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Advancing statistical literacy for prospective teachers: A systematic review of contemporary approaches and best practices

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Abstract

This study employs a Systematic Literature Review (SLR) to explore the development of statistical literacy among prospective teachers, which is crucial in today's data-driven educational landscape. The review synthesizes findings from 18 selected studies published between 2015 and 2024, focusing on various pedagogical approaches, challenges in implementation, and strategies for enhancing statistical literacy instruction. Current approaches and best practices include inquiry-based learning, real-world data applications, and interactive digital tools. These approaches aim to engage prospective teachers in authentic statistical experiences, which can enhance their ability to teach statistical concepts effectively. The study identifies key themes in statistical literacy education using a comprehensive methodology that includes defining research questions and establishing inclusion and exclusion criteria. Key findings reveal four primary research themes: strategies for teaching statistical literacy, competencies needed for prospective teachers, educational contexts, and the role of technology in statistical learning. The review also identifies significant gaps in the existing literature, particularly related to effective curriculum integration and the specific challenges educators face. This SLR contributes to the ongoing discourse on educational statistical literacy, providing a foundation for future research and practical applications in teacher preparation.

Keywords: pedagogical strategies; prospective teachers; statistical literacy; systematic literature review; teacher education

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Introduction

Statistical literacy has been the subject of much discussion because of its significance in many domains, such as mathematics education, social science, health, and psychology (Budgett & Rose, 2017; Gal, 2002; Schield, 2017). Several studies underscored the importance of providing students with opportunities to enhance their statistical literacy skills. For instance, Ben-Zvi (2020) emphasizes the integration of real-world data into educational practices, which fosters critical thinking and engagement with statistical concepts. Wallman (1993) argues for the necessity of statistical literacy in a data-driven society, advocating for educational reforms that prioritize this skill. Additionally, Weiland (2017) explores the role of technology in teaching statistics, demonstrating how digital tools can create interactive learning experiences that improve students' statistical reasoning. In today's data-driven world, statistical literacy has become a fundamental skill across diverse fields of study and professional practice (Lestariningsih, 2022). Statistical literacy is now widely acknowledged as an essential skill for students (Weiland, 2017). It allows individuals to comprehend and apply statistics effectively in their personal, professional, and daily lives (Muñiz-Rodríguez et al., 2020).

Wallman (1993) initially stated that statistical literacy was defined as the intersection of classroom-based probability and statistics with practical applications. However, over time, the definition of "Statistical Literacy" has expanded to include the capacity to comprehend and assess statistical data in various settings (Gal, 2000; Schield, 2017). Statistical literacy is an individual's competence to comprehend, analyze, and utilize statistical information effectively (Gal, 2004; Sharma, 2017).

Statistical literacy encompasses various competencies, including understanding fundamental statistical principles, the ability to read and interpret data, knowledge of probability, skills in evaluating data quality, and the aptitude for using statistics in logical reasoning and drawing conclusions. Callingham and Watson (2017) highlight the importance of these competencies in educational contexts, emphasizing how they contribute to informed decision-making. Gal (2002) explores the role of statistical literacy in everyday life, arguing that it empowers individuals to assess information critically. Rumsey (2002) further discusses the necessity of statistical literacy in a data-rich environment, advocating for its integration into educational curricula to enhance students' analytical skills.

The importance of future educators' good statistical literacy abilities grows as data-driven decision-making becomes more prevalent in many areas, including education (Muñiz-Rodríguez et al., 2020). Prospective teachers can develop these abilities to improve their effectiveness in teaching statistics and to incorporate data analysis into their instructional techniques (Aslan, 2019; Utari et al., 2023). It will lead to better student results and contribute to developing a more statistical-literate generation (Delport, 2022). Although statistical literacy is widely acknowledged as important, there is still a significant lack of understanding regarding how these skills are taught and incorporated into teacher training programs (Tishkovskaya & Lancaster, 2010). Moreover, Tiro (2018) stated that statistical literacy courses are not mentioned explicitly in the Indonesian educational curriculum. This statement aligns with Rafi & Retnawati (2023), who stated that the intended mathematics curriculum in Indonesia does

not explicitly address statistical literacy; teaching statistics indirectly promotes statistical literacy.

