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The Challenge Of Learning Statistical Literacy In Higher Education: A Systematic Literature Review

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Abstract

This study aims to look deeper into the definition of statistical literacy (SL) and learning challenges to improve SL, as SL has become essential for students to face the era of data disruption and quantitative information. Previous research has investigated the level of elementary to high school students. Not many still discuss the definition of SL in students in higher education and what challenges teachers need to prepare for in improving SL. The research questions of this study are as follows: 1) What is the distribution of SL definitions often used in higher education? 2) What challenges will be faced in improving SL? This study was a systematic review of 10 articles with inclusion criteria. The article search was assisted by Publish Or Perish (PoP) software by entering the keyword "SL" in the "title words" in the Scopus search and specifying the year “2018-2023”. The results of this study found that 1) The ability to comprehend, interpret, evaluate critically, communicate, describe, organize, generalize, hypothesize, and visualize statistical data and information is frequently emphasized as constituting SL.; 2) The challenge in improving SL is that educators can develop learning models with a contextual approach and the development of evaluation tools with a contextual approach. In future research, the author suggests that research can be conducted to develop learning models that can improve SL at the college level based on a contextual approach.

Keywords: statistical literacy, higher education, contextual approach, systematic literature review

INTRODUCTION

The development of technologies that facilitate the swift distribution of information based on data has been a significant factor in the mandate for statistical literacy among students. Students must not just consume information in this age of continuously expanding information (Ben-Zvi & Garfield, 2004; Damouras et al., 2021; Ferligoj, 2015; Gal, 1995; Guler et al., 2016; Holmes & Rinaman, 2014; Koparan &

Güven, 2015), but they must also be able to critically identify, analyze, and assess data (Bilgin, 2021; Çatman Aksoy & Işıksal Bostan, 2021; Hidayati et al., 2020; Hourigan & Leavy, 2020; Malaspina & Malaspina, 2020; Murod et al., 2019; Souza et al., 2020; Utomo, 2021). Statistical Literacy equips them with the ability to understand statistics often used in various contexts, from news to scientific research to business decisions. (Spartanburg Comunity College Library, 2023). Thus, statistical literacy is an additional skill and an essential foundation for preparing students to face an increasingly data-driven world.

Statistical Literacy (SL) is one of the tools (abilities) for us (adult humans) to filter and draw conclusions from the disruption of information and data currently circulating in the media, news, polling, and others. However, the definition of SL has yet to reach a consensus among statistical educators, statisticians, and researchers (McMaster, 2022; Sharma, 2017). The definition of *SL* that researchers often use comes from thinking Gal (2002), Watson (2013), and Wallman (1993), namely: (i) the capacity to evaluate and interpret statistical data critically in various contexts and (ii) the ability to discuss statistical information. Consequently, a systematic literature review is warranted to enhance comprehension of SL. This review will commence with an examination of the existing body of literature about SL. Subsequently, it will assess frameworks frequently employed by university researchers and among students from 2018-2023. Finally, it will offer recommendations for pedagogy and future research.

Previous Studies

Walker (1951) believed the term SL to be a bridge of communication between statisticians. Social scientists have significantly influenced the development of science, especially in education. Then, the debate over the term *SL* continued to develop, such as D.G Haack (1979), Wallman (1993), Gal (1995), delMas (2002), Rumsey (2002), Dani & Ben-Zvi (2004), Sharma (2017). The literature review study on SL conducted by Sharma (2017) is the last literature review study found in the Scopus and WoS databases. This development indicates that the SL trend is still reaping debate to achieve the desired scientific novelty.

Each literature review research has its role and contribution. However, the author will still limit data such as search strategy, inclusion and exclusion criteria (table 3), publication period, research object, and interest in research questions. In Table 1, the definition by Gal (2002) has the most references compared to other researchers.

