

Key factors affecting statistical literacy in mathematics education: Insights from students and lecturers

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ABSTRACT

The importance of statistics in everyday life and the world of work has prompted educational institutions to increase their focus on statistical literacy. Statistical literacy has also been described as an essential learning outcome in learning statistics in higher education, including in mathematics education study programs. This study aimed to reveal the key factors influencing the statistical literacy skills of mathematics education students in Indonesia. A qualitative phenomenological approach was adopted, involving lecturers and students from mathematics education study programs nationwide as research participants. A total of 36 participants, consisting of nine lecturers and 27 students, were interviewed online using a semi-structured format. This study identified four main themes that influence the statistical literacy skills of mathematics education students: internal student factors, learning strategies or methods, supporting infrastructure factors, and other contextual factors, such as the limited number of credits allocated to statistics courses and the competence of lecturers in teaching statistical literacy. The findings and their implications for educational practice and policy are discussed.

Keywords: statistical literacy, mathematics education, phenomenological study, statistics education, obstacles to statistics education

INTRODUCTION

Statistical literacy has become a necessity in modern society. In a data-driven technological society, understanding and applying statistical literacy is essential for all levels of society (Berndt et al., 2021; Schield, 2022; Setiawan & Sukoco, 2021; Sharma, 2017; Umbach, 2022; Watson, 2014). Various information and research reports often appearing in the mass media and used for decision-making are usually presented as statistics (Apino et al., 2024; Ingram, 2015; Sharma, 2017; Tishkovskaya & Lancaster, 2012). In this case, people without statistical literacy may be unable to differentiate between credible information (Apino et al., 2024; English & Watson, 2016; Galesic & Garcia-Retamero, 2010; Kurnia et al., 2023) and have difficulty interpreting, critically evaluating, and communicating statistics and data information (English & Watson, 2016; Setiawan & Sukoco, 2021; Sharma, 2017). Therefore, statistical literacy is crucial in enhancing the quality of decision-making by individuals, communities, and governments.

In the digital era, statistical literacy is essential as learners will be continuously presented with statistical data from various sources (Kurnia et al., 2023; Sharma, 2017). Statistical literacy has also been described as an essential learning outcome in learning basic or introductory statistics in higher education (Garfield & DelMas, 2010; Guven et al., 2021; Özmen & Baki, 2021; Phadke et al., 2024; Retnawati et al., 2019; Setiawan & Sukoco, 2021; Ziegler & Garfield, 2018). The importance of statistical literacy has prompted the Statistics Education Research Journal to publish a special issue (May 2017) dedicated to the topic of statistical literacy (Ziegler & Garfield, 2018). The guest editor of the special issue concluded that statistics educators should take the time to promote statistical literacy directly (Ziegler & Garfield, 2018). As data has become increasingly important in our daily lives, it is essential to have basic skills such as making effective decisions and making situation-based inferences (Güven et al., 2021). These basic skills can be achieved if learners have statistical literacy.

Statistical Literacy: Conceptualization and Potential Influencing Factors

At the tertiary level, statistical literacy is a learning outcome of introductory statistics (Garfield & DelMas, 2010; Ziegler & Garfield, 2018). However, it remains challenging to find research that accurately captures students' statistical literacy levels broadly and the factors that influence them. Information about students' statistical literacy levels on a broad scale and the factors that influence them will be very valuable in designing future improvements in statistics learning (Callingham & Watson, 2017;

Sabbag et al., 2018; Ziegler & Garfield, 2018). That information is helpful for educators in designing appropriate statistics teaching (Berndt et al., 2021; Pierce et al., 2014; Sabbag et al., 2018; Ziegler & Garfield, 2018). The information can also be utilised by researchers to map the potential for future research, both in the context of improving the statistics learning process (Apino et al., 2024; Berndt et al., 2021; Ziegler & Garfield, 2018) and its assessment (Apino et al., 2024; Ziegler & Garfield, 2018).

While several relevant studies have been conducted to investigate the factors that influence statistical literacy, it remains challenging to find studies that focus on the context of mathematics education at the tertiary level. For example, Gonulal (2018) investigated the predictors of statistical literacy to reveal factors that significantly contribute to statistical literacy. However, these studies only focus on the context of Second Language Acquisition (SLA) involving doctoral students. Auliya (2019) investigated the effect of perceptions of math and statistics on statistical literacy, but the respondents involved were students majoring in informatics. Previous studies have not explicitly revealed the factors influencing statistical literacy in mathematics education students. On the other hand, important findings from other studies (i.e., Apino et al., 2024; Guven et al., 2021; Özmen & Baki, 2021; Setiawan & Sukoco, 2021) recommend the need to improve the practice of teaching and learning statistics in mathematics education programs in tertiary education to strengthen the statistical literacy of undergraduate students. Such improvements can begin by investigating factors that might shape and influence the statistical literacy of undergraduate mathematics education students.

Retnawati et al. (2024) have attempted to explore the factors and conditions that have the potential to shape the statistical literacy of undergraduate mathematics education students in Indonesia. This study employed a quantitative approach, examining four predictors that were believed to influence students' statistical literacy performance: gender, status of the higher education institution (public vs. private), laptop ownership (owned vs. not owned), and research preference (quantitative vs. qualitative). The findings of this study revealed that only three predictors significantly influenced statistical literacy, namely gender, status of higher education, and laptop ownership. Although the study by Retnawati et al. (2024) successfully identified three crucial factors that influence statistical literacy, there are still gaps, as the findings only consider the perspective of students, specifically those in mathematics education. In addition, the identified factors do not consider other potential factors such as statistical learning strategies and methods in the classroom (Farmus et al., 2020; Kovacs et al., 2021; Neumann et al., 2013), student attitudes, motivation, and interest in statistics (Abbiati et al., 2021; Kulacki & Aikens, 2024; Neumann et al., 2013), learning facilities and resources (Jainuri, 2025; Schwerter & Brahm, 2024), and other factors related to lecturers' skills in teaching statistical literacy (Callingham et al., 2016; Schreiter et al., 2024). To explore these potential factors, more in-depth information is needed, involving not only students but also statistics educators. In this case, to expand on the findings of previous studies, it is urgent to use different methodological approaches (i.e., qualitative) and involve other stakeholders, particularly statistics educators, to identify key factors that influence statistical literacy.