Due to the lack of integration of statistical literacy with the curriculum, specific approaches and methodologies to effectively develop statistical literacy skills among prospective teachers are varied and sometimes inconsistent (Andriatna et al., 2021; Habibie & Hidayat, 2022). This situation can impact the quality of statistical education that prospective teachers receive, and as a result, it can affect their preparedness to teach these topics to their students (Weiland, 2017). Conducting a comprehensive literature review is crucial to discovering and combining the existing studies on the development of statistical literacy abilities for prospective teachers. This review aims to thoroughly analyze the existing knowledge to identify effective techniques and approaches and point out gaps and limitations in the current understanding. An analysis of such a review will offer valuable perspectives on the strategies that have demonstrated success and identify areas where additional research is necessary to improve prospective teachers' skills. Based on this introduction, the problem formulation in this article is as follows:

RQ1 : What approaches are currently being applied in the development of statistical literacy skills among prospective teachers?

RQ2 : What challenges and limitations are encountered in the implementation of these approaches, and how do they affect the quality of statistical literacy instruction?

RQ3 : How can the findings from this systematic literature review be used to design and implement more effective strategies for developing statistical literacy skills for prospective teachers?

RQ1 aims to determine the various methods that prospective teachers utilize to cultivate statistical literacy skills. It encompasses pedagogical approaches, course content, and tactics employed in various educational establishments. RQ2 aims to analyze the challenges and limitations faced in implementing various statistical literacy development approaches. It involves identifying resource constraints, resistance to new methods, or lack of curriculum support. RQ3 aims to formulate evidence-based recommendations for designing and implementing better strategies for prospective teachers. It involves developing practical recommendations for educators and policymakers to enhance the quality of statistical literacy education.

This Systematic Literature Review (SLR) enhances the current understanding, specifically in the domain of statistical literacy for prospective teachers. Furthermore, it aids educators and researchers in performing additional investigations on the development of learning methods for statistical literacy, building upon the findings of this review. The SLR provides a complete examination of existing research on statistical literacy for prospective teachers. It encompasses a thorough grasp of the many teaching and learning outcomes related to statistical literacy that previous researchers have developed. The review thoroughly examined the literature's profile and content to provide the theoretical foundation for enhancing students' development in statistical literacy abilities, modeling tools, and employed activities.

The study analyses deficiencies in the existing body of literature to provide insights and recommendations for further research on statistical literacy.

Methods

This descriptive study uses the Systematics Literature Review (SLR) method to describe the results of literature reviews related to statistical literacy for prospective teachers. The purpose of this research is to summarize study findings, highlight significant contributions, and appraise the corpus of current knowledge by methodically locating, evaluating, and interpreting all pertinent publications about a specific research subject or area of interest to answer the research question (Dahlan et al., 2021; Xiao & Watson, 2019). Figure 1 illustrates the process of SLR.

