonstrating that such limitations are rooted in students' learning experiences. It is also consistent with the findings of Azis and Dahlan (2024), which indicate that students' statistical literacy requires improvement, particularly in data interpretation and analysis.

More broadly, the study highlights that the development of statistical literacy should emphasize the integration of conceptual understanding, meaningful learning experiences, and critical thinking about data. In the era of data science and artificial intelligence, statistical literacy should be developed as part of a broader data literacy framework, encompassing the ability to understand, analyze, and critically evaluate data across contexts (Bauder & Cave, 2025; Biehler et al., 2025; Phadke et al., 2024). Therefore, statistics instruction in higher education needs to be designed in a more contextual, reflective, and data-driven manner to foster deeper conceptual understanding among students.

CONCLUSION

Based on the findings, it can be concluded that the statistical literacy of mathematics education students is still dominated by procedural understanding, particularly in aspects of calculation and the application of analytical techniques, but has not yet developed optimally in the conceptual, interpretative, and evaluative domains. These findings indicate that students tend to understand statistics as a series of mechanical steps rather than as a tool for constructing meaning from data within research contexts. From a phenomenological perspective, this study reveals that students' learning experiences in statistics lead to the formation of a pattern of understanding conceptualized in this study as *surface statistical thinking*, a condition in which students are able to perform statistical procedures but are not yet able to meaningfully interpret the results of their analyses. This condition is characterized by limited knowledge transfer, fragmented conceptual understanding, and low evaluative ability toward statistical information. Therefore, statistics instruction in higher education needs to be directed toward strengthening conceptual understanding through more contextual, reflective, and data-driven approaches, as well as integrating the development of data literacy and critical thinking skills in response to the challenges of the artificial intelligence era. In this way, students are expected not only to be able to perform statistical analyses, but also to understand, evaluate, and use data meaningfully across various academic and real-world contexts.

DECLARATION OF AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this manuscript, the authors used ChatGPT to assist in improving the clarity of language and grammar. The authors carefully reviewed and edited the content and take full responsibility for the accuracy and integrity of the manuscript.

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AUTHORS' CONTRIBUTION

Author 1: Conceptualization; Data collection; Data analysis; Writing – original draft.
Author 2: Supervision; Methodology validation; Writing – review and editing.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no competing interests.

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