Table 1. Some highly cited literature reviews on SL yang published in Scopus

Author(s)	n	Period	Article Title
Gal, I. (2002)	383	1999-2003	Adults' *SL*: Meanings, Components, Responsibilities
Rumsey (2002)	136	1999-2003	*SL* as a Goal for Introductory Statistics Courses
Gould (2017)	72	2014-2018	Data Literacy is *SL*
Engel (2017)	67	2014-2018	*SL* for active citizenship: A call for data science education
DelMas (2002)	60	1999-2003	*SL*, Reasoning, and Learning: A Commentary

Author(s)	n	Period	Article Title
Loewen (2014)	48	2014-2018	*SL* Among Applied Linguists and Second Language Acquisition Researchers
Weiland (2017)	39	2014-2018	Problematising *SL*: An intersection of critical and statistical literacies
Watson & Moritz (2000)	38	1999-2003	Development of understanding of sampling for *SL*
Sharma (2017)	37	2014-2018	Definitions and models of *SL*: A literature review

Review literature is research that is needed today to provide the current state of affairs. (Tang et al., 2023) to understand the study of the potential of *SL* in the world of Education, as well as provide views on the appropriate application in teaching and learning. Therefore, we need to update the big picture of this research theme. This study will review SL in learning at the university level.

The structure of this research is as follows: Previous efforts to systematize the findings of prior research on SL are detailed in Point 2. A description of the adopted systematics is provided in Point 3, while the results of the work presented in Point 3 are detailed in Point 4. The findings and analyses of the research inquiries are presented in Point 5. These responses are further analyzed in Point 6, which identifies critical SL teaching and learning issues. In Point 7, conclusions and future work are detailed.

METHODS

In this systematic literature review process, several steps will be passed, namely: (Petticrew & Roberts, 2006, 2020):

Research Questions

RQ1: What is the distribution of SL definitions often used in higher education?

RQ2: What challenges will be faced in improving SL?

The determination of RQ1 assumes that the author believes that knowing the definition and indicators/frameworks used can see the expected increase in student SL; the direction in question is student SL with education context and student SL as data consumers and data producers (McMaster, 2022). Simultaneously, RQ2 researchers aim to generate future images that serve as predictions for subsequent researchers and potentially as policymaker considerations.

Search Strategy

The search is initiated utilizing the Publish or Perish (PoP) software by inputting the term "Statistical Literacy" into the "title words" field of the Scopus and WoS search and specifying the period from "2018 to 2023". Articles from the search results will be selected according to inclusion and exclusion criteria.

Selection Strategy

The number of search result articles: In this step, the first selection uses inclusion and exclusion criteria (table 2) as a reference after duplicate articles are issued. Other researchers will assist in reviewing and analyzing each article by recording all events that include inclusion and exclusion criteria.

Table 2. Inclusion and Exclusion Criteria

Category	Inclusion Criteria	Exclusion Criteria
Publication period	2018-2023	Research conducted beyond this timeframe
Literature type	Peer-reviewed journals	Dissertations and theses
Document Type	Scholarly articles and conference proceedings published in peer-reviewed journals and conferences proceedings	Publications not appearing in a peer-reviewed journal or conference proceeding
Accessibility	Full text available	Not accessible
Database	Scopus and WoS	Others
Language	English	Other than English
Area of Study	Education	In addition to education
Object of study	College Student	Student

Quality Assessment

In this stage, researchers use two investigators to independently assess the paper's quality. Microsoft Excel records information/data included in the inclusion criteria by investigators. If there is a disagreement between two investigators, the investigator directs the third investigator to resolve the matter. The technique of judging the article by giving a score (0 = very poorly; 1 = poorly; 2 = reasonably; 3 = well; 4 = very well) (Medeiros et al., 2019).

The paper quality assessment is conducted according to criteria that have been chosen and modified from the guidelines that Kitchenham & Charters (2007) has developed, focusing on his methods and scientific accuracy. For papers based on field studies (qualitative and quantitative approaches), the criteria are:

1. What is the quality of data collection?
2. In what manner is the methodology and structure of the analysis executed?
3. To what extent are context and data sources defined and maintained?
4. Do the connections between data, interpretation, and conclusions exhibit clarity and coherence?