Several studies using a qualitative approach in the context of statistical literacy have been conducted, although their primary focus is not on revealing the factors that influence statistical literacy. Setiawan and Sukoco (2021) highlight the influence of students' prior knowledge and the quality of initial instruction (e.g., how lecturers introduce the concept of visualisation) on the statistical literacy competence of undergraduate mathematics education students. Lukman et al. (2022) employed a grounded theory approach to develop a conceptual framework of statistical literacy among students. They demonstrated that the time spent interacting with statistical practices (e.g., data project assignments, class discussions) and opportunities for reflection were crucial in shaping undergraduate students' statistical literacy. The focus on prospective teachers discussed by Guven et al. (2021) reveals another dimension, where teachers' pedagogical competence and didactic pathways influence both students' understanding and their future ability to teach statistical literacy.

The Current Study

Although previous qualitative studies have indirectly identified various factors that influence statistical literacy, the perspective of statistics educators (lecturers) who directly design learning experiences and play a primary role in shaping students' statistical literacy has not been explored in depth. In fact, factors such as lecturers' pedagogical beliefs about the importance of statistical literacy, the instructional strategies they apply, and the curriculum context they interpret and adapt in their teaching have great potential to influence students' statistical literacy levels (Guven et al., 2021). Furthermore, there have been few studies that integrate the perspectives of students and lecturers simultaneously to understand how the interaction between learning design, classroom environment, and individual student characteristics contributes to the development of statistical literacy in the context of mathematics education. This situation has resulted in our understanding of the dynamics of factors influencing students' statistical literacy remaining partial, as it is separated between the student and lecturer aspects, thus failing to provide a comprehensive picture of the process of statistical literacy development. Based on this gap, this study aims to qualitatively reveal the factors that influence the statistical literacy of mathematics education students, considering both the perspectives of students and statistics educators (lecturers). The current study is expected to make theoretical and practical contributions, aiming to enhance the quality of teaching and learning statistics while strengthening students' statistical literacy, particularly in the context of mathematics education.

METHODS

Research Design

This study aims to reveal the factors that influence students' statistical literacy in mathematics education in Indonesia. This study was motivated by the findings of previous research, which have successfully revealed that the statistical literacy

Table 1. The main questions in the interview protocol

Key questions for lecturers	Key questions for students
1. What factors do you think influence students' statistical literacy? <i>Notes:</i> <i>Answers should cover the following three aspects: internal student factors, lecture/ learning process, supporting facilities and infrastructure.</i>	1. Last year you participated in the statistical literacy survey, did you have difficulty answering the questions given? What were your obstacles in answering the questions?
2. In your university there are some students whose statistical literacy achievements are quite good, what do you think causes the achievements of these students to be better than other students?	2. Based on your experience taking Statistics courses in your study program, have your lecturers ever given such problems (statistical literacy problems)?
3. Nowadays, statistical literacy plays an important role in making data-based decisions, both in everyday life and the academic field. What do you think are the obstacles in developing students' statistical literacy skills in statistics lectures?	3. Do you think that the learning strategies, methods, or approaches used by lecturers during Statistics courses can affect your statistical literacy achievements? (<i>Try to explore what kind of learning is expected by students so that they can develop their statistical literacy</i>).
4. Based on these obstacles, what strategies do you think need to be made to overcome them?	4. Do you think the facilities on your campus are adequate to support your statistical literacy development?

achievement of mathematics education students in Indonesia remains low (see Retnawati et al., 2024). This research uses a qualitative approach through a phenomenological study involving lecturers and students of the Mathematics Education Study Program as research participants. Lecturers who became participants were lecturers in the Mathematics Education Study Program who had experience teaching Statistics courses. Meanwhile, the students who became participants became the sample for the 2023 statistical literacy survey, organised by the research team. The selected students represent the highest, medium, and low literacy achievement groups from each of the 2023 statistical literacy survey college samples.

Participants and Setting

This study involved nine lecturers and 27 students to obtain rich and relevant information regarding factors that may influence statistical literacy in higher education. Participants were selected based on their ability to provide insights relevant to the study objectives. Lecturers were included if they had experience teaching statistics courses at the university level, while students were included if they had completed or were currently enrolled in statistics-related courses.

The nine lecturers were recruited from nine different universities across Indonesia to capture diverse perspectives. Among them, two were male and seven were female. Six taught at public universities and three at private universities. Regarding institutional characteristics, seven were affiliated with general universities and two with religious universities. The lecturers also represented varying levels of teaching experience in statistics, ranging from three to ten years. Although the statistics curriculum varied across institutions, all lecturers considered statistical literacy to be an essential learning outcome of statistics education in higher education.

In addition to lecturers, this study also involved mathematics education students as participants. They were undergraduate students who had taken statistics courses at their university. Like the lecturers, the students came from nine different universities in Indonesia. The students came from the same universities as the participating lecturers, where each university involved three students as participants. As explained previously, the students selected as participants had participated in the statistical literacy survey organised by the research team in 2023 (see Retnawati et al., 2024). We reported the statistical literacy survey into three ability levels (high, medium, and low) for each university to the lecturer. Based on the category, we then randomly select a student to represent each ability level. In this case, the students selected as participants were representative of survey participants at high, medium, and low ability levels from each university. Therefore, seven students represented each ability level. At the time of data collection, the students were in the third to seventh semesters.

Data Collection

Data collection used semi-structured interview techniques to explore in depth the key factors that can influence the statistical literacy achievements of mathematics education students in Indonesia. The interviews were conducted by four interviewers, three of whom were members of the research team. To avoid overlap, each interviewer was assigned a distinct set of participants, ensuring that every participant was interviewed once. The interviews with lecturers and students were conducted separately to ensure the independence and objectivity of participants in providing information or data. Before the interview began, the researcher asked the participant for their readiness to be interviewed and consent to record the interview process. The interviews lasted approximately 30 minutes. To ensure the consistency of the interview for each participant, the researcher used an interview protocol. The research team collaboratively developed the interview protocol through several meetings, providing feedback on the questions to be asked and ensuring that each question was understood within a shared framework. Additionally, these meetings aimed to align the researchers' perceptions, ensuring that everyone understood the same goals regarding the information needed from participants before conducting the interviews.

The interview protocol contained the main aspects to be asked of the participants (see Table 1). Although the prepared protocol guided the interview, the researcher could ask additional questions to further explore the required information. Before the interview began, the researcher also explained, in general, the results of the statistical literacy survey conducted in 2023 at the participant's university. This was to provide an overview to participants (both lecturers and students) regarding the achievements in statistical literacy at their universities, so that they could respond to these achievements.

