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Exploring Influential Factors and Conditions Shaping Statistical Literacy Among Undergraduate Students in Mathematics Education

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Abstract: Statistical literacy (hereafter SL) has been considered an important learning outcome in statistics learning in higher education, yet studies that focus on investigating the factors and conditions that influence students' SL, especially mathematics education students, are still limited. This study seeks to uncover the factors and conditions that significantly contribute to the SL of mathematics education students. This survey study involved 1,287 mathematics education students from 21 higher education institutions in Indonesia. Linear regression analysis involving four predictor variables (i.e., gender, status of higher education institution, laptop ownership, and research preference) was performed to determine the variables that contributed significantly in predicting SL achievement. The results revealed that gender, higher education institution's status, and laptop ownership contributed significantly, but research preference was not significant in predicting mathematics education students' SL. Furthermore, laptop ownership was found to have the highest contribution in predicting mathematics education students' SL. All findings and their implications are discussed.

Keywords: *gender, laptop ownership, mathematics education, research preference, statistical literacy, status of higher education institution.*

Introduction

Given that the world is developing so rapidly and complexly, students need to be facilitated to master fundamental skills to deal with daily life and various complex challenges and build character (intrapersonal and interpersonal) needed in dealing with dynamic environments. These fundamental skills are associated with the term 'literacy' whose meaning has expanded beyond simply referring to the skills of reading and writing effectively in a variety of contexts (Pilgrim and Martinez, 2013; Watson and Callingham, 2003). In addition to the expansion of meaning, literacy has also developed in terms of types based on the combination of literacy and a particular specialised discipline or field (Gal, 2002) to keep up with the challenges of an increasingly complex world. Among the types of literacy developed in the last two decades, such as mathematical literacy, ICT literacy, and cultural and civic literacy, we are more interested in exploring SL further. Although SL is considered as one of the new literacies needed along with the development of ICT which has led to the availability of large data and the rapid and wide distribution of data in the last decade, the term SL has in fact been introduced since 1979 by Haack. SL was introduced by Haack (1979a, 1979b) as a form of his concern for statistics which was positioned more as a research tool than as a language. As a result, statistics learning is only focused on facilitating students to remember formulas and the use of these formulas without understanding the meaning, so that students do not experience progress after participating in statistics learning, where they still cannot better understand the statistics they encounter in the media. Thus, this SL implicitly leads to positioning statistics as a language and is interpretive rather than calculative so that students who have adequate

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statistical literacy competence can apply the statistical principles they learn to the statistics they encounter in everyday life (Haack, 1979b).

SL then continues to evolve and receive increasing attention from researchers so that various meanings of SL have been offered – no consensus has been reached on the meaning of SL. Of the various narrow and broad meanings of SL, SL is seen as a key competency that refers to the ability to interpret, critically evaluate, and communicate statistical data, statistical information, or arguments contained in various forms of media in the context of everyday life (Gal, 2002; Kurnia et al., 2023; Schield, 2010; Sharma, 2017; Wallman, 1993). The prerequisite for a person to have behaviours that reflect statistical literacy is that the person masters the knowledge or understanding and fundamental competencies that include the symbols, concepts, terms, and language of statistics and mathematics (Gal, 2003; Rumsey, 2002) and is able to apply them (Gal, 2002). Given the significance of SL, it makes sense that existing studies (e.g., Carvalho and Solomon, 2012; Chick & Pierce, 2012, 2013; Gal, 2002; Kurnia et al., 2023; Sharma, 2017) have widely recognised that being statistically literate is not only essential for students, but also for everyone as individuals or as part of society, both in professional and social life. The importance of being statistically literate is again inseparable from the demands of the development of information technology that allows us to obtain, process and disseminate data and information for various purposes, such as making decisions and policies (Chick and Pierce, 2012, 2013; Gal, 2002; Sharma, 2017).

Given the importance of students and adults being statistically literate, a number of efforts to promote statistical literacy have been made by previous studies ranging from secondary school to higher education (Aksoy and Bostan, 2021; Forgasz et al., 2022; Yotongyos et al., 2015). Such efforts can certainly be based on aspects or components of SL, the results of studies that focus on investigating the achievements of SL so as to detect which aspects need more attention, and the results of studies that focus on investigating the factors that directly or indirectly influence SL. A number of studies focusing on the latter have successfully identified factors that potentially influence (Aizikovitsh-Udi and Kuntze, 2014; Aziz and Rosli, 2021; Carmichael et al., 2009; MacFeely et al., 2017) and that affect (Lukman and Wahyudin, 2020; Pamungkas and Khaerunnisa, 2020; Sproesser et al., 2014) SL. Based on literature reviews, systematic reviews, and interview studies that researchers have conducted, they suggest critical thinking (Aizikovitsh-Udi and Kuntze, 2014), student demographics, learning environment, student attitudes, basic knowledge and skills in statistics (Aziz and Rosli, 2021), interest or attitude towards statistics (Carmichael et al., 2009), and learning support including the application of specific learning models and the use of technology (Aziz and Rosli, 2021; MacFeely et al., 2017) as factors considered vital in influencing SL.

From the empirical studies we have identified, some of the factors that influence students' SL are socio-economic status, general cognitive abilities, and knowledge of specific content in mathematics especially those related to probability and functional reasoning (Sproesser et al., 2014). From their findings, Sproesser et al. (2014) recommended future studies to investigate the extent to which students' socio-economic status can explain the diversity of their SL. In another empirical study conducted by Lukman and Wahyudin (2020) which focused on investigating the factors influencing the SL of undergraduate students in terms of aspects or components of SL, fundamental knowledge in mathematics and statistics and adequate language skills acted as these factors. Prior knowledge and mathematical self-esteem have also been reported to be two factors that influence students' SL (Pamungkas and Khaerunnisa, 2020). Another study indicated that grade level affects the SL of high school students (Kurnia et al., 2023); although there were also studies (e.g., Yolcu, 2014) that reported the insufficient influence of grade level on students' SL.