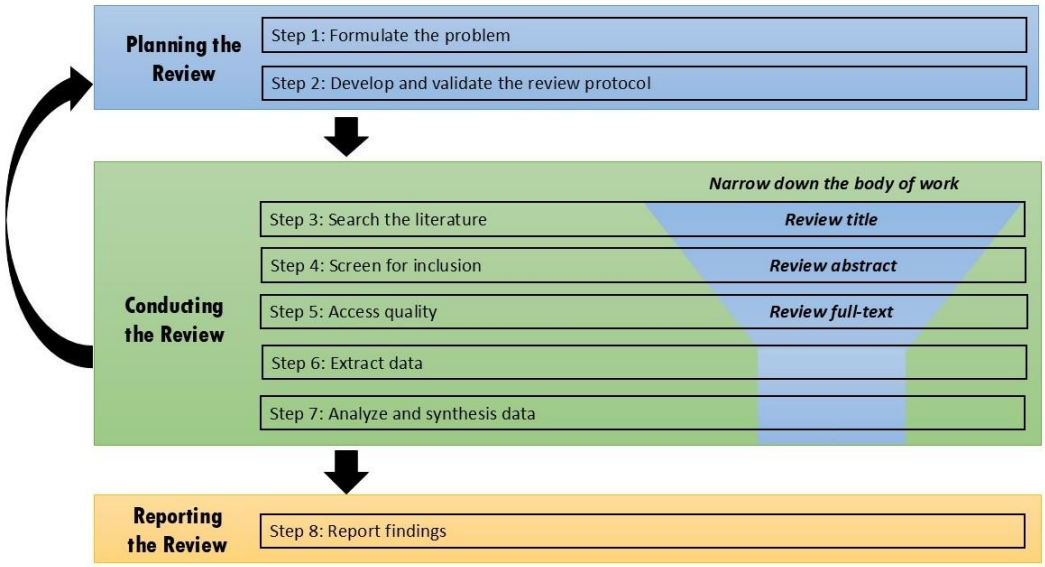

Figure 1. Process of systematic literature review

Based on Figure 1, The SLR approach consists of three primary stages: planning the review, conducting the review, and reporting the review (Xiao & Watson, 2019). The reason for selecting SLR in this study is that it aligns with purpose of identifying the statistical literacy learning carried out by earlier researchers and revealing any gaps and limitation in statistical literacy (Sharma, 2017). The findings will enable us to deduce conclusions and make well-informed judgments on future study (Dahlan et al., 2021). The following is a description of each stage of the research.

Planning the review

Researchers define the problem formulation and create and validate the review process during the planning the review stage. In the initial phase, the researchers establish identifies the issue and the research question. Following that, the researchers created a review procedure that included crucial decisions about the database, inclusion and exclusion criteria, and keyword selection. The databases such as Scopus and Education Resources Information Center (ERIC) were utilized to discover studies that fulfilled the specified criteria. The researchers employed

the terms or keywords selection, include: statistical literacy, prospective teachers, and educational domains, in this study the domains take. In addition, the literature used was checked to make sure it was pertinent to the review using inclusion and exclusion criteria (Xiao & Watson, 2019).

Conducting the review

At the conducting the review stage, there are several steps taken by researchers, including: literature search, screen for inclusion, assess quality, extract data, analyze and synthesize data. The quality of data search using electronic databases, backward searching, and forward searching (Xiao & Watson, 2019). In this study, Scopus, which serves as the primary database, was used to discover relevant literature that was incorporated into this review. ERIC was utilized as an adjunctive repository to identify supplementary papers pertaining to the investigation. The establishment of inclusion and exclusion criteria was done to ensure the significance and quality of the literature. Inclusion criteria are requirements or standards that must be met by a study or article to be included in the literature review. Exclusion criteria are conditions that cause studies or articles not to be included in the literature review. Table 1 displays the specific criteria that were used to determine which subjects were included or excluded in this analysis.

Table 1. Search keywords, database, inclusion, and exclusion criteria

Database	Scopus, ERIC
Title word	Statistical literacy
Keywords	"Statistical literacy", "prospective teacher", "pre-service teachers", "teachers educational program", and "higher education"
Inclusion criteria	1. Relevant topic: the study should address a topic that is relevant to the purpose of the literature review. Relevant topic according to keywords, title, abstract, full-text. 2. Time range: literature review includes studies published in the last 10 years. 3. Language: articles published in English. 4. Quality: published on scopus, and ERIC databases. 5. Sources can be in the form of journal articles, book chapters, books, thesis.
Exclusion criteria	1. Irrelevant topics: studies that do not address the main topic of the literature review will be excluded. 2. Incomplete studies: articles that do not have complete data or are only available in abstract form without detailed information are often excluded. 3. Age of publication: articles published outside the specified time span may be excluded, unless there is a compelling reason to include older studies. 4. Language: articles written in a language that the researcher does not understand, in the absence of a translated source, may be excluded. 5. Quality and credibility: articles from non-credible sources or poorly indexed journals may be excluded.

Researchers conducted initial screening using keywords, article time range between the last ten years 2015-2024, and relevant databases. Researchers use some applications to do SLR, like Zotero, Harzing Publish or Peris. The Harzing Publish or Perish application to filter articles or papers from relevant sources and credible databases. The initial screening results are as many as 119 documents, from Scopus (n = 31) and ERIC (n = 88). Table 2 is a breakdown of the search results by database, title words, keywords, and year of publication.