Data Analysis

Qualitative data analysis was conducted on the interview data. The researcher transcribed all interview recordings. The interview transcripts were then re-read to ensure consistency with the recordings. Furthermore, the researcher carefully read all transcripts to familiarise themselves with the data. Data analysis in this study was conducted using thematic analysis (Braun & Clarke, 2006). The finalised transcripts were then coded to capture the essential meanings of the data segments. Some codes were predefined based on the theoretical review (theory-driven), while others were generated within the data analysis framework (data-driven).

The coding process was carried out on all interview transcripts. First, we coded the transcript data from the lecturer participants, and then the coding focused on the transcript data from the student participants. The coding process was conducted systematically, focusing on one transcript at a time and then proceeding to the other transcripts. Although interviews were conducted separately, depending on the availability of both interviewers and participants, each interviewer was responsible for leading the session, documenting the process, preparing the transcripts, and generating initial codes and emerging themes. The research team subsequently engaged in collaborative discussions to compare interpretations, refine codes, and reach consensus on the thematic structure. This iterative and collective approach not only enabled the analysis to reach saturation but also ensured that the findings were firmly grounded in participants' perspectives, thereby strengthening the credibility and overall trustworthiness of the findings regarding factors influencing statistical literacy. All qualitative data analysis procedures, including data visualisation, were conducted using ATLAS.ti 24 software.

In this study, theme validation was conducted through several systematic procedures to enhance the trustworthiness of the findings. First, the internal coherence of the themes was examined by reviewing the consistency of meaning between codes and data quotations in each theme, so that each theme represented a conceptually homogeneous phenomenon. Second, the distinctions between themes were evaluated by comprehensively comparing them to ensure clear thematic boundaries and avoid overlapping meanings. Third, the suitability of themes with the raw data was ensured by retracing the transcripts and identifying negative cases to ensure that the themes were truly rooted in empirical data.

Trustworthiness

Given the nature of qualitative inquiry, and in order to ensure the rigour and reliability of both the study and its findings, this research placed particular emphasis on the four criteria of trustworthiness, namely credibility, transferability, dependability, and confirmability (Lincoln et al., 1985; Nowell et al., 2017; Stahl & King, 2020). First, as noted in the preceding section, four interviewers were involved in the data collection, each working independently with different participants. Credibility and dependability were strengthened through preparatory meetings that aligned their understanding of the interview protocol and standardised the procedures. In addition, to further support the credibility of the data, a conceptual framework was developed from a review of relevant literature and incorporated into the design of the interview protocol. Furthermore, credibility was reinforced during the data collection process through the use of clarification or confirmation questions, whereby interviewers invited participants to verify and elaborate on their intended meanings in real-time. This practice, which included prompts such as "Could you clarify what you mean?", "Do you mean it in this way?" or "Is it correct to conclude that you are saying this?" functioned as a form of member checking that enabled participants to validate the researchers' interpretations and reduce the risk of misinterpretation.

Credibility and confirmability were further enhanced by the inclusion of direct quotations, which illustrated how interpretations were derived from participants' accounts and provided transparency in linking the data to the reported themes. To support consistency and confirmability, the raw data and analytic outputs, including the codes, were securely stored by the researchers so that they could be reviewed by other researchers for potential verification in the future. In addition, transferability was promoted through the provision of a thick description of the study context, the participants involved, and the research setting, thereby enabling readers to judge the extent to which the findings may be applicable to their own or other contexts.

FINDINGS

The study's findings revealed four main themes that describe the factors influencing the statistical literacy of mathematics education students (see **Figure 1**). These themes include internal student factors, learning strategies/methods, supporting infrastructure factors, and other factors. Internal student factors are the most dominant factor affecting students' statistical literacy, and nine codes describe this factor. Learning strategies/methods, as well as supporting infrastructure factors, have three codes, while other factors have only two.

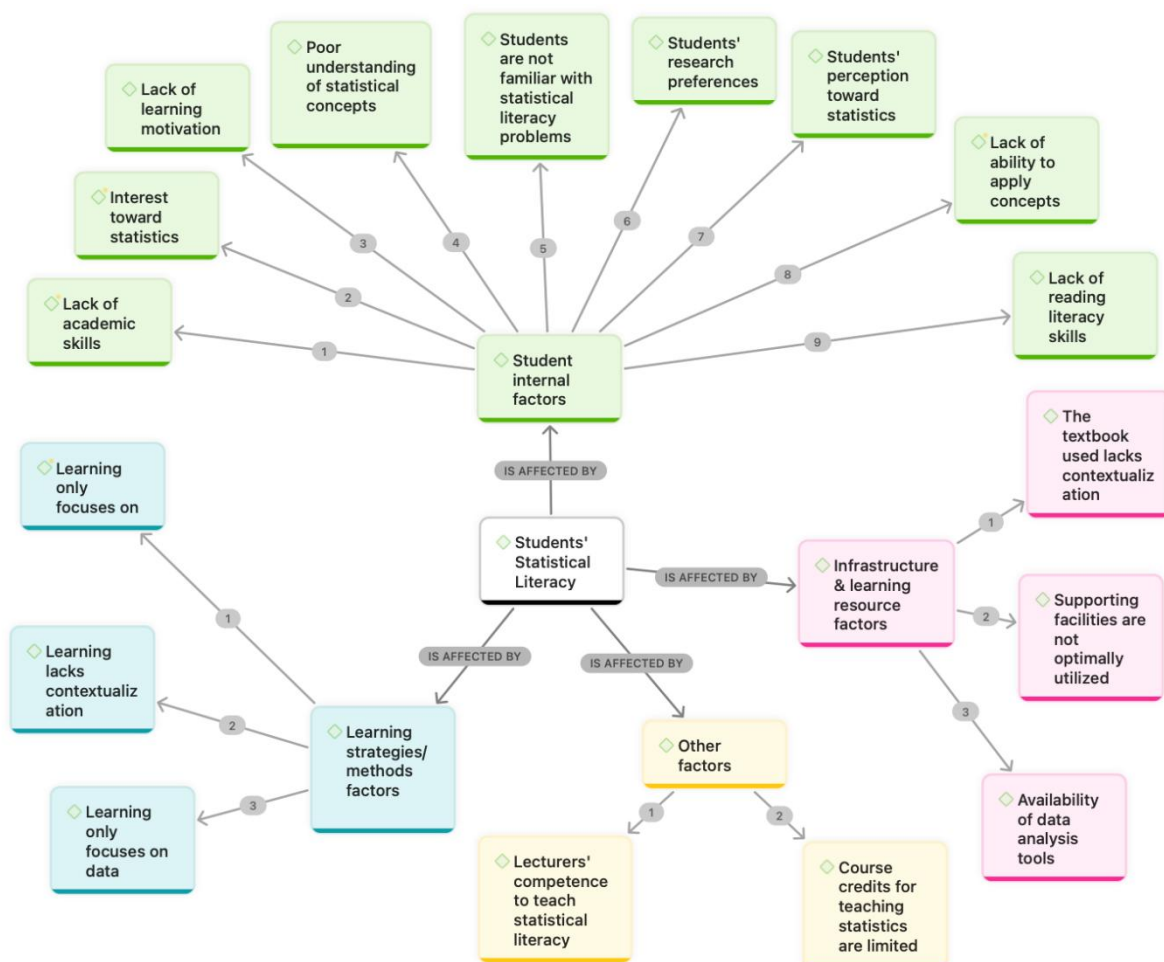


Figure 1. Codes and themes of factors affecting the statistical literacy of mathematics education students (Source: Authors' own elaboration, using ATLAS.ti 24)