When it comes to SL, we struggled to find sufficient studies that reveal the factors that influence and cause the differences in SL achievement. This is in contrast to when it comes to literacy achievement in mathematics – one of the focuses in the OECD's Programme for International Student Assessment (PISA) – and achievement in statistics. Extensive empirical studies have identified various factors that influence students' mathematical literacy achievement. The PISA 2018 results have suggested that immigrant background, gender, and the socio-economic status of students' families and schools have been factors that influence students' achievement in mathematical literacy across countries (OECD, 2019). Meanwhile, Wang et al. (2023) through a systematic literature review of 156 empirical studies have successfully identified 135 factors that contribute to influencing student achievement in mathematical literacy in PISA, where these factors are then categorised into five levels: individual student as level 1, household context as level 2, school community as level 3, education system as level 4, and macro society as level 5. One of

the results revealed from the systematic study of Wang et al. (2023) at level 1 is that although the influence of gender on students' mathematical literacy achievement has been extensively investigated, the results in this regard are still mixed in a number of countries. Mixed results were also found on the factor of students' experience in using ICT. At level 2, the study conducted by Wang et al. (2023) indicates that the factor of ICT availability at home has received relatively little attention by previous studies compared to other factors at level 2. Previous studies show mixed results regarding the effect of ICT availability at home on students' mathematical literacy – some show a positive effect, while others show a negative or insignificant effect. Furthermore, among the three factors most investigated by previous studies at level 3, the effect of school type (i.e., private or public) on students' mathematical literacy is the most diverse than socio-economic status (SES) composition and school location (Wang et al., 2023).

It has been mentioned earlier the importance of mastering two things, namely fundamental knowledge in statistics and statistical reasoning, in order to be statistically literate. Both of these can be reflected by students' achievements in statistics, where one of the factors that affect students' achievements in statistics is their perception or attitude towards statistics (Emmioğlu and Capa-Aydin, 2012; Ncube and Moroke, 2015; Ramirez et al., 2012). In addition, perceptions or attitudes towards statistics can also influence undergraduate students in determining the preference of the research method or approach they will choose, whether it is more quantitative or qualitative (Dani and Al Quraan, 2023). When students have negative perceptions or attitudes towards statistics due to various factors including the view that statistics overemphasises numerical and technical activities in their experience in dealing with mathematics and statistics during high school, they tend to avoid quantitative research (Dani and Al Quraan, 2023) and prefer qualitative research. Their aversion to quantitative research may also reflect their reluctance to engage in learning related to statistics, so it could possibly hinder their opportunity to develop their SL. However, how much students' preference for research methods or approaches contributes to their SL is still under-investigated. Therefore, in this study, we endeavour to shed light on the extent to which research method or approach preferences contribute to students' SL, including how the potential of gender, higher education institution's status, and laptop ownership to explain students' SL. In detail, this study focused on answering the following two research questions (RQs).

RQ1: How is the SL profile of undergraduate students in mathematics education programme in terms of gender, higher education institution's status, laptop ownership, and research preference?

RQ2: What factors and conditions significantly predict the SL of undergraduate students in mathematics education programme?

Statistical Literacy and Statistical Literacy of Undergraduate Students

It cannot be denied that SL is considered important to have in the midst of the massive distribution of data and information containing statistics which brings its own opportunities and challenges. Various meanings of SL have been offered by the literature, where the diversity concerns what competencies build SL and what content needs to be the focus in SL. By Wallman (1993), SL is interpreted as a competency built by cognitive abilities in the form of understanding and critically evaluating statistical results in people's daily lives and the ability to appreciate the role of statistical thinking to solve problems and make decisions in various contexts of daily life. It is implied that to be statistically literate which is demonstrated through the ability to critically evaluate, one must first have an adequate understanding of the underlying concepts or ideas associated with these statistical results. The basic idea of grouping the skills that build SL into cognitive and affective elements is also offered by Gal (2002), where according to him, SL is a competence composed of skills that support each other which can be grouped into knowledge and dispositional elements. The skills in the knowledge element include general literacy skills – the ability to read and interpret data, information, or readings in various forms and contexts and communicate what has been read and interpreted clearly, basic knowledge of statistics and mathematics, basic knowledge related to various contexts in everyday life, and critical thinking skills (Gal, 2002). Meanwhile, the dispositional elements of SL include attitudes and beliefs to engage in statistical thinking for various purposes and having the willingness to think critically about information that contains statistics despite having no formal learning experience in statistics or mathematics (Gal, 2002).

The idea that Wallman puts forward that places an important role on understanding basic statistical concepts as the foundation of SL is in line with some of what Watson (1997), Sharma (2017), and Gonda et

al. (2022) stated in presenting the meaning of SL. According to them, SL in addition to being built by higher order cognitive skills (i.e., interpreting, making predictions, thinking critically) is also built by basic skills or lower order cognitive skills consisting of understanding basic concepts, symbols, and terminology in numeracy, mathematics, probability, and statistics and general literacy skills (i.e., reading, understanding what is read, and communicating what is understood from reading). The meaning of SL in more detail is conveyed by Watson (2006), where the meaning of SL does not only emphasise on the components of the skills that build SL but also on the components of the topic, context, motivation, and task form that encourage someone to demonstrate their SL. Based on the components of SL that Watson (2006) provides and the interaction between these components, SL refers to the mathematical or statistical skills and literacies that a person demonstrates when faced with a task whose context relates to variation, data collection including sampling, presentation of data in various representations, averaging, chance, and inference. The task requires the person to choose the best among a number of options or provide a range of alternative possible solutions. The meaning of SL that Watson (2006) put forward aligns with that of Gonda et al. (2022) mentioned that some of the skills that make up SL, especially the basic skills, are working with data which includes organising data, presenting data into various representations, and using these various data representations for specific purposes.