Table 2. Result of literature by title words, keywords, and database

Title Words	Keywords	Scopus	ERIC
Statistical literacy	"Statistical literacy", "pre-service teacher", and "higher education".	4	77
	"Statistical literacy", and "prospective teacher"	27	0
	"Statistical literacy", "pre-service teacher", and "teachers education program"	0	11
	Total documents	31	88
	Total of all documents	119	

Table 2 is the result of initial filtering using the Harzing Publish or Perish and ERIC search application. The results of the articles obtained will then be re-identified to discard inaccessible, incomplete, and duplicated documents. The results of quality screening as well as reading titles and abstract analysis obtained 98 documents that met the criteria. Furthermore, the researchers conducted an analysis using the inclusion and exclusion criteria (eligibility screening). We read 33 documents for analysis that met the requirements of the previously defined inclusion and exclusion criteria (see table 1) and 65 documents did not meet these criteria. After reading and analysing the 33 eligible documents, 18 documents have the potential to answer the research question that has been set. This selection process is carried out using the PRISMA selection process. Figure 2 below is the PRISMA process diagram.

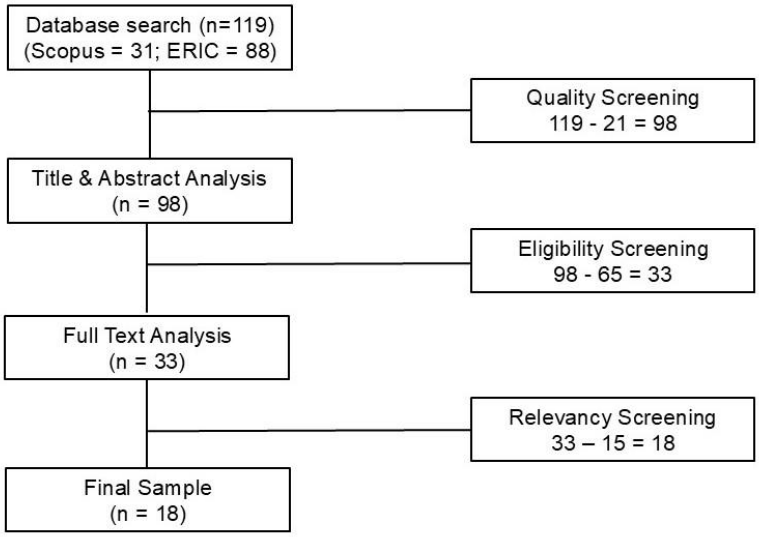

Figure 2. The PRISMA selection process diagram

From figure 2 the PRISMA selection process, there are 18 documents that were reviewed and analysed further. Each document is given a code related to the author's name, publication year, publication source, article/paper title, paper type, method, research objectives, main findings, research limitations.

Reporting the review

The process of producing a trustworthy and replicable literature review entails giving thorough documentation of systematic studies that explains the reasoning behind each inclusion and exclusion criterion. Reporting the results of the literature search, screening, and quality evaluation is also crucial. The review report was organised as follows: first, a quantitative descriptive analysis of the literature profile; second, a qualitative literature analysis; and third, a critical review analysis. The literature content analysis was reported in a descriptive manner.

Results

In this section, researchers present a synthesis of 18 articles in a systematic literature review (SLR) related to statistical literacy. The synthesis is divided into seven main items, including the year of study, teaching approaches, goals of development, teaching context, challenges, and impacts on instructional quality. This aims to provide a clear overview of trends and practices in teaching statistical literacy.

The analysis reveals a variety of approaches utilized, ranging from collaborative learning models to the use of real data, all aimed at enhancing student understanding and self-efficacy. Challenges encountered, such as limited resources and varying levels of prior knowledge, pose significant barriers to the implementation of teaching strategies. Meanwhile, positive impacts on instructional quality are reflected in the improved learning outcomes of students.

Furthermore, researchers discuss three key points: the approaches used in developing statistical literacy skills, the challenges and limitations in implementation, and the implications of findings for more effective development strategies. This result aims to offer deeper insights into how to enhance statistical literacy among prospective teachers and create a more supportive learning environment. Table 4 presents a detailed synthesis of the specified items related to articles on statistical literacy.