This study identified a total of 16 codes that were found to influence students' statistical literacy. Some of the codes had high groundedness and were sourced from both lecturer and student participants, such as students' lack of familiarity with statistical literacy, poor understanding of statistical concepts, and students' research preferences, including learning that focuses only on data analysis, as well as a lack of reading literacy skills (see **Figure 2**). These codes are considered to have the most significant influence on the statistical literacy of mathematics education students. **Figure 2** also shows that from the lecturers' perspective, 15 factors were identified as influencing statistical literacy, while from the students' perspective, only six factors were identified as influencing statistical literacy. From the lecturer's perspective, factors such as learning that focuses only on theory, students' perceptions of statistics, and textbooks that lack contextualization are considered the most influential on students' statistical literacy. From the students' perspective, factors such as students' lack of familiarity with statistical literacy problems, lack of understanding of statistical concepts, and students' research preferences are considered the most influential factors on statistical literacy.

		Lecturer 9 60	Student 24 48	Totals
◆ Availability of data analysis tools	1	1		1
◆ Course credits for teaching statistics are limited	2	2		2
◆ Interest toward statistics	2	2		2
◆ Lack of ability to apply concepts	4	4		4
◆ Lack of academic skills	4	4		4
◆ Lack of learning motivation	3	3		3
◆ Lack of reading literacy skills	5	1	4	5
◆ Learning only focuses on data analysis	2		2	2
◆ Learning only focuses on theory	7	5	2	7
◆ Lecturers' competence to teach statistical literacy	4	4		4
◆ Poor understanding of statistical concepts	14	3	11	14
◆ Students are not familiar with statistical literacy problems	16	4	12	16
◆ Students' perception toward statistics	5	5		5
◆ Students' research preferences	7	2	5	7
◆ Supporting facilities are not optimally utilized	3	3		3
◆ The textbook used lacks contextualization	5	5		5
Totals		48	36	84

Figure 2. Groundedness factors affecting statistical literacy from the perspectives of lecturers and students (Source: Authors' own elaboration, using ATLAS.ti 24)

Theme 1: Internal Student Factors

The theme related to students' internal factors has nine codes, including students' weak academic ability, interest in statistics, low learning motivation, low understanding of statistical concepts, students' lack of familiarity with statistical literacy problems, research preferences, students' perceptions of statistics, lack of ability to apply concepts, and lack of reading literacy skills. In this study, the factor of students' lack of familiarity with statistical literacy problems was revealed most by study participants, followed by students' lack of understanding of statistical concepts and research preferences.

Students lack familiarity with statistical literacy problems

Both lecturers and students pointed out that one of the causes of the low achievement of statistical literacy is the unfamiliarity of students with statistical literacy problems. Students' lack of familiarity with solving statistical literacy problems causes them to struggle with understanding and identifying important information in the problem, making it difficult for them to relate it to relevant statistical concepts. Some student participants said they were surprised to see that the problems had long narrative texts. Some students admitted that they rarely encounter statistical literacy problems in statistics lectures. Because they rarely encounter these problems, they admit that they need a considerable amount of time to understand the information in the problem, as illustrated by the following interview excerpt.

"Maybe because the information presented (in statistical literacy questions) is quite complex and tends to be long ... So, to read the whole of one question and all the answer choices requires quite a lot of time, and of course, we also (need to) look carefully at what is meant by the question and which is the correct answer to the question. This is challenging for me, especially when we are racing against time" (Student AK).

"... the problem is time because there are many discourse texts and data presented in the questions, while understanding them takes much time ..." (Student GAB).

The results of interviews with lecturers also confirm students' unfamiliarity with statistical literacy problems. Some lecturers stated that their students were unfamiliar with statistical literacy problems. One of the lecturer participants said that one of the reasons is that, according to students, statistics are just calculations, as illustrated in the following interview quote.

"They (students) are surprised or unfamiliar because they think that statistics is just calculating, as they understood when they knew statistics in junior high or high school, they think statistics is just calculating the mean and then making graphs, diagrams, and others" (Lecturer YMS).

Another lecturer also said that students were unfamiliar with the problem of statistical literacy because, so far, learning had not directed students to strengthen their statistical literacy.

"... it turns out that our students are not familiar, because they (students) are not familiar with being directed there (statistical literacy). Even though literacy itself is actually statistical data in everyday life" (Lecturer ES).

Lack of understanding of statistical concepts

Finding solutions to statistical literacy problems requires a good understanding of statistical concepts. Some students admitted that they had forgotten the statistical concepts they had learned, making it challenging to answer statistical literacy questions.

“But the biggest obstacle is that we have forgotten the content (statistics) that was taught, so we had difficulty yesterday answering the questions (statistical literacy problems)” (Student RN).

Another indication of students' lack of understanding of simple statistical symbols is reflected in the following interview excerpt.

Interviewer: ... Are you familiar with the acronym *SD*? What does *SD* denote?

Student KK: Oh, I know *SD*, the standard deviation. However, I do not know the others.

Interviewer: Okay, what do you know about *M*? (referring to the mean symbol)

Student KK: I do not know.

Interviewer: You do not know what the *M* symbolises? Then what does this *p* indicate? Do you know it or not?

Student KK: I do not know the *p* either.

Lecturers also revealed that their students' difficulty in solving statistical literacy questions is their lack of understanding of basic statistical concepts. Students sometimes still struggle to explain basic concepts, such as what an alpha level is, what a type I error is, what a type II error is, and why it is important to understand these terms.

Students research preferences

Some students reported being more interested in qualitative research than quantitative research. This tendency towards qualitative research affects their interest towards statistics. Some student participants avoided quantitative research partly to avoid using statistics in data analysis, as stated by the following students:

“If I look at the quantitative (research), it seems like analysing the data is difficult...” (Student NI).