Based on the meanings of SL that we have found in the literature, we agree with those mentioned by Kurnia et al. (2023) that SL includes the skills involved when one provides data or information for others to use or receives data from others to use for a specific purpose. The skills involved in producing data include the skills to ask questions (e.g., what to investigate, what problems to answer, and what is needed), collect data, analyse data, and interpret the results of the data analysis. Meanwhile, the skills involved when one uses or receives data may include describing the data, organising the data so that one can determine what is important, analysing the data, interpreting or evaluating the data, and critiquing the data received. These skills are ultimately inseparable from the skill of communicating what has been gained from working with data. Furthermore, all the skills we have mentioned are again based on an understanding of context, representation, and basic knowledge of statistics and mathematics (Gal, 2002; Gonda et al., 2022; Watson, 1997, 2006). An understanding of the basic knowledge of statistics required to be statistically literate includes the rationale and techniques or methods of data collection, descriptive statistics, data presentation and interpretation, basic notions of probability, and statistical inference. Thus, based on the meaning of SL that we described based on the literature, we conclude that SL is the skill of applying an understanding of basic ideas about statistics (and probability) supported by an understanding of basic ideas in mathematics, interpreting statistical data and information, communicating statistical data and information in various forms effectively, and critically evaluating the results of data analysis or inference in various contexts and basic topics in statistics (and probability).

Previous studies have attempted to investigate the extent of students' SL at the secondary school level (Aksoy and Bostan, 2021; Kurnia et al., 2023; Utomo, 2021) to higher education (Forgasz et al., 2022; Hassan et al., 2020; Lukman & Wahyudin, 2020; Setiawan and Sukoco, 2021; Yotongyos et al., 2015). When it comes to undergraduate students, we found limited studies exploring the extent of their SL attainment. One of the studies that focused on undergraduate students was a study conducted by Setiawan and Sukoco (2021) with the aim of uncovering the SL of 39 first-year undergraduate students in a statistics study programme at a public higher education institution in terms of their skills in describing and visualising data. This study reported that the SL level of students in general could already be categorised as high in terms of skills in describing data, while in terms of skills in visualising data, the SL level of students was still in the medium category.

In another study (i.e., Hassan et al., 2020) involving 360 undergraduate students in their eighth semester from programmes in applied science and social science disciplines, it was revealed that their SL in terms of statistical symbols, central tendency, descriptive and inferential statistics, and elements of data analysis in SPSS programme were overall at a low level. Although the study descriptively showed that students from applied science programmes had better SL than those from social science programmes, there was no statistically sufficient evidence that the achievements of students from the two disciplines were different or that one was superior to the other. In addition, involving 114 undergraduate students from mathematics and mathematics education programmes and using the SL framework proposed by Gal (2002), Lukman and Wahyudin (2020) found that students' SL was already at a satisfactory level and found that the SL achievement of students who had taken elementary statistics was significantly better

than those who had not. By also using the SL concept that Gal (2002) proposed which divides SL into knowledge and dispositional components, Yotonyos et al. (2015) reported that the overall SL of 103 undergraduate students in the faculty of education at a public higher education institution was moderate.

Potential Factors and Condition Contributing to Statistical Literacy

Many previous studies have attempted to investigate the factors that might influence student learning outcomes in primary to higher education and that might lead to differences in outcomes between one group and another. In science and mathematics, including statistics, gender – the biological difference of being male or female (El Refae et al., 2021) – has been recognised as one such factor (Meinck and Brese, 2019; Wang et al., 2023). Student learning outcomes in terms of gender show mixed results (Yolcu, 2014), both in small-scale and large-scale assessments. Some studies demonstrate that male students significantly outperform female students, but others show the opposite (Meinck and Brese, 2019; OECD, 2019; Wang et al., 2023). However, there are also studies that do not show sufficient evidence that the achievement of one group is superior to the other in terms of gender (Arroyo-Barrigüete et al., 2023). Studies focusing on literacy in mathematics – part of SL – of students aged around 15 years report that male students perform better than female students (OECD, 2019), although this is not uniform across countries in the world as reported in the study by Wang et al. (2023). Nevertheless, some studies that directly focus on SL leading to students' skills in understanding, interpreting and communicating data show that female students outperform male students (Risqi and Ekawati, 2020; Yolcu, 2014). Another study conducted by Kurnia et al. (2023) showed that there was no significant difference in students' SL achievement in terms of gender. Based on the results of these studies, it can be said that the influence of gender on students' SL achievement and differences in students' SL achievement in terms of gender still need to be explored further considering that there is still an opportunity to obtain different results depending on various contexts, including research subjects.

It is believed that the status of a school or higher education institution, public or private, also has an influence on student achievement. The main distinction between public and private higher education institutions is in terms of funding sources. This distinction is considered to contribute to differences in the provision of learning opportunities and facilities to students, which in turn may lead to differences in student achievement. Previous studies, however, have reported inconsistent results on the consequences of differences in the status of higher education institutions on student outcomes as reported by Wang et al. (2023) who focused on literacy in mathematics. A number of studies reported a significant difference in students' literacy achievement in terms of school status, where students from private schools outperforming those from public schools (Cheema, 2015, 2016). However, it is still unclear how the SL achievement of students from public higher education institutions differs from those from private.

The use of technology in learning has been widely shown by previous studies (e.g., Kristanto, 2018; Liestari and Muhandis, 2021; Rusilowati et al., 2022) to support students' learning process, which in turn can promote learning achievement. The availability of access to technology such as laptops or computers allows students to be able to gain the potential offered by the technology when it is used optimally, which can develop problem-solving skills, communication, and conduct research through searching for important information relevant to the research being carried out (Kposowa and Valdez, 2013). When students have widespread access to technological devices such as laptops, they are likely to have a better chance than those without laptops of using their time flexibly to optimise their learning, such as doing homework, conducting research, and reading study materials (Reisdorf et al., 2020). The presence of technological advances that occur today has the consequence that the use of technology in learning is inevitable, especially in higher education, where the use of laptops is considered an integral part of the learning culture in the classroom. On the one hand, this phenomenon is certainly an opportunity that should be utilised, but on the other hand, by Reisdorf et al. (2020) it is considered to bring its own challenges for those who do not have a laptop. It is clear that the ownership of technological devices such as laptops will have an influence on students' learning and their learning achievement, especially when the role of laptops has become an integral part of learning.