For theoretical papers, the criteria are:

1. To what extent does the analysis fulfill its initial intent and objective?
2. What knowledge or comprehension is increased due to this research?
3. To what extent is the diversity of contexts and perspectives investigated?

Data Collection and Analysis Strategy

Data that has been extracted from each article will be recorded (data/information) in spreadsheet format, namely:

1. Title, keywords, author, publisher, article type, and year
2. Research Objects
3. Research Methods (qualitative and/or quantitative approach)

Other investigators will check the data extracted by one investigator. Discussions

are held as mediation to reach an agreement if there is a disagreement. It is handed over to the third investigator if it still needs to be achieved. The analysis of answers from research formulations using an inductive approach (Medeiros et al., 2019) starts by collecting the exact key terms of each article. Then, the different terms are identified and consolidated with synonymous terms.

Method Application

The previous search strategy yielded 246 research articles from Scopus-indexed online databases and WoS (Web of Science). After deleting duplicate articles, as many as 157 articles, 89 articles are retained. 76 articles were removed from the record because they were in the exclude criteria, so the remaining 10 were retained (Figure 3 and Table 3). The distribution of articles in 2023 was obtained as many as three, four in 2022, 3 in 2021, and one in 2019. All articles selected (retained) have an excellent score to use as articles with inclusion criteria.