“Because in quantitative, it is a bit complicated to calculate the statistics, making me confused” (Student DR).

Study program policies also influence students' tendency to prefer qualitative research. Some study programs direct students to choose qualitative research or research and development (R&D) for their thesis or final project, as illustrated by the following interview excerpt. According to the lecturer, this condition also affects students' statistical literacy because they were not initially interested in statistics.

“In our study program, it is rare for students to take quantitative (research); on average, they take qualitative research. The research trend in our study program tends to be qualitative and development research; rarely do they (students) take pure quantitative (research)” (Lecturer YMS).

Student perception towards statistics

The lecturer revealed that students' perceptions of statistics also influence their statistical literacy. Most students think statistics are only helpful in quantitative research and have no role in everyday life. This is revealed in the following excerpt from the interview.

“What I capture when explaining (statistics) to them (students), they seem to think that statistics is not related to real-world life, ... like thinking statistics just contains ordinary formulas so ...” (Lecturer PS).

“... because the statistics paradigm is statistical probability, while mathematics is deductive deterministic. The thinking patterns are different, so they (students) study statistics, their motivation may only be to help them in research, how to analyse data after the research data is collected” (Lecturer FA).

Students also think that statistics is limited to calculations, tends to be complicated, and many formulas must be memorised.

“They (students) feel that statistics is only about calculation, not looking at data ...” (Lecturer YMS).

“The perception of students is that statistics is similar to mathematics, difficult, heavy, and dealing with formulas that must be memorised...” (Lecturer NI).

Lack of ability to apply concepts

Although students have a good understanding of the concept, when it is applied to solving contextual problems, they still encounter difficulties. According to some lecturers, this is one of the causes of students' low statistical literacy. Sometimes, students can memorise statistical formulas well, but when using or applying these formulas, students tend to be confused.

"... so what I see is that they (students) memorise the statistical formulas, the memorisation of the formulas is good, but where to apply it, they cannot... So, to apply what has been learned, including how to interpret or interpret the findings, is also still an obstacle ..." (Lecturer PS).

Students are also confused when the problems given during exams or assignments differ from the examples given during exercises. Even though the new problem given has the same substance as the example problems they have worked on before, they have not yet addressed it.

"I always make the problem different (from what has been taught during learning). It is just that they (students) will protest why the problem (in the assignment or exam) is different from when it was taught ..." (Lecturer ES).

Interest towards statistics

The lecturer also revealed that students' interest towards statistics greatly affects their statistical literacy. When they are highly interested in statistics, it will encourage them to be more active in studying statistics.

"The first factor that might cause this is that there are students whose statistical literacy achievement is quite good, depending on their interest. Suppose they are interested in statistics, no matter how difficult it is, they will study it seriously" (Lecturer FZ).

Interestingly, one of the lecturers revealed that, although they were students in the mathematics education study program, not all of them liked statistics.

"In my opinion, not all (students) are interested in statistics even though they are in the mathematics education study program; not all of them are necessarily happy with statistics" (Lecturer DA).

Lack of learning motivation

Lecturers revealed that they had tried to make learning statistics more enjoyable for students by preparing teaching modules. However, the prepared teaching modules are not necessarily read or studied by students.

"Sometimes, we have prepared modules that they just need to read, so that when learning in the classroom, we just need to discuss what is not understood from the modules that have been given. (The module) is also not read (by students). Therefore, we, as lecturers, are unsure. This is actually (students) already understood, (the module) is not read, or (students) are confused, do not understand at all or how ..." (Lecturer FZ).

The lack of motivation to learn is also associated with students' views or perceptions towards statistics. Thus, this lack of motivation to learn indirectly affects their understanding of statistics. This is a challenge for statistics teachers.

"... the cause is related to their views or perceptions towards teaching or learning (statistics), where indeed their interest (in learning) is low, their motivation (to learn) is lacking, including the awareness to learn on their own is lacking" (Lecturer FZ).

Lack of reading literacy skills

The statistical literacy problems given also require good reading literacy skills. One of the obstacles students face is difficulty understanding the information presented in the problem discourse. Students often find the discourse presented in statistical literacy problems too lengthy, which confuses them about capturing the important points in the problem.

"Maybe the obstacle is in the data part (the data presented in the problem), ... the sentence is also too long, ... even though I want to go straight to the point (directly presented what is known and what is asked), here the text is long, so I was a little confused for a long time, where is the purpose of this problem" (Student BN).

Students said that the presentation of statistical literacy problems was boring for them. Basically, they revealed that they preferred short problems.

"Yes, when I read (the questions), much data is presented, so it is difficult to understand. If possible, keep the questions short; if they are long, people will also get bored reading them ..." (Student KK).

Lack of academic ability

Lecturers also revealed that one factor strongly suspected of affecting students' statistical literacy is their academic ability. Lecturers from private universities complained that the quality of their students' input was indeed lower compared to that of

public universities. Regarding the low academic ability of these students, statistics lecturers should spend more time instilling basic concepts first, rather than focusing on strengthening statistical literacy.

“The student input itself here is still very low in ability (academic), so when teaching, the learning objectives should be for students to be able to apply concepts; it turns out that when learning in the classroom it turns out that students still have difficulty understanding concepts” (Lecturer PS).

“It cannot also be denied how the input conditions of our students come from private schools; there are students who have good abilities, but the average is middle to lower (academic ability). ... I think it also affects the students’ statistical ability” (Lecturer DA).

Theme 2: Learning Method or Strategy Factors

Themes related to learning methods or strategies have three codes that are thought to affect students’ statistical literacy. The three codes include learning that focuses too heavily on the theory (rather than the application) of statistics, learning that rarely presents real-world contexts, and learning that emphasises the data analysis process over its interpretation.

Learning is only (too) focused on theory

One of the reasons for not optimising students’ statistical literacy skills is that learning focuses too much on discussing the theory of the statistical concepts studied. In this case, it remains rare for students to be presented with case examples relevant to academic and professional contexts.

“... but the learning that has happened so far, we direct the learning of statistics to (mastery of) theory only ... (Lecturer ES).

“Lecturers or students refer to textbooks and may learn more theory than analysing problems related to statistical applications” (Lecturer FA).

Because learning is often too focused on discussing theory, it rarely facilitates students in doing direct practice to apply the knowledge or theory they have obtained.

“... we focus too much on theory, and maybe the practice is rarely done. ... even if it is done (practice), it only mentions cases or research in the context of education. ... while literacy is related to problems in general, everyday life, so they (students) may not be used to it” (Lecturer FA).