In mathematics and statistics learning, ownership of a laptop can also lead to differences to a varied degree in learning opportunities that students receive and in students' learning achievement. A number of studies (e.g., Kposowa and Valdez, 2013; Papadakis et al., 2016) have suggested that when

technological devices such as laptops are used appropriately, including with teacher guidance, to conduct mathematical or statistical exploration activities through applications available on laptops and access any relevant information that students learn using the internet, it will provide greater opportunities for students to be able to more easily understand concepts that are abstract in nature than when they do not use laptops. Other studies (e.g., [Wittwer and Senkbeil, 2008](#)) have also implicitly demonstrated the effect of home computer use on students' mathematics achievement. In contrast to most studies that show a large effect of home computer use on students' academic performance at school such as mathematics achievement, [Wittwer and Senkbeil's study \(2008\)](#) shows the frequency of computer use and how it is used by students has little impact on their mathematics achievement. Such mixed results are influenced by a variety of factors such as the context of the country in which the study was conducted and the educational level of the students involved in the study ([Wang et al., 2023](#)). [Wittwer and Senkbeil's study \(2008\)](#) suggests that the computers students own can have a greater impact on their mathematics achievement depending on the students' skills in using the computers and the problem-solving and higher-order thinking activities that teachers facilitate in the classroom using the computers or laptops. To date it remains unknown whether laptop ownership can lead to differences in undergraduate students' SL achievement and to what extent laptop ownership supports undergraduate students' SL.

Lastly, one's research preferences (i.e., qualitative and quantitative) clearly influence one's development as a researcher, such as motivation to conduct specific research method and attitude towards research ([Gonulal, 2018](#); [Nenty, 2009](#)). Researchers who embrace a more quantitative research orientation may wish to develop themselves in areas related to statistical methods, and engage in more quantitatively orientated research ([Gonulal, 2018](#)). Quantitatively-orientated students are likely to take more statistics courses and do more self-training in statistics ([Gonulal, 2018](#)). On the other hand, those who have tended to avoid their orientation towards quantitative research, or tended to be orientated towards qualitative research methods, it is possible that they have difficulties in learning quantitative or empirical research methods ([Nenty, 2009](#)). In this regard, because learning quantitative or empirical research methods can be associated with learning statistics, there are indications that those who are more orientated towards qualitative research or have a negative view of quantitative research tend to struggle more in learning statistics. This implicitly leads to the hypothesis that there will be differences in students' SL achievement, where those who favour quantitative research are likely to perform better in statistics than those who favour qualitative research.

Materials and Methods

Design of the Study

This survey study ([Check and Schutt, 2012](#)) focused on uncovering the factors and conditions that are thought to influence mathematics education students' SL attainment. A total of four predictor variables have been selected to test their contribution in predicting the SL of mathematics education students. The four predictor variables are gender, higher education institution's status, laptop ownership, and research preference. In order to capture information related to students' SL achievement and the predictor variables that influence it, we administered a survey to mathematics education students who were taking or had taken Elementary Statistics course or its equivalent course. Although the survey could be accessed online, the administration of the survey was still carried out in the classroom or computer laboratory directly supervised by the survey supervisor. This is to ensure that the responses obtained are accurate and truly represent the actual condition of the participants.

Participants

A total of 1,287 undergraduate students in their first to tenth semesters from mathematics education programmes participated in completing the SL survey in this study. They were taking or had taken Elementary Statistics, Introduction to Statistics, Educational Statistics, or equivalent course. Participants were spread across 21 higher education institutions (university, college, or institute) selected through convenience sampling technique ([Edgar and Manz, 2017](#)). This technique was chosen because it is relatively cheap, less time-consuming, and simple ([Stratton, 2021](#)). In addition, this sampling technique

was also used with the consideration that the results of this study could contribute to developing potential hypotheses or references for further studies that are more rigorous (Stratton, 2021).

Table 1. Description of participants ($n = 1,287$)

Variable	<i>n</i> (%)
Gender:	
Male	227 (17.6)
Female	1060 (82.4)
Higher education institution's status:	
Public	1053 (81.8)
Private	234 (18.2)
Laptop ownership:	
Yes	1011 (78.6)
No	276 (21.4)
Research preference:	
Quantitative	867 (67.4)
Qualitative	420 (32.6)

The institutions were divided into two status categories, namely public ($n = 15$) and private ($n = 6$). In addition, the institutions were also divided into three area categories based on time zones in Indonesia, namely western area ($n = 11$), central area ($n = 7$), and eastern area ($n = 3$). The higher education institutions involved in this study were mostly in the western area because most higher education institutions in Indonesia are located in the western area. The participants in this study were mostly female students and came from public higher education institutions. Table 1 presents description in detail of the participants involved in this study.

Instrument and Data Collection

We developed an online survey to capture information related to SL of mathematics education students and the factors and conditions that influence it. The online survey consisted of two parts. The first part captured information related to students' higher education institution where the student studies, gender, laptop ownership, and research preference. The second part was a test used to measure the SL of mathematics education students. In this study, the test to measure SL was developed based on the aspects and their respective descriptions that were derived based on the results of the literature review (e.g., Gal, 2002; Gonda et al., 2022; Sharma, 2017; Watson, 2006) (see Table 2). Besides considering the aspects and indicators in Table 2, the SL test also focused on the core content of elementary statistics. We used four basic statistical contents in the SL test, namely sampling techniques and probability, data presentation (i.e., tables, diagrams, and graphs), descriptive statistics (i.e., measures of central tendency and dispersion), and inferential statistics (i.e., *t*-test, correlation, regression, and analysis of variance). Thus, a total of 20 multiple-choice items with four options were used to measure the SL achievement of mathematics education students. Before being used for data collection, the SL test was first sent to three reviewers for collecting feedback. They were experts in statistics education, statistics, and educational measurement. They were asked to provide suggestions and assessments of the correctness of the substance and quality of the SL test items. All feedback from reviewers was accommodated to improve the quality of SL test. The test reliability estimate obtained Cronbach's $\alpha = .612$. Although the reliability coefficient is not very high, the test is reliable enough (Reynolds et al., 2010; Rudner and Schafer, 2002; Taber, 2018) or it can be regarded as having moderate reliability (Taber, 2018) to measure the SL of mathematics education students.