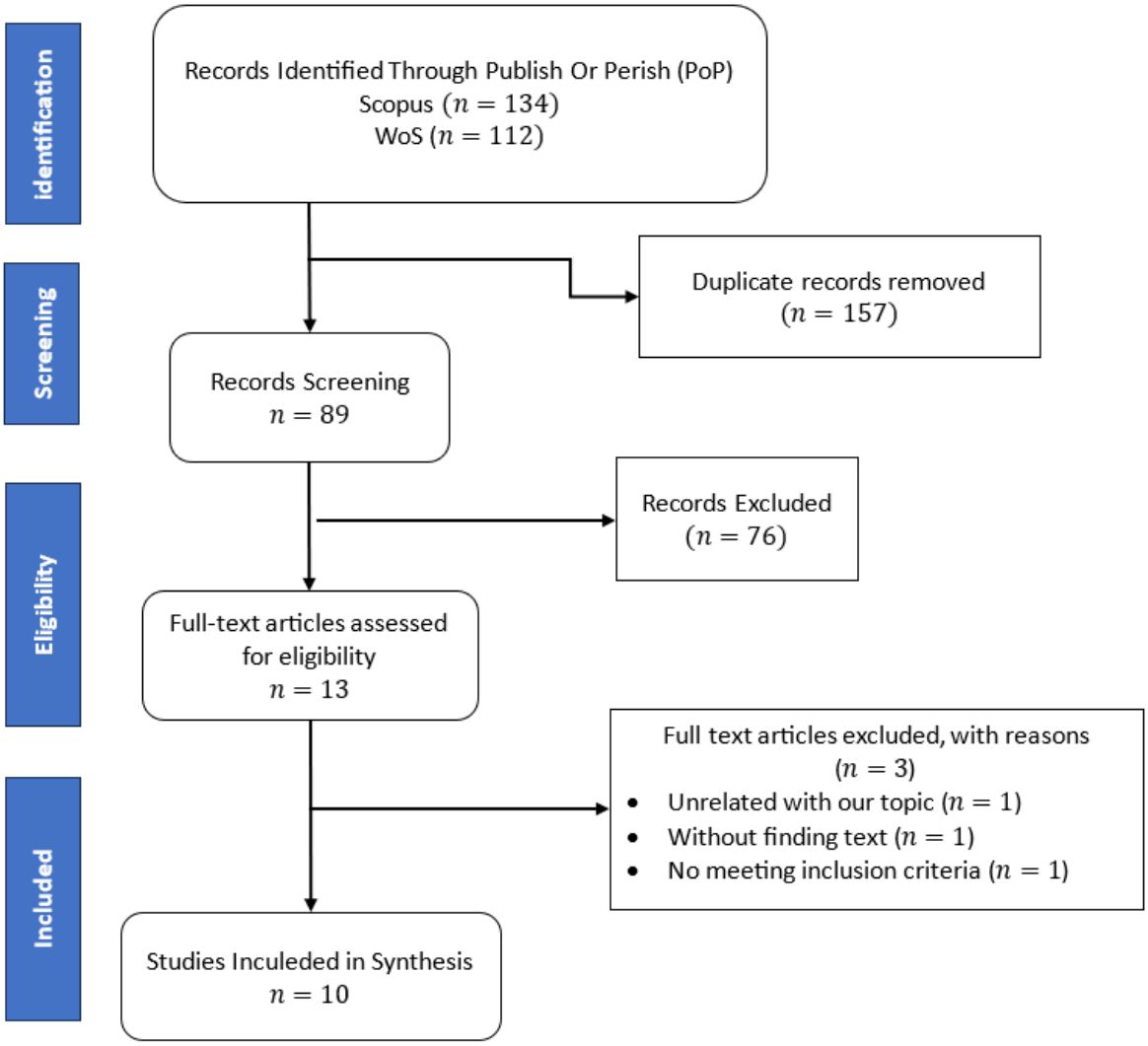

Figure 3. The PRISMA Flow of The Current Review

Table 3. Demographics of the included studies

Code	Author(s)	Title(s)	Research Method	Country	Database
A01	Tran et al. (2023)	Changes in Lesson Plans as Teachers Participate in Professional Development on Statistical Literacy	Design Research	Vietnam	ScienceDirect
A02	Gunawan et al (2023)	Statistical Literacy Process of Prospective Mathematics Teachers: A Case Study of Pisa Model Problems	Descriptive Approach	Indonesia	Proquest
A03	Forgasz et al. (2022)	Evaluating pre-service teachers' statistical literacy capabilities	Survey Study	Australia	Springer
A04	Gonda et al. (2022)	Implementation of Pedagogical Research into Statistical Courses to Develop Students' Statistical Literacy	Pedagogical experiment	Slovakia	MDPI
A05	Lim et al. (2022)	SOLO-Based Task to Diagnose Adult Learners' Statistical Literacy in the Twenty-First Century	Descriptive study	Malaysia	Springer
A06	Sarid et al.(2022)	The Role of reading skills in statistical literacy among bilingual and native Hebrew-speaking college students	Comparative study	Israel	Taylor & Francis Group
A07	Berndt et al.(2021)	Investigating statistical literacy and scientific reasoning argumentation in medical-, social sciences-, and economics students	explorative study	Germany	ScienceDirect
A08	Engledowl & Weiland (2021)	Data (Mis)representation and COVID-19: Leveraging Misleading Data Visualizations For Developing Statistical Literacy Across Grades 6–16	Qualitative research	Texas, USA	Taylor & Francis Group
A09	Setiawan & Sukoco (2021)	Exploring first-year university students' statistical literacy: A case on describing and visualizing data	Case study	Indonesia	ERIC
A10	Said et al. (2019)	Development of Mobile Learning Applications as Scaffolds to Enhance Postgraduate-Level Statistical Literacy	Quantitative survey study	Malaysia	IEEE Xplore Digital Library

RESULT AND DISCUSSION

Definition of Statistical Literacy (RQ1)

Despite efforts to define SL, there is no scientific consensus (Sharma, 2017). Even though SL is an umbrella term whose meaning has evolved (Berndt et al., 2021), researchers are trying to look deeper into the definition of SL that is often used. Data and statistical information comprehension, interpretation, critical evaluation, visualization, description, organization, generalization, hypothesis formation, and communication are frequently emphasized in SL. For further details, please refer to Table 4 and Table 5 below.