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Table 4. The detailed synthesis addressing the specified items of statistical literacy' articles

Year of study	Title	Approach to teaching statistical literacy	Goals of statistical literacy development	Teaching context	Challenges and limitations	Impact on instruction quality
2016	The effectiveness of CPS-ALM model in enhancing statistical literacy ability and self concept of elementary school student teacher (Takaria & Rumahlatu, 2016).	The CPS-ALM model is characterized by its emphasis on collaborative problem-solving and active learning strategies.	Equipping prospective teachers with the skills to interpret data accurately, make informed decisions based on statistical evidence, and develop critical thinking abilities.	The teaching context involves a cohort of elementary school student teachers who are undergoing training to become educators	The varying levels of prior knowledge among prospective teacher, which can impact their engagement with statistical concepts. The need for ongoing support and professional development for educators to enhance their instructional strategies.	CPS-ALM model has shown a positive impact on the quality of instruction by promoting active engagement and collaborative learning among Prospective teachers.
2016	Teachers' perceptions of learners' proficiency in statistical literacy, reasoning and thinking (Kalobo, 2016).	A constructivist approach to teaching statistical literacy, where learners are encouraged to engage actively with statistical concepts through inquiry-based learning and real-world applications	Developing statistical literacy and enhancing students' reasoning abilities, which are essential for understanding complex statistical concepts and applying them in various contexts	The teaching context involves primary and secondary school teachers who are assessing their students' proficiency in statistical literacy	Limitations related to the availability of resources and training for teachers, which can hinder the effective implementation of statistical literacy programs. The challenges underscore the need for professional development and support for educators to enhance their instructional strategies in teaching statistical literacy.	The perceptions of teachers regarding their students' proficiency in statistical literacy significantly impact the quality of instruction. Teachers who recognize the importance of statistical reasoning and thinking are more likely to incorporate these elements into their teaching practices, leading to improved student outcomes
2017	Evaluating the practices of instructors teaching statistics courses from different undergraduate programs in terms of statistical literacy (Özmen & Baki, 2017).	The multifaceted approach to teaching statistical literacy that incorporates active learning strategies, real-world applications, and collaborative problem-solving.	The study aims to enhance students' ability to analyze data critically and apply statistical concepts in real-world situations, which is increasingly important in a data-driven society.	The teaching context involves instructors from various undergraduate programs, including mathematics, social sciences, and health sciences, who are responsible for teaching statistics courses. The study highlights the diversity of teaching practices and the varying levels of emphasis placed on statistical literacy across different disciplines	The limitations related to the availability of resources, such as access to technology and teaching materials, which can hinder the effective implementation of statistical literacy programs. Some instructors may lack confidence in teaching statistics, which can negatively impact student learning outcomes.	The study suggests that instructors who prioritize statistical literacy and employ effective teaching strategies are more likely to enhance student engagement and understanding of statistical concepts. Furthermore, the integration of statistical literacy into various disciplines can lead to improved student outcomes and better preparation for real-world applications of statistics.

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Year of study	Title	Approach to teaching statistical literacy	Goals of statistical literacy development	Teaching context	Challenges and limitations	Impact on instruction quality
2017	Enhancing statistical literacy (Van Dijke-Droogers et al., 2017).	Using a differentiated module in the Digital Mathematics Environment (DME) alongside investigation activities during classroom sessions	Engage students actively and tailor learning to their individual needs, promoting a deeper understanding of statistical concepts	The teaching context focuses on enhancing statistical literacy among pre university studentw through a differentiated, technology-rich approach using DME and TinkerPlots software. The intervention involves individualized learning routes, collaborative investigation activities, and emphasizes developing procedural skills and statistical reasoning.	The study lacked a control group, making it unclear if the differentiated approach or the focus on statistical literacy and reasoning led to the observed improvement. Since the pilot was conducted in a single class by the researcher, the findings are not generalizable, and further research is required. Limitations highlight the need for further research to confirm these findings.	The impact of instruction quality, suggests that a differentiated learning trajectory focusing on statistical reasoning and visual representations significantly enhances students' statistical literacy. The results showed substantial improvements in RTTI scores and the ability to interpret and critically evaluate statistical information, benefiting both basic and advanced students,
2020	Using real data in a quantitative methods course to enhance teachers' and school leaders' statistical literacy (Heinz, 2020).	Emphasizing the use of real national datasets, to engage teachers and school leaders in practical applications of quantitative methods. This hands-on approach is designed to bridge the gap between theoretical knowledge and practical application	Fostering a deeper appreciation for the value of quantitative research in education and to empower teachers and school leaders to utilize data-driven decision-making in their practices.	The context of the teaching involved a quantitative methods module redesigned to incorporate real data. The use of real data was intended to make the learning experience more relevant and applicable to their daily responsibilities.	This lack of confidence can hinder participation and engagement in statistical training programs. Additionally, the reliance on real datasets may pose challenges in terms of accessibility and the complexity of data interpretation for some educators.	Positive impact on instruction quality, as participants reported increased engagement and appreciation for quantitative research in education. The use of real data not only enhanced their statistical skills but also fostered a greater understanding of the relevance of data in educational decision-making.
2020	What are the roles of technology in improving student statistical literacy? (Suhermi & Widjajanti, 2020).	A literature review methodology discuss the use of technology in statistical learning. This approach allowed for a comprehensive understanding of various technological tools and their effectiveness in teaching statistical concepts	Identifying how technology can facilitate the development of statistical literacy among students.	Encompassing various educational settings where technology is integrated into statistical education. This includes the use of software, online platforms, and interactive tools that support statistical analysis and visualization, thereby making learning more interactive and practical	Disparities in access to technology among students, varying levels of technological proficiency, and the potential for technology to distract rather than enhance learning if not implemented thoughtfully. Additionally, there may be resistance from educators who are not familiar with these technological tools.	The use of technology positively impacts the quality of instruction by making statistical concepts more relatable and easier to grasp. Technology facilitates active learning and allows students to engage with data in a hands-on manner, which can lead to deeper understanding and retention of statistical knowledge
2021	The level of statistical literacy in future	A mixed-methods approach that combined	Enhancing the statistical literacy of future teachers	The teaching context involved pre-service teacher education	The study identified challenges such as varying levels of	Integrating technology into statistical literacy education