Table 2. Indicators of SL and their descriptions

Aspect	Description	Item
Application of statistics concepts (Application)	Able to apply basic concepts of statistics in various contexts	1, 6, 11,
	Understand the use of various simple statistical symbols	16
Interpretation of statistical data and information (Interpretation)	Able to read and interpret tables, graphs and charts accurately	2, 3, 7, 8,
	Identify trends, patterns, and outliers in data	12, 13,
	Draw accurate conclusions from data and hypothesis testing results	17, 18
Communication skills (Communication)	Able to effectively communicate important statistical findings to an audience	4, 9, 14,
	Able to present information using visual aids to enhance understanding	19
Critical evaluation (Evaluation)	Able to assess the credibility and reliability of statistical claims	5, 10, 15,
	Able to make effective decisions based on data	20
	Recognise data limitations and potential biases	

We used Zoho Survey (<https://www.zoho.com/id/survey/>) to distribute the online survey to mathematics education students. Data collection through the online survey was conducted during October 2023. We recruited mathematics education lecturers at the higher education institutions selected for the sample to administer and supervise the survey at their institutions. To ensure that data collection was conducted in an honest manner, we invited all recruited lecturers to attend a technical briefing on the rules for conducting the survey. The recruited lecturers were given the responsibility to conduct data collection in their respective institutions honestly. Students completed the survey by accessing the survey link and password shared by our recruited lecturers. Students could access the survey via their laptops or smartphones. In order for the survey to run smoothly, we required that the survey be completed in the classroom and guided and supervised directly by the lecturers we have recruited. Completing the survey could also be done in the computer labs owned by each higher education institutions that we have selected as a sample. Students were expected to take about 5 minutes to complete their personal data on the survey. Meanwhile, the time provided to answer the SL test is a maximum of 45 minutes. To anticipate students answering the SL test carelessly, we set a minimum time to complete the SL test. Students could not submit their answers if they have not passed 25 minutes. In taking the SL test, students were not allowed to collaborate with other students and use a web browser other than to access the survey and take the SL test. In addition, students were not provided with a piece of paper to do calculations because in the SL test students did not need to do any calculations.

Data Analysis

After the data collection process, we conducted data verification to remove duplicate responses and incomplete responses. Data on gender, the higher education institution where the student studies, laptop ownership, and research preference were binary coded. For gender, code 1 for male and code 0 for female. For the higher education institution where the student studies, code 1 was given if the student was from a public higher education institution and code 0 for a student from a private higher education institution. For laptop ownership, code 1 was given for students who own a laptop and code 0 for students who do not own a laptop. Meanwhile, for the research preference, code 1 was assigned for students who chose quantitative and code 0 was assigned for students who chose qualitative. These binary codes were used to describe the SL achievement of mathematics education students in terms of each code.

We assigned a score of 1 for the correct answer on each SL test item. Thus, respondents will obtain a maximum score of 20 if they can answer all SL test items correctly. A score of 0 is given for each item answered incorrectly and there is no penalty (point deduction) for each incorrect answer. The total score of each respondent was then used to describe the SL profile of mathematics education students in general and based on the four aspects of SL (i.e., application, interpretation, communication, and critical evaluation). The SL scores were then cross-tabulated with the variables of gender (male vs. female), status of higher education institution (public vs. private), laptop ownership (yes vs. no), and research preference (quantitative vs. qualitative). This cross tabulation was conducted to compare students' SL score achievement in terms of the category of each variable. An independent sample *t*-test procedure was conducted to test the significance of differences in mean SL scores in terms of gender, higher education institution's status, laptop ownership, and research preference. The *t*-test was conducted by first providing

evidence that the statistical literacy score data was normally distributed (skewness = 0.012, $SE_{skewness} = 0.068$, kurtosis = -0.258 , $SE_{kurtosis} = 0.136$) and evidence that there was no significant difference in the variance of statistical literacy scores between the two groups by gender ($F = 0.959$, $p = .328$), higher education institution's status ($F = 0.683$, $p = .409$), laptop ownership ($F = 0.219$, $p = .64$), and research preference ($F = 0.699$, $p = .403$). Lastly, we used linear regression analysis to investigate the variables that contributed significantly in predicting the SL level of mathematics education students. We conducted this linear regression analysis on the basis that the assumption of collinearity has been confirmed in regard to gender (VIF = 1.01, Tolerance = 0.995), status of institution (VIF = 1.03, Tolerance = 0.974), laptop ownership (VIF = 1.03, Tolerance = 0.971), and research preference (VIF = 1.00, Tolerance = 0.996) and autocorrelation was not a concern (autocorrelation = 0.123, Durbin-Watson = 1.75). All statistical tests used a significance level of 5%.

Results

A total of 1,287 mathematics education students participated in this study. First, we report the SL profile of mathematics education students in general and by gender, higher education institution's status, laptop ownership, and research preference. Afterwards, we report the results of regression analysis to reveal the variables that significantly contribute to predicting the SL of mathematics education students.

SL Profile of Mathematics Education Students

Table 3 presents descriptive statistics of SL of mathematics education students in general and based on SL aspects. In general, the mean score of SL of mathematics education students is not satisfactory. Based on four aspects of SL, the mean score of the interpretation is the highest, while the mean score of the critical evaluation is the lowest. Furthermore, when it comes to the variance of students' SL scores based on the aspects of SL, students' scores on the interpretation aspect were the most varied compared to the other three aspects.