Table 4. Overview of Defenition of Statistical Literacy by Emphasize

Emphasizing the Definition of Statistical Literacy		Kode article
Statistical literacy is the ability to:		
Emphasize	Understand	A01, A02, A03, A04, A06, A08, A10
	Interpret	A01, A02, A03, A05, A06, A07, A10
	Critically Evaluate	A01, A02, A03, A06, A08, A10
	Communicate	A01, A02, A03, A06
	Describe	A05, A09
	Organize	A05
	Generalize	A05
	Hypothesize	A05
	Visualize	A09
Statistical information		A01, A03, A04, A06, A07, A08
Data		A02, A05, A08, A09, A10

Table 5. Definition of Statistical Literacy by Author

Author(s)	Statistical Literacy is the ability to:								
	Understand	Interpret	Critically Evaluate	Communicate	Describe	Organize	Generalize	Hypothesize	Visualize
Wallman (1993)	✓		✓						
Gal (2002)	✓	✓	✓	✓					
Watson and Callingham (2003)	✓	✓							
Ben-Zvi and Garfield (2004)	✓			✓		✓			✓
Setiawan & Sukoco (2021)					✓		✓		
The SOLO Model (2022)		✓			✓	✓	✓	✓	

From Table 5, we can learn that the popular definitions used from the articles that the researchers analyzed have insignificant differences. They concur with Wallman, Gal,

Watson & Callingham, Ben-Zvi, and Garfield that SL is the capacity to communicate, comprehend, interpret, and evaluate critically. (including the ability to visualize and organize) statistical information and data to make decisions (Kurnia et al., 2023). Then, Setiawan & Sukoco and The SOLO Model emphasize the ability to interpret, describe, organize, generalize, hypothesize, and visualize data. In addition, tables 4 and 5 show that the definition of SL used in research in which students are participants is divided into two perspectives: consumer data and producer data. Students consider themselves data producers when attempting to resolve statistical problems (Aliaga et al., 2005; Carver et al., 2016). We can see from the emphasis on the ability to formulate questions, collect, analyze, and interpret results.

Learning Challenges to Improve SL Students (RQ2)

In the field of SL improvement, researchers have identified two primary challenges to learning: the utilization of contextual learning models and the availability of practical evaluation tools. The subsequent discussion will elaborate on these points.

Contextual Learning Model

Statistical-based information (quantity information) is ubiquitous today. However, citizens' ability (statistical literacy) still needs to be at the level where data can be accessed, used, and interpreted appropriately (Gonda et al., 2022). Another problem is that students have difficulties in SL, and teachers must have the necessary skills and knowledge to teach them effectively (Sarid et al., 2022). In addition, understanding statistical information and applying it in decision-making is paramount in many professional contexts and societies increasingly based on quantitative knowledge and evaluation (Berndt et al., 2021). These facts challenge future teachers to find effective ways to use phenomena (fundamental research) in teaching.

Contextual learning also places a severe emphasis: "*One effective approach to developing SL is through using tasks that involve presenting students with real-world problems or situations that require statistical analysis and interpretation"*[*A01, P.286*]. One solution in teaching is that students face contextual tasks that require statistical analysis and interpretation while developing students' statistical communication skills due to being able to present and interpret to others. In addition, teachers must be able to develop students' ability to investigate statistics because, so far, students still often analyze data and interpret results without knowing which statistical questions they investigate and the type of data needed for those questions. "*They are often engaged with data analysis and, in some cases, interpreting results without knowing which statistical questions they are investigating and the types of data needed for the questions"*[A01, P. 286].

Teachers can present real problems or statistical information to be used as a basis for decision-makers. "*The ability to understand statistical information and to apply it in decision-making is of ample importance in many professional contexts and in a society increasingly based on quantitative knowledge and evidence*" [A07, P. 01].

Educators need to detect early student SL in the first year of university as a form of initial diagnostics related to students' initial skills before attending statistics lectures, requiring students to work with and interpret data through research. "*Students' SL can be used as a diagnostic tool before learning the introductory statistics course at the*

university. Proper ability to use statistics, as well as the result of the university statistical course (if any), should enable students to work with data and do meaningful research for their thesis" [A10, P. 428].