Lack of contextualised learning

Lecturers also admit that the statistics learning they have been applying is still lacking in presenting contexts relevant to the studied statistics content. This can also be caused by statistics lecturers not being used to providing these contexts, as illustrated by the following interview excerpt.

“... I am rarely, yes, but rather not used to teaching students with contexts because of our lack of knowledge about contexts that can be used for statistical literacy lectures” (Lecturer YMS).

Although sometimes lecturers try to present case examples related to the field of education, they are considered inadequate in improving students’ statistical literacy.

“They (students) study statistics that focus on educational research, so maybe they (students) are basically rarely given problems (other contextual ones) that they can analyse using statistical concepts” (Lecturer FA).

Learning is only (overly) focused on data analysis

Students also revealed that one of the things that caused them difficulty in solving statistical literacy questions was that they were not trained to interpret the results of data analysis in depth. The learning they have followed so far is too focused on the data analysis process rather than on how to interpret the results of the data analysis.

“In our opinion, it seems that learning is still not focused on how to interpret the results of data analysis. ... learning statistics on our campus is more about the analysis part. Reading (understanding) data and interpreting (interpreting the analysis results) is rather difficult. The lecturer has taught (related to data analysis) several times; some students have been able to analyse data, but are still confused about how to interpret the results of the analysis of the data” (Student ZR).

Theme 3: Supporting Infrastructure and Learning Resources Factors

This study reveals that three codes represent infrastructure and supporting learning resources as one factor influencing students’ statistical literacy. The three codes are textbooks that lack contextualisation, supporting facilities (computer labs and data analysis tools) that have not been optimally utilised, and the availability of data analysis tools.

Textbook content lacks contextualisation

Textbooks used in learning statistics are considered to have an impact on students' statistical literacy. The books used so far are too theoretical and sometimes do not present examples of applying statistical concepts relevant to the academic and professional world. This is considered less facilitating for students to understand how to apply statistical concepts in various contexts. The following interview excerpt illustrates this.

"...but indeed, what I explained earlier, which is a limitation, is the supporting book. The supporting textbook (used) presents more statistical formulas, so at the beginning, there is very little content related to how statistics can be used in real life ..." (Lecturer IK).

"It is just that sometimes the lecturer only presents problems that are available in the textbook, sometimes in the textbook, it is not a contextual problem in everyday life, so yes, maybe that is the cause (low literacy) ... students cannot find a connection between statistics and real life" (Lecturer PS).

Available supporting facilities have not been optimally utilised

Interestingly, in some universities, supporting facilities such as computer laboratories and data analysis tools are adequate, but the problem is that statistics lecturers have not optimally utilised these facilities. The following interview excerpt illustrates this.

"The obstacle is that sometimes the lecturers also do not facilitate there (practice in the computer lab); even though the computers in the lab are equipped with SPSS and Minitab, the lecturers who use it (computer lab) are still limited, so they tend to do data analysis manually, going to the lab only once in a while" (Lecturer PS).

"... our computer lab has supported (the development of statistical literacy) actually (through the use of) technology and all kinds. The only obstacle is the lecturers themselves; the lecturers have not been able to design learning that is integrated with the use of computer labs and supporting software" (Lecturer ES).

Although supporting facilities have been utilised, they are sometimes only used to analyse specific cases. They are rarely used to analyse data from cases or problems that are general or related to everyday life.

"... our computer lab is equipped with software like SPSS, R or Amos for advanced data analysis and statistics. It is just that they (lecturers) only use it to analyse certain examples of cases, which may be limited in nature, so it may also concern them (students) when they are faced with, for example, general problems or problems related to everyday life" (Lecturer FA).

Availability of data analysis tools

One lecturer highlighted that the availability of data analysis tools can affect students' statistical literacy. As illustrated by the following interview excerpt. The availability of adequate data analysis tools can reduce the burden on students in manual computations and visualising data or analysis results, so that learning can be more focused on applying statistical concepts in various situations and contexts.

"Yes ..., facilities and infrastructure (can also affect students' statistical literacy achievement), at least related to the availability of data analysis tools ..." (Lecturer FZ).

Theme 4: Other Factors

In addition to the previous three themes, this study uncovered other factors that were thought to influence students' statistical literacy. These other factors consist of two codes: the limited number of course credits allocated to teach statistics and the lecturers' competence in teaching statistical literacy in statistics learning.

The number of course credits to teach statistics is limited

Lecturers acknowledged that a significant amount of statistical content must be taught to students. However, in some universities, courses related to statistics are limited in number and credit weight. When the number and credit weight of courses to teach statistics require statistics lectures to focus solely on understanding theory. It is not possible for a lecture to train statistical literacy skills amid this limited time allocation. The following interview quote illustrates this.

"We know that there is a lot of statistical material, and I have to pack it into two lecture credits, so what is delivered is only the outer skin (basic content); if the content is more in-depth, I have to give it through assignments to students ..." (Lecturer YMS).

"The problem seems to be that our curriculum structure places a limited number of courses related to statistics (compared to other courses). Only four out of dozens of courses are offered, which I think is insufficient to help students develop their statistical literacy skills" (lecturer FA).

Lecturers' competence in teaching statistical literacy

How lecturers design lecture activities is also thought to affect students' statistical literacy. The inability of lecturers to present contextual problems in learning and to process statistical learning makes what is learned less meaningful to students. The following interview quote illustrates this.

"In our study program, in fact, statistics courses are given to lecturers whose background is more in educational science, not statistics. This has an impact on the way they teach statistics to students" (Lecturer FZ).

"Maybe like this, if the students are lacking (statistical literacy), maybe the lecturers also lack statistical literacy; this is very likely to happen because the lecturers are not used to teaching statistics by involving relevant contexts" (Lecturer YMS).

"I observe that the ways of teaching lecturers, including myself, do not yet lead to statistical literacy, so they (lecturers) tend only to provide material, but how to process data, read, and understand what it means (data, analysis, and analysis results) is rarely taught. That is the weakness" (Lecturer ES).

DISCUSSION

This study aimed to identify the factors that influence mathematics statistical literacy skills in the Indonesian context. The study identified four main factors that are thought to influence the statistical literacy skills of mathematics education students. The first main factor is related to factors originating from internal students, such as students' lack of familiarity with statistical literacy problems, lack of understanding of statistical concepts, research preferences, students' perceptions of statistics, interest in statistics, lack of ability to apply concepts, lack of learning motivation, lack of reading literacy skills, and lack of academic ability. The unfamiliarity of students with statistical literacy problems and their limited ability to apply concepts to various contexts indicate that teaching and learning statistics in the classroom have not focused on problem-solving and decision-making related to statistics. This condition contradicts the GAISE 2016 recommendation (Carver et al., 2016) that statistics learning should focus on problem-solving and decision-making.