Year of study	Title	Approach to teaching statistical literacy	Goals of statistical literacy development	Teaching context	Challenges and limitations	Impact on instruction quality
	teachers and the use of available technology with the aim to increase it (Almašiová et al., 2021)	quantitative assessments of statistical literacy levels with qualitative insights on the use of technology in education.	by integrating available technology into their learning processes, thereby preparing them for effective data interpretation and analysis in their future classrooms.	programs where technology was utilized to facilitate learning in statistical literacy, allowing students to engage with statistical concepts through practical applications.	technological proficiency among future teachers and the need for adequate training to effectively use technology in teaching statistical concepts.	positively impacted instructional quality by making learning more interactive and relevant, thereby increasing student engagement.
2021	Statistics education from the perspective of statistical literacy: Reflections taken from studies with teachers (Monteiro & de Carvalho, 2021).	A reflective approach based on qualitative studies with teachers to examine how statistical literacy is taught and perceived in educational contexts.	Enhancing teachers' statistical literacy, enabling them to effectively teach statistical concepts and foster critical thinking in their students	The teaching context involved various educational settings where teachers engage with statistical content, focusing on real-world applications and the importance of data interpretation	Identifying challenges such as teachers' limited statistical knowledge and confidence, which can impede their ability to teach statistics effectively	Improving teachers' statistical literacy positively influences instructional quality, allowing for clearer and more effective teaching of statistical concepts
2021	Developing a mobile application to improve the levels of statistical literacy among graduate students in university (Bilgin, 2021).	Utilizing a technology-based approach by creating a mobile application that provides interactive learning experiences and resources to improve students' understanding of statistical concepts.	Elevating the statistical literacy levels of graduate students, enabling them to effectively interpret and analyze statistical data in their academic and professional contexts.	The teaching context involved integrating the mobile application into graduate-level courses, allowing students to access statistical resources and tools conveniently through their smartphones.	Identifying challenges such as potential resistance from students towards using mobile technology and the necessity for adequate training to ensure effective utilization of the application	Findings indicated that the mobile application positively influenced instructional quality by making statistical concepts more engaging and accessible, thereby enhancing students' learning experiences.
2021	Developing student statistical literacy through scientific approaches (Syaban et al., 2021).	A scientific approach that emphasizes inquiry-based learning, where students engage in hands-on activities to explore statistical concepts.	Enhancing students' statistical literacy by fostering critical thinking and the ability to analyze and interpret data effectively.	The teaching context involved integrating scientific methods into the curriculum, allowing students to apply statistical concepts in real-world scenarios and experiments.	Identifying challenges such as students' initial lack of familiarity with statistical concepts and the need for adequate resources to support inquiry-based learning.	Scientific approach significantly improved the quality of instruction by making statistical learning more engaging and relevant to students' experiences.
2021	Evaluating the statistics courses in terms of the statistical literacy: Didactic pathways of pre-service mathematics teachers (Guven et al., 2021).	A didactic approach that emphasizes the integration of statistical concepts into teaching practices, aiming to enhance understanding and application among pre-service teachers	Develop statistical literacy skills in pre-service mathematics teachers, enabling them to interpret data and make informed decisions based on statistical information	The teaching context involved statistics courses within teacher education programs, where pre-service teachers engaged with statistical content through various instructional strategies	The challenges such as insufficient emphasis on practical applications of statistics in the curriculum, which hindered the development of statistical literacy among pre-service teachers	Findings indicated that the current statistics courses did not adequately prepare pre-service teachers to demonstrate statistical literacy, impacting the overall quality of instruction they could provide in their future classrooms.
2021	Exploring first years university students' statistical literacy: A	A descriptive and visual approach to teaching statistical literacy,	The primary goal was to assess and enhance first-year students' abilities to	The teaching context involved a university setting where students engaged with	The study identified challenges such as students' varying levels of prior knowledge in statistics,	Findings indicated that enhancing students' statistical literacy through descriptive and