The proper Evaluation Tool

Researchers see the evaluation tool as one of the challenges for teachers. Researchers have found various reasons for this. Let us take a look:

Students and researchers still have much confusion in determining/choosing the correct statistical tests for various types of research, data distribution, and variable types, "*Researchers often found remembering which statistical test is suitable to use in certain conditions because various statistical tests exist. Plus, different types of research designs, data distribution, and variable types are among the important deciding factors that must be considered when choosing a suitable statistical test"* [A10. P.01]. For this reason, teachers must present assignments or projects related to research data or data obtained from research results so that students are accustomed to determining statistical measuring instruments/tests to analyze quantitative data.

Students have the competence to find specific data. However, they cannot see the critical issues illustrated by graphs or tables, "*They have the competence to locate specific data but are unable to discern the important issues illustrated by graphs or tables*" [A05 P.142]. Therefore, developing good diagnostic tools, such as performance appraisal methods that systematically identify the weaknesses and strengths of adult learners in SL, is essential.

Students have difficulty understanding statistical data and applying statistics in everyday life [A02] and [A07]. Indirectly, we know that the emphasis of student SL evaluation tools is on a contextual approach.

Information about the SL of first-year students can be input for improving statistics teaching (reflection) [A09]. For the points of reflection to be described correctly, the proper evaluation tool must be used to measure student SL before taking the Education Statistics course.

Discussion

Some of the topics that emerged from this review that can be included in the research roadmap on SL at the student level and the challenges of improving SL students are as follows:

Understanding of Statistical Literacy at the College Student Level

Statistical proficiency is essential for students because it becomes a strong foundation for understanding the world around us. In an age filled with data, students need to be able to read, interpret, and assess statistical data often used in various disciplines. These skills are supportive in academic research and valuable for everyday decision-making. (Jr. & Diego, 2021; Kurnia et al., 2023; Malaspina & Malaspina, 2020; Palmeiro-Silva et al., 2021; Thanopoulos & Karamichalakou, 2021; Umbach, 2022). With SL, students can recognize trustworthy resources, avoid misunderstandings, and contribute to improving the quality of scattered information. In addition, mastery of statistics helps students develop analytical skills that apply to various subject areas and the future of their careers. With a good understanding of statistics, students can become

more skilled, critical individuals (Gonda et al., 2022; Guler et al., 2016; Koga, 2022; Lukman & Wahyudin, 2020; Schield, 1999), and adaptive to the challenges of an increasingly connected and complex world.

The definition of SL has undergone significant evolution over time. Initially, SL was only seen as a basic understanding of statistical concepts, such as average, median, and standard deviation (Porter & Doshi, 2017). However, with the advancement of technology and the increasingly widespread use of data in various aspects of life, this definition has evolved into something more complex (Grant, 2017; Macfeely et al., 2017; Nalborczyk et al., 2019). Today, SL includes the ability to understand the basic concepts of statistics and collect, analyze, and interpret data correctly. In addition, the ability to recognize biases and errors in data (Engledowl & Weiland, 2021) Moreover, being critical of statistical information presented in the media is also an integral part of SL. These developments reflect the importance of our adaptability in the face of increasingly complex data challenges and higher statistical competency requirements in various aspects of modern life.

In this study, researchers look deeper into the definition developed by previous researchers, which then researchers try to see from two perspectives: (a) Consumer Data (Gonulal, 2018; Kurnia et al., 2023; Schield, 2004, 2011; Souza et al., 2020), namely SL is the ability to formulate questions, collect data, analyze data, and interpret results; while (b) Data Producer (Kurnia et al., 2023; Schield, 2011; Souza et al., 2020), SL requires students' abilities or skills in responding to statistical information, such as the ability to understand, critically evaluate, interpret, organize, communicate (including Visualize) statistical information, and statistical results from various results.