This study also revealed that students' research preferences are thought to influence their statistical literacy. This finding is unsurprising, as previous studies have also revealed it (Gonulal, 2018; Gonulal et al., 2017; Loewen et al., 2014). However, a study conducted by Retnawati et al. (2024) revealed that research preferences did not affect the statistical literacy of mathematics education students. This situation indicates that the effect of research preference on statistical literacy is still debatable, so it is interesting to explore it in more depth in future studies. Although there is an assumption that mathematics education students tend to prefer quantitative research to qualitative research, this fact does not guarantee that their statistical literacy is better, as revealed in the findings of Apino et al. (2024).

Other internal factors, such as students' perception of statistics, interest in statistics, and a lack of interest in learning, pose challenges for statistics teachers. Statistics educators need to make efforts to make statistics enjoyable for students. Using real, complex data and real-world contexts provides opportunities for rich and authentic statistical learning. Still, it requires careful consideration and expertise in statistics to effectively integrate the contexts into the learning process (MacGillivray, 2023). Additionally, incorporating real-life data into statistics learning can enhance students' engagement and understanding (Neumann et al., 2013). We suspect that the current teaching and learning of statistics still lack the presentation of contextual data relevant to the studied statistical content. This certainly significantly affects students' perceptions and interest towards statistics itself. Hence, their efforts to explore more deeply related to using statistics in various contexts are not as expected.

Students' negative initial perception of statistics is also evident in some students. Some believed that the material is complicated, especially when formulas are involved. Some others are also reluctant to engage with the questions that include numerous numbers and statistical terms. Therefore, students' perceptions of statistics develop over time and are influenced by their prior experiences with the subject before enrolling in mathematics education programs. It is essential to consider these experiences, as they are closely tied to the national curriculum and how students acquire statistical content from elementary to secondary school. Often, students encounter complex statistical concepts that are presented in a non-hierarchical manner. Consequently, if they fail to master one stage of statistical knowledge, they may struggle to understand more advanced concepts later on. This situation conflicts with cognitive learning theory, which asserts that the complexity of tasks assigned to students should align with their cognitive abilities, ensuring that the material is neither too challenging nor irrelevant to their existing knowledge (National Academies of Sciences, Engineering, and Medicine, 2018).

Not only did their experience in learning statistics at school, but some undergraduate students may also come from a non-mathematics background. Malik (2015) found that undergraduates from non-mathematics backgrounds experience high statistics anxiety and feel challenged in solving statistical problems, resulting in poor performance. Based on the results, we also need to consider students' backgrounds and evaluate their prior knowledge and skills related to statistics, especially in the Introductory Statistics course, so that they can be prepared to learn more complex and advanced statistics courses. The lecturer can conduct a diagnostic test and follow up on the result by providing differentiated instruction.

Reading literacy and lack of academic ability add a new dimension to the context of teaching and learning statistics integrated with statistical literacy. A link exists between reading literacy skills and academic performance. GAISE's recommendation that statistics teaching and learning focus on students' understanding of key concepts, illustrated with a few techniques, rather than covering many techniques with minimal focus on the underlying ideas (Carver et al., 2016), can be used to address students' lack

of academic ability. The lack of reading literacy skills is closely related to students' learning habits. Familiarising students with contextual problems is key to practising their reading literacy skills, including in statistics learning. In relation to constructivist theory, relying on such well-structured problems does not effectively promote statistical reasoning and problem-solving skills (Wild & Pfannkuch, 1999). Although students may favour clearly defined problems, lecturers should not solely focus on these kinds of problems. Instead, lecturers need to gradually introduce ill-structured problems to enhance students' problem-solving skills in statistics.

The second main factor is factors related to the strategies or methods used in learning statistics. In this context, several factors affect students' statistical literacy, including learning that is overly focused on mastering theory, learning that fails to present real-world contexts, and learning that emphasises data analysis over its interpretation. These learning practices are considered less relevant to the needs of statistical education in the modern era. The undergraduate statistics curriculum needs to focus on equipping students with problem-solving skills to meet new challenges in diverse fields (Borror et al., 2012). Students should not leave statistics courses with the false impression that statistics consists only of unrelated formulas and methods (Carver et al., 2016). Instead, students should understand that statistics is a problem-solving and decision-making process that is fundamental to scientific inquiry and essential for making informed decisions (Carver et al., 2016).

The third main factor relates to the availability and utilisation of infrastructure and other supporting learning resources. In the digital age, infrastructure is one of the key external factors that support success in learning, alongside social support and culture (Adiarti et al., 2026; Anwar et al., 2024). The availability of computer laboratories and computer devices, along with supporting statistical software, is crucial to improving the understanding of statistical concepts. Unfortunately, although these facilities are available in some universities, statistics lecturers can sometimes not utilise them optimally. In fact, in the era of modern statistics education, technology needs to be used to explore concepts and analyse data. Statistical software such as R is particularly relevant for studying statistics, as it enables more efficient data processing, provides engaging data visualisation (Parra et al., 2023), and supports effective learning (Wessa & Ao, 2009) by helping students develop computational thinking and engage in inquiry-based learning experiences. The statistics textbooks used are also very influential on students' statistical literacy. When textbooks are rich in context, rather than just statistical formulas, they will significantly help students understand how statistics can be applied to various real-world contexts.

Other factors that affect students' statistical literacy skills include the adequacy of the number of credits allocated to statistics or similar courses and the competence of lecturers in teaching statistical literacy. It cannot be denied that the statistical content that students at the undergraduate level must learn is quite extensive. To learn these statistical contents in depth, students must be offered several courses, such as introductory statistics, applied statistics, and other relevant courses. GAISE (Carver et al., 2016) recommends removing basic content, such as probability theory, to integrate statistical literacy into the statistics education curriculum. Therefore, learning can be more focused on applying statistical concepts to various real-world contexts and critically analysing statistical data and information that can be encountered in the academic and professional world. For statistical literacy to be optimally integrated into statistics teaching, statistics lecturers must also have the competencies to deliver it (Apino et al., 2024; Retnawati et al., 2024).