Year of study	Title	Approach to teaching statistical literacy	Goals of statistical literacy development	Teaching context	Challenges and limitations	Impact on instruction quality
	case on describing and visulizating data in university (Setiawan & Sukoco, 2021)	emphasizing the importance of data visualization and interpretation skills.	describe and visualize data effectively, thereby improving their overall statistical literacy.	statistical concepts through practical exercises and real data applications.	which affected their ability to grasp new concepts.	visual methods significantly improved their understanding and engagement with statistical data.
2022	Measurement, assessment, and improvement of statistical literacy in relevant contexts (Phadke, 2022).	The approach to teaching statistical literacy emphasized the use of practical assessments and tailored instructional strategies that align with the specific needs of learners in different contexts, thereby promoting a deeper understanding of statistical concepts.	fostering critical thinking skills, enabling students to interpret and utilize statistical information effectively, and preparing them for data-driven decision-making in their respective fields.	The teaching context encompasses a diverse range of educational environments, highlighting the importance of adapting statistical literacy initiatives to fit the unique characteristics and challenges of each setting.	Challenges and limitations identified in the study include varying levels of prior knowledge among students, resistance to engaging with statistical content, and the need for ongoing support and resources to sustain learning outcomes.	The impact on instruction quality is notable, as improved statistical literacy has been linked to enhanced student engagement, better academic performance, and a greater ability to apply statistical reasoning in real-world situations.
2023	Changes in lesson plans as teachers participate in a professional development on statistical literacy (Tran et al., 2023)	A design-based research methodology that emphasizes collaborative planning and the integration of statistical concepts into lesson plans, thereby fostering a deeper understanding among students.	Improving teachers' abilities to design lessons that effectively incorporate statistical reasoning and data analysis, ultimately enhancing students' critical thinking skills.	The teaching context is situated within a professional development framework that supports teachers in revising their lesson plans to align with updated curricular standards and pedagogical practices aimed at fostering statistical literacy.	Challenges and limitations identified in the study include teachers' initial resistance to changing established lesson plans and the need for ongoing support to ensure the effective implementation of new strategies in the classroom.	The impact on instruction quality is notable, as the professional development initiative led to significant improvements in lesson plan quality, which in turn positively influenced student engagement and understanding of statistical concepts.
2023	Statistical literacy process of prospective mathematics teachers: A case study of PISA model problems (Gunawan et al., 2023)	Emphasizes the use of real-world PISA model problems that encourage problem-solving and critical thinking skills among prospective teachers.	Enhancing teachers' abilities to interpret and analyze data, thereby preparing them to effectively teach statistical concepts to their future students.	The teaching context is situated within a mathematics education framework that integrates PISA-style assessments, aiming to align teacher training with international standards of mathematical literacy.	Challenges and limitations identified in the study include prospective teachers' varying levels of familiarity with statistical concepts and the need for more comprehensive training to bridge these gaps.	The impact on instruction quality is noted as significant, with the study suggesting that engaging with PISA model problems leads to improved pedagogical practices and a deeper understanding of statistical literacy among future educators.
2024	Evaluating pre-service teachers' statistical literacy capabilities (Forgasz et al., 2024)	Integrating practical data analysis tasks and real-world applications to enhance understanding and relevance for pre-service teachers.	Development focus on enabling pre-service teachers to effectively interpret and utilize statistical information, thereby fostering informed	The teaching context is situated within teacher education programs, where statistical literacy is increasingly recognized as a critical competency for	Challenges and limitations identified in the study include varying levels of prior knowledge among pre-service teachers and the need for more comprehensive	The impact on instruction quality is evident, as enhanced statistical literacy among pre-service teachers is linked to improved teaching practices and better student outcomes in