Table 3. Descriptive statistics of SL of mathematics education students ($n = 1,287$)

Aspect of SL	M (SD)	Min.	Max.
Application	1.70 (0.96)	0	4
Interpretation	3.96 (1.48)	0	8
Communication	1.63 (0.87)	0	4
Evaluation	1.47 (1.02)	0	4
Score of SL	8.76 (2.70)	0	17

SL Profile of Mathematics Education Students Based on Gender

The SL profile of mathematics education students in terms of gender (male vs. female) is summarised in Table 4. The results presented in Table 4 demonstrate that both male and female students performed the best in the interpretation aspect compared to the other three aspects. In addition, male students outperformed female students in every aspect of SL and the overall SL. Furthermore, through inferential analysis, the current study revealed that the mean score of SL of male and female students differed significantly ($t(1285) = -3.913$, $p < .01$), where SL scores of male students were higher than female students. On the application aspect, the mean score of male and female students was not significantly different ($t(1285) = -0.512$, $p = .608$). In the interpretation aspect, the mean score of male students is significantly higher than female students ($t(1285) = -2.361$, $p = .018$). On the communication aspect, there was no difference in mean score of SL between male and female students ($t(1285) = -1.746$, $p = .081$). On the critical evaluation aspect, this study found that the mean score of male students was higher than female students ($t(1285) = -4.944$, $p < .01$).

Table 4. Descriptive statistics of SL of mathematics education students based on gender

Aspect of SL	Male (n = 227)			Female (n = 1060)		
	M (SD)	Min.	Max.	M (SD)	Min.	Max.
Application	1.73 (0.93)	0	4	1.70 (0.97)	0	4
Interpretation	4.17 (1.54)	0	8	3.92 (1.46)	0	8
Communication	1.72 (0.86)	0	4	1.61 (0.87)	0	4
Evaluation	1.78 (1.06)	0	4	1.41 (1.00)	0	4
Score of SL	9.40 (2.84)	0	17	8.63 (2.65)	0	16

Statistical Literacy Profile Based on Status of Higher Education Institution

The SL profile of mathematics education students based on the higher education institution's status (public vs. private) is summarised in Table 5 indicating that students from both public and private higher education institutions performed best in interpretation and performed poorest in evaluation. Students from public higher education institutions in general out-performed those from private higher education institutions. The performance of students from private higher education institutions was slightly better than those from public higher education institutions, although in the other three aspects of SL those from public institutions were superior.

Table 5. Descriptive statistics of SL of mathematics education students based on higher education institution's status

Aspect of SL	Public (n = 1053)			Private (n = 234)		
	M (SD)	Min.	Max.	M (SD)	Min.	Max.
Application	1.70 (0.97)	0	4	1.69 (0.94)	0	4
Interpretation	4.02 (1.46)	0	8	3.67 (1.52)	0	7
Communication	1.62 (0.86)	0	4	1.64 (0.88)	0	4
Evaluation	1.52 (1.03)	0	4	1.28 (0.94)	0	4
Score of SL	8.87 (2.71)	2	17	8.27 (2.59)	0	15

This study revealed that the mean SL scores of students from public and private higher education institutions were significantly different ($t(1285) = 3.091, p < .01$), where the SL scores of students from public higher education institutions were higher than private higher education institutions. In the application aspect, the mean score of students from public and private higher education institutions is not significantly different ($t(1285) = 0.239, p = .811$). In the interpretation aspect, the mean score of students from public higher education institutions is significantly higher than private higher education institutions ($t(1285) = 3.391, p < .01$). On the communication aspect, there was no difference in mean score between students from public and private higher education institutions ($t(1285) = -0.190, p = .850$). In the critical evaluation aspect, this study found that the mean score of students from public higher education institutions was significantly higher than private institutions ($t(1285) = 3.190, p < .01$).

Statistical Literacy Profile Based on Laptop Ownership

The SL profile of mathematics education students based on laptop ownership (yes vs. no) is summarised in Table 6. Table 6 indicates that ownership of a laptop offers more opportunities to perform better in SL, including in every aspect of SL, than those who do not own a laptop.

Table 6. Descriptive statistics of SL of mathematics education students based on laptop ownership

Aspect of SL	Has a laptop (n = 1011)			Has no laptop (n = 276)		
	M (SD)	Min.	Max.	M (SD)	Min.	Max.
Application	1.74 (0.95)	0	4	1.56 (0.10)	0	4
Interpretation	4.10 (1.46)	0	8	3.46 (1.45)	0	7
Communication	1.64 (0.85)	0	4	1.58 (0.91)	0	4
Evaluation	1.56 (1.02)	0	4	1.14 (0.95)	0	3
Score of SL	9.04 (2.64)	2	17	7.75 (2.65)	0	14

This study also found that the mean score of SL of students who own a laptop is significantly different from students who do not own a laptop ($t(1285) = 7.219, p < .01$). In terms of application, the mean score of students who have laptops is significantly higher than students who do not have laptops ($t(1285) = 2.812, p < .01$). In terms of interpretation, the mean score of students who have laptops is also significantly higher than students who do not have laptops ($t(1285) = 6.413, p < .01$). However, in terms of communication, the mean score of students who own and do not own a laptop was found not significantly different ($t(1285) = 1.024, p = .306$). While in terms of communication aspect, the mean score of students who own a laptop is significantly higher than students who do not own a laptop ($t(1285) = 6.125, p < .01$).

Statistical Literacy Profile Based on Research Preference

The SL profile of mathematics education students based on research preference (quantitative vs. qualitative) is summarised in Table 7. Table 7 reports that those who favour quantitative research tend to have better SL performance, both overall and by aspects of SL, than those who favour qualitative research.