As previously mentioned, the statistics lecturers need to master the concept of pedagogical content knowledge (PCK). It entails a deep understanding of statistical content with effective pedagogical strategies to teach the content to students (van Driel & Berry, 2017). Lecturers are encouraged to convey statistical concepts in a meaningful way to students. This includes fostering data awareness by posing open-ended questions integrating statistics in everyday life, addressing misconceptions in statistical pedagogy that students may believe about statistics before learning process/course, selecting appropriate methods for data production and representation that can help students make meaning of, accurately interpreting data processing results based on the real-world context and situations, and effectively communicating statistical information in both verbal and written forms (Rumsey, 2002). Students should engage in real-life experiences where they take on the role of someone explaining data visualisations or statistical conclusions to others in different contexts and situations. That way, students not only understand the statistical concepts but also grasp the meaningful context behind them.

The emergence of these factors can be understood within the context of higher education in Indonesia, particularly in the context of mathematics education. Statistics courses are often positioned as methodological courses that are considered to support only research activities and the completion of undergraduate theses. Consequently, students may view statistics merely as a technical tool for data analysis, rather than as a means to interpret, evaluate, and communicate statistical data and information encountered in daily life. Furthermore, teaching practices often emphasize computational procedures and routine problem-solving exercises, which can limit students' opportunities to engage in data interpretation, critical evaluation of statistical information, and statistical reasoning. Differences in curriculum design and implementation across universities in Indonesia increasingly contribute to variations in students' learning experiences and their exposure to teaching focused on statistical literacy. Furthermore, a lack of engagement with scientific literature—particularly publications written in English—can limit students' access to empirical evidence, contemporary data-driven issues, and the application of statistics in various contexts. Collectively, these cultural, institutional, and curricular characteristics help explain why factors such as research preferences, contextual learning experiences, reading literacy, and academic abilities emerge as significant influences on statistical literacy within the context of mathematics education in Indonesia.

Implications for Practice and Policy

This study reveals that lecture strategies or methods support students' statistical literacy. This aligns with previous studies (i.e., Garfield, 1993, 1995; Marriott et al., 2009; Tishkovskaya & Lancaster, 2012). Previous studies have recommended problem-based learning in statistics courses to support the achievement of statistical literacy (e.g., Garfield, 1993, 1995; Marriott et al., 2009;

Tishkovskaya & Lancaster, 2012). Collaborative learning, such as group presentations and jigsaws, has also been recommended in previous studies. Therefore, using student-centred learning strategies is recommended in teaching and learning statistics, integrated with strengthening students' statistical literacy. Lecture strategies and methods that are attractive to students are also expected to be a solution to control factors that affect statistical literacy originating from internal students.

This study also revealed that presenting a real-world context is essential for effective teaching and learning of statistics. This finding is consistent with the findings of previous studies (i.e., Chance, 1997; Gal, 2002, 2003; Garfield, 1993, 1995; Marriott et al., 2009; Wallman, 1993). Previous studies have highlighted the use of context encapsulated in real-life examples presented by statistics educators (e.g., Chance, 1997; Gordon et al., 2007). The findings of this study reinforce what previous researchers have found: the use of context, particularly in real-life situations, is crucial for learning statistics. This aligns with constructivist learning, emphasising the importance of active student engagement with real-world data and problems. Dewey (1938) argued that learning should be rooted in authentic experiences that connect knowledge to learners' lives and societal roles as citizens. In relation to statistical education, students must not only learn formulas and methods but also understand statistical knowledge and information in context-rich environments.

This study also revealed that the use of technology is a key aspect of teaching and learning statistics. This finding aligns with previous studies that have emphasised the importance of technology in statistics learning (i.e., Apino et al., 2024; Chance, 1997; Garfield, 1993, 1995; Retnawati et al., 2024; Roseth et al., 2008). The use of technology is expected not only in the teaching and learning process but also in its assessment (Kristanto, 2018; Rostika et al., 2025; Suárez-Álvarez et al., 2021). Some previous researchers have suggested that technology can be applied to assessment (e.g., Apino et al., 2024; Chance, 1997; Retnawati et al., 2024), including the potential use of generative artificial intelligence (AI) tools in educational assessment (e.g., Corbin et al., 2025; Omojekunola & Kardanova, 2024; Trajkovski & Hayes, 2025). Hence, both the learning process of statistics and its assessment need to consider using technology to facilitate students' development of their statistical literacy.

Given the diversity of higher education contexts, particularly in mathematics education, the implementation of these recommendations needs to be adjusted to institutional resources, curriculum structures, and student characteristics. For institutions with limited technological resources, contextual learning can be facilitated through locally relevant datasets and case studies drawn from students' everyday experiences. In contexts where statistics is taught as a methodological course, instructors may need to place greater emphasis on data interpretation, critical evaluation of statistical information, and the application of statistics in the real world. Furthermore, the integration of technology must align with students' prior knowledge and institutional capacity to ensure meaningful support for the development of statistical literacy.

Limitations and Future Directions

The study only involved participants from Indonesia, so socio-cultural bias needs to be considered when utilising the findings of this study. Not all the findings of this study are applicable to specific cultural contexts and socioeconomic backgrounds. To explore the factors that influence statistical literacy achievement in a broader context, future research is expected to involve participants from various countries representing various socio-economic backgrounds. Therefore, the mapping results related to the factors that allegedly influence the statistical literacy achievement of mathematics education students become more relevant to the global education context.

This study employed only interview techniques to collect data, so the research findings may not accurately reflect the actual conditions in the field. It is also possible that the information conveyed by the participants during the interview does not align with the facts in the field, especially regarding the learning process during statistics teaching. Therefore, future research should consider additional techniques, such as learning observation, observation of the learning environment, and content analysis of textbooks used in teaching statistics, to enhance data collection and analysis. Using various data collection techniques will ensure the credibility of the data so that the research conclusions truly describe the actual phenomena in the field.

CONCLUSION

As an essential skill in the modern data-driven era, various factors can influence statistical literacy. In the Indonesian context, several key factors are believed to influence students' statistical literacy skills in mathematics education significantly. These factors relate to the internal conditions of students, the teaching and learning strategies or methods applied by statistics lecturers, the support of infrastructure and relevant learning resources, the adequacy of the number of courses related to statistics and the competence of lecturers to integrate statistical literacy in teaching statistics. These findings are helpful for relevant institutions and statistics educators to evaluate curricula and design strategic policies to promote statistical literacy in statistics education, especially in mathematics education. Although the findings of this study are preliminary and cannot be generalised in a broader context, this study at least contributes to providing an initial picture of the problems in teaching and learning statistics that integrate statistical literacy as its primary goal. Future research is expected to re-examine this topic using more sophisticated approaches that involve participants from diverse cultural and socio-economic backgrounds.

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