Learning Approaches to Improve Statistical Literacy of College Students

The relevance of the importance of developing learning strategies to improve SL is crucial in an era that is increasingly flooded with data and statistical information. In this framework, developing effective learning strategies is critical in helping individuals master SL (Maryati, 2024). Efficient learning strategies allow individuals to understand statistical concepts, practice data analysis, and identify potential errors or biases in statistical data. By implementing appropriate learning strategies, individuals can maximize their ability to understand statistical data, which is beneficial in various aspects of life, including personal decision-making, research, and career development. Therefore, developing learning strategies focusing on SL is essential in helping individuals become more competent in dealing with a world increasingly connected and colored by statistical data.

One strategy that can be used is a learning strategy with a contextual approach. A learning strategy with a contextual approach emphasizes the importance of relating learning material to real situations or relevant contexts (Muñiz-Rodríguez et al., 2020; Purwadi, 2021; Yurt, 2023). This approach emphasizes deep understanding and application of learning concepts in real situations. In contextual learning, students not only understand theories or concepts theoretically but can also relate them to practical situations they are experiencing. It allows students to see the relevance and benefit of daily learning. This approach encourages students' active involvement, increases learning motivation, and helps them understand how academic concepts can be applied in various

life contexts. Learning strategies with a contextual approach encourage more profound and sustainable understanding and better prepare students to face real-world challenges.

In addition, learning strategies can be used to improve student communication skills. This learning strategy is the key to comprehensive preparation in higher education (Sari et al., 2024). Good communication skills, including presenting data in tables, graphs, or diagrams, are needed in various aspects of student life as data consumers and producers. Through an approach that focuses on communication, students can develop clarity of thinking, the ability to convey ideas effectively, and the ability to listen and respond well to the ideas of others. With the right learning strategies, students can improve their communication skills, which will support them in facing academic tasks, contributing to class discussions, and achieving future success in the professional world. Moreover, strong communication skills also allow students to participate actively in social life and build positive societal relationships. Communication-focused learning strategies are essential to students' personal and career development.

Development of Contextual Statistical Literacy Evaluation Tools

Early detection of student SL is the initial door for teachers in learning statistics. At least students understand statistical tools and know-how teachers use to develop evaluation tools for the early detection of student SL. Researchers suggest developing SL evaluation tools with a contextual or natural approach in this study because contextual approaches can link learning with real-life situations or contexts. Then, students can understand the concept more deeply; they memorize the information and understand how and why it is used in certain situations. So, the hope is that students will not just answer questions, get right and wrong answers, get grades, and end up in class rankings alone.

Evaluation tools with a contextual approach are designed to measure students' understanding in real situations or contexts. The evaluation tool referred to in this paper is a test question. Here are some examples of using a contextual approach in test questions: (1) Problem-based test questions, create questions that illustrate real problems or situations that require solving. Students must then apply their knowledge to overcome the problem. Examples: give problems involving personal financial calculations or everyday problems involving statistics; and (2) Test questions related to actual events, integrate questions with actual events or issues that are happening in the world such as literacy rankings of ASEAN countries, Internet Use (based on age, gender, or country), and others. This can encourage students to relate the subject matter to their daily lives.

CONCLUSION

This systematic review uses ten recent articles (2018-2023) to understand the definition of SL and see the challenges faced in improving SL in Higher Education. In RQ1, SL is often emphasized as the ability to Understand, interpret, critically evaluate, Communicate, Describe, Organize, Generalize, Hypothesize, and Visualize data and statistical information. In addition, the definition can also be seen from two perceptions, namely 1) Producer Data is a way for students to think as statisticians to solve statistical problems that can emphasize the ability to formulate questions, collect data, analyze data, and interpret results. 2) Data Consumers demand the ability or skill of students to respond

to statistical information, such as the ability to understand, critically evaluate, interpret, organize, and communicate (including visualize) statistical information and statistical results from various results. In RQ 2, the challenge in improving SL is that educators can develop learning models and evaluation tools with a contextual approach.

In future work, the author suggests that research can be conducted to develop learning models to improve SL at the university level based on contextual approaches. It is also necessary to consider the current situation that massively utilizes digital technology as a learning or alternative medium. In addition, the author suggests a deeper study of the definition of SL because the discussion about the definition is still rolling, or there needs to be a consensus regarding the definition of SL.

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