Table 7. Descriptive statistics of SL mathematics education students based on research preference

Aspect of SL	Quantitative (n = 1011)			Qualitative (n = 276)		
	M (SD)	Min.	Max.	M (SD)	Min.	Max.
Application	1.71 (0.95)	0	4	1.68 (0.98)	0	4
Interpretation	4.02 (1.48)	0	8	3.85 (1.47)	0	7
Communication	1.63 (0.84)	0	4	1.61 (0.91)	0	4
Evaluation	1.48 (1.02)	0	4	1.45 (1.02)	0	3
Score of SL	8.85 (2.68)	2	17	8.60 (2.73)	0	14

In this study, the mean score of SL of students who favour quantitative research was found to be not significantly different from that of students who favour qualitative research ($t(1285) = 1.547, p = .122$). The study also revealed that there was no significant difference in mean score between students who preferred quantitative and qualitative research in terms of application ($t(1285) = 0.476, p = .634$), interpretation ($t(1285) = 1.933, p = .054$), communication ($t(1285) = 0.436, p = .663$), and critical evaluation ($t(1285) = 0.470, p = .639$).

Factors and Conditions Affecting Statistical Literacy

In this study, we used four predictors to determine the factors and conditions that influence the SL of mathematics education students. We binary coded each predictor to perform linear regression analysis. The first stage of regression analysis involved all predictors. Simultaneously, all four predictors significantly contributed to the SL achievement of mathematics education students ($F(4, 1282) = 20.042, p < .001$), but these four predictors only had a coefficient of determination $R^2 = 0.059$. This indicates that the four predictors used can only explain about 5.9% of the variation in the statistical literacy scores of mathematics education students. Table 8 presents the coefficients of the regression equation and the contribution of each predictor. Gender, higher education institution's status, and laptop ownership each contributed significantly in predicting the SL achievement of mathematics education students, but research preference was found not to contribute significantly.

Table 8. Regression coefficient involving all predictors

Predictors (Reference)	Unstandardized Coefficients		Standardized Coefficients	t	p
	B	SE	β		
(Constant)	7.104	0.237		29.926	.000
Gender (Male)	0.878	0.192	0.124	4.573	.000
Institution's status (Public)	0.440	0.192	0.063	2.292	.022
Laptop ownership (Yes)	1.276	0.181	0.194	7.067	.000
Research preference (Quantitative)	0.213	0.156	0.037	1.365	.173

We then eliminated the insignificant predictor (i.e., research preference) from the regression model and re-analysed, and obtained the results as presented in Table 9. The three predictors simultaneously still contributed significantly in predicting the SL achievement of mathematics education students ($F(3, 1283) = 20.084, p < .001$). However, the coefficient of determination of these three predictors is $R^2 = 0.057$, meaning that they only explain about 5.7% of the variation in the SL scores of mathematics education students, while the rest (i.e., more than 90%) may be explained by other predictors. In addition, the three predictors, namely gender, higher education institution's status, and laptop ownership, each still made a significant contribution in predicting the SL achievement of mathematics education students. Although the contribution of these three predictors simultaneously only explains about 5.7% of SL achievement, laptop ownership has the highest contribution in predicting the SL achievement.

Table 9. Regression coefficient after removing insignificant predictors

Predictors	Unstandardized Coefficients		Standardized Coefficients	t	p
	B	SE	β		
(Constant)	7.247	0.213		33.997	.000
Gender (Male)	0.877	0.192	0.124	4.563	.000
Institution's status (Public)	0.428	0.192	0.061	2.233	.026
Laptop ownership (Yes)	1.289	0.180	0.196	7.148	.000

Discussions

This survey study sought to uncover how gender, higher education institution status, laptop ownership, and research preferences affect the SL attainment of mathematics education students. Firstly, our study found that there is a significant difference in the SL attainment of mathematics education students in terms of gender. This finding is consistent with the findings of previous studies (Cheema, 2015, 2016), but different from the findings of other studies (Kurnia et al., 2023; McLauchlan and Schonlau, 2016). This gender predictor was found to contribute significantly in predicting the SL achievement of mathematics education students. Based on our findings, males were predicted to have higher SL than females. This indicates that the current statistics learning curriculum tends to favour male students. This has an impact on the SL gap between men and women. Cheema (2015, 2016) explains that the existence of a literacy gap in terms of gender indicates that the education process has not been able to serve male and female students fairly. Referring to this argument, we believe that this also occurs in the learning process of statistics in mathematics education study programmes. Thus, this finding also encourages higher education institutions, especially mathematics education study programmes, to adjust the statistics learning curriculum in order to fairly develop the SL potential of both male and female students.

In terms of higher education institution's status, this study revealed that the SL achievement of students from public and private higher education institutions differed significantly. This finding is consistent with the findings of previous studies (Cheema, 2015, 2016). This indicates that there is a gap in students' SL in terms of higher education institution's status. Thus, this reveals the fact that there is still a gap in the statistics lecture process between public and private universities. In addition, the predictor higher education institution's status was found to have a significant contribution in predicting the SL achievement of mathematics education students. Our study reveals that students from public higher education institutions are predicted to have better SL than students from private higher education institutions. This finding encourages private higher education institutions to pay more attention to the quality of statistics learning in their institutions. Cheema (2016) asserts that learning in private educational institutions is more varied than public, where those with high economic status can obtain higher quality learning. Thus, it can be understood that students in private higher education institutions have not been thoroughly provided with equal services in learning statistics. This is strongly suspected to contribute to the differences in SL of mathematics education students. In addition, Cheema (2015) revealed that there may be three things that cause differences in student literacy between public and private institutions, namely

the ability to recruit qualified educators, differences in curriculum, and the availability of facilities, and infrastructure to support learning. We believe that these three factors are plausible causes of differences in SL of students from public and private higher education institutions.

In this study, we use the variable of laptop ownership to describe the economic status of students. Students who own a laptop represent middle to upper economic status, whereas students who do not own a laptop represent middle to lower economic status. Our findings revealed that the SL attainment of mathematics education students was also found to be significantly different between students who owned and did not own laptops. Unsurprisingly, this finding is consistent with several previous studies (Cheema, 2015, 2016) which revealed that there is a literacy gap in terms of students' economic status. The predictor of laptop ownership was also found to contribute significantly in predicting the SL achievement of mathematics education students. We found that students who own a laptop are predicted to have higher SL achievement than students who do not own a laptop. As stated by Cheema (2016), learners with socioeconomic status advantage can access higher quality education services. We believe that the different opportunities to gain access to better education between students with high and low economic status contribute to the development of SL of mathematics education students.

Unlike the other predictors, research preference (quantitative vs. qualitative) was found not to contribute significantly in predicting the statistical literacy achievement of mathematics education students. This finding is different from previous findings (Gonulal, 2018; Loewen et al., 2014). Although Gonulal (2018) stated that one's research orientation (i.e., qualitative or quantitative) will influence one's development as a researcher, or vice versa, this study did not find any differences in students' SL in terms of their chosen research orientation. Gonulal (2018) explained that researchers who adopt a quantitative research orientation tend to take more statistics courses, but our study did not find evidence that this had an impact on the SL achievement of mathematics education students. It should be noted that the studies of Loewen et al. (2014) and Gonulal (2018) were conducted in the context of Second Language Acquisition (SLA) so the sample characteristics in these two studies are clearly different from our study. Mathematics education students, although preferring qualitative research, are still required to take statistics courses, both at the basic and advanced levels, as offered by the study programme curriculum. Whereas students of non-statistics and non-mathematics study programmes, there is no such obligation. This is what we believe to be the cause of the absence of differences in SL achievement of mathematics education students in terms of their research choices.

Overall, this study managed to reveal three predictors that significantly influenced the statistical literacy achievement of mathematics education students, namely gender, higher education institution's status, and laptop ownership. However, these three predictors only explained about 5.7% of SL achievement. The contribution of these three predictors in predicting the SL achievement of mathematics education students is relatively small. This means that these three predictors are not the main predictors in predicting SL of mathematics education students. Although the contribution of these three predictors is small, these three predictors are still useful for predicting the SL achievement of mathematics education students. Compared to the other two predictors, laptop ownership has the largest contribution in predicting SL achievement. Without ignoring the contribution of the other two predictors, it seems that the issue of socio-economic status gap needs to get more serious attention to overcome the gap in SL achievement of mathematics education students. We present some recommendations in this regard in the implications section.

Implications for Practices and Policies

The gap in SL achievement in terms of gender, higher education institution's status, and laptop ownership indicates that the statistics learning curriculum in the mathematics education study programme has not been able to serve the SL development needs of all students. Reorganising the statistics learning curriculum is needed to overcome, at least reduce the gap. The existence of a statistics learning curriculum that is fair, equal, and able to facilitate students from all economic groups is believed to be able to provide new hope for the SL development of mathematics education students. The facility gap as one of the triggers of the SL gap is the responsibility of the authorities to provide equitable distribution of learning support facilities (for example, computer laboratories, statistics applications or software, and other statistics learning resources) for public and private institutions. For statistics educators, they are

expected to be able to design statistics learning and assessment that is fair for males and females and able to facilitate the learning needs of students from economically disadvantaged groups. Although the use of technology is inseparable in learning statistics (Austerschmidt et al., 2022; Koparan, 2019; Lloyd and Robertson, 2012; Sosa et al., 2011), it needs to be considered so that the use of technology does not become a problem for students from low economic backgrounds.

Limitations and Future Directions

The main limitation of this study lies in the non-random sampling technique. Although the number of respondents involved in this study is quite large and we have strived to consider the distribution of higher education institutions based on the coverage of regions in Indonesia, the generalisation of the research findings cannot fully reach all members of the population. Thus, in the future we encourage other researchers to conduct studies on this topic by applying random techniques in selecting research samples. In addition, we believe that the characteristics of mathematics education students between countries may differ. Therefore, we encourage studies in this area to also involve samples from various countries. The existence of new studies in this area involving a wider population is expected to be used as a consideration in making policies related to improving the SL achievement of mathematics education students. In addition, considering that the three predictor variables in this study can only explain a small part of the SL of mathematics education students, future studies are advised to explore other factors that have the potential to further explain students' SL. Given the study conducted by Kurnia et al. (2023) and the recent study by Wang et al. (2023) which showed that grade level has an impact on high school students' attainment, while the study by Yolcu (2014) suggested no significant impact of grade level on students' SL, what year a student is in university or college could be considered by future studies as one of these other factors.

Conclusions

This study offers results that contribute to efforts to promote SL in prospective mathematics teachers through the disclosure of factors that potentially affect SL achievement which include gender, higher education institution's status, and laptop ownership. Differences in gender, higher education institution's status, and laptop ownership cause a gap in SL achievement. Although the contribution of these three factors in predicting SL is small, these three factors are important to consider in designing curriculum and policies to improve the SL of mathematics education students. This study encourages the need to reorganise the statistics education curriculum so that it can facilitate all student characteristics in developing their SL. Based on the findings of this study, we also encourage other researchers to investigate other factors that are thought to contribute significantly in predicting the SL achievement of mathematics education students.

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Conflict of interests

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Author Contributions

Conceptualization, H.R. and K.H.; methodology, H.R. and E.A.; software, E.A., I.R. and M.N.R.; validation, H.R. and K.H.; formal analysis, E.A. and I.R.; investigation, E.A., I.R. and M.N.R.; resources,

H.R. and K.H.; data curation, E.A., I.R. and M.N.R.; writing—original draft preparation, E.A. and I.R.; writing—review and editing, H.R. and K.H.; visualization, I.R.; supervision, H.R.; project administration, M.N.R.; funding acquisition, H.R. and K.H. All authors have read and agreed to the published version of the manuscript.

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