Year of study	Title	Approach to teaching statistical literacy	Goals of statistical literacy development	Teaching context	Challenges and limitations	Impact on instruction quality
			decision-making in their future educational practices.	educators to support student learning and data-driven instruction.	training to address these disparities effectively.	mathematics and science education.
2024	The statistical literacy of mathematics education students: An investigation on understanding the margin of error (Apino et al., 2024).	A survey methodology that assesses students' comprehension of the MoE through specific questions designed to evaluate their ability to apply statistical concepts in practical scenarios.	include enhancing students' ability to interpret statistical information accurately and fostering critical thinking skills necessary for effective data analysis in educational contexts.	The teaching context is situated within mathematics education programs at various universities, where students are expected to engage with statistical concepts as part of their curriculum.	Challenges and limitations identified in the study include varying levels of prior knowledge among students, which can affect their understanding of statistical concepts, and the need for improved instructional strategies to address these disparities.	The impact on instruction quality is significant, as the findings suggest that a deeper understanding of the MoE can lead to better educational outcomes and more informed decision-making among future educators.
2024	Improving statistical literacy through evidence based strategies among first-year education students in a state university (Castillo, 2024)	The approach to teaching statistical literacy involves evidence-based strategies that integrate active learning techniques, which have been shown to significantly improve student engagement and understanding of statistical concepts.	The primary goals of statistical literacy development include equipping students with the necessary skills to critically analyze data, make informed decisions based on statistical evidence, and apply these skills in educational research and practice.	The teaching context is set within a state university environment, where the curriculum is designed to address the specific needs of first-year education students, emphasizing practical applications of statistical knowledge.	Challenges and limitations identified include students' initial apprehension towards statistics, a lack of foundational knowledge, and the need for ongoing support to sustain their learning and application of statistical concepts	The impact on instruction quality is significant, as the implementation of these eviden.ce-based strategies has been linked to improved student outcomes, increased confidence in handling statistical data, and enhanced overall educational quality.

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Disscussion

Approaches used in enhancing statistical literacy skills

Based on Table 4, the reviewed studies highlight various effective approaches to enhance statistical literacy skills among prospective teachers. The CPS-ALM model significantly improved statistical literacy and self-concept in elementary school student teachers (Takaria & Rumahlatu, 2016), while perceptions of learner proficiency were explored to gauge the effectiveness of teaching strategies (Kalobo, 2016). Evaluative studies on statistics course practices emphasized the importance of pedagogical methods that promote statistical reasoning (Özmen & Baki, 2017) and the incorporation of real data to contextualize learning for teachers and school leaders (Heinz, 2020).

Technology's role emerged as a critical factor, with studies indicating that its integration can substantially elevate statistical literacy levels (Almašiová et al., 2021; Suhermi & Widjajanti, 2020). Furthermore, innovative tools, such as mobile applications, were developed to enhance statistical literacy among graduate students (Bilgin, 2021). The significance of scientific approaches in developing student statistical literacy was also emphasized (Syaban et al., 2021), alongside the need for continuous evaluation of existing statistics courses to better align with statistical literacy goals (Guven et al., 2021).

Professional development initiatives demonstrated the potential to transform teachers' instructional practices and lesson plans, underscoring the importance of ongoing training (Tran et al., 2023). Lastly, the studies collectively reveal a commitment to refining assessment methods and instructional strategies to better prepare prospective teachers for the demands of statistical literacy in education (Castillo, 2024; Phadke, 2022). This comprehensive approach highlights the multifaceted nature of statistical literacy development and the need for cohesive strategies that integrate theory, practice, and technology.

Challenges and limitations in implementation

The reviewed studies reveal significant challenges and limitations in implementing statistical literacy programs for prospective teachers. One prominent issue is students' varying levels of prior knowledge, which can affect their engagement and ability to grasp statistical concepts. For instance, several studies by Apino et al. (2024) and Takaria and Rumahlatu (2016) highlight how discrepancies in foundational knowledge can hinder students' understanding and application of more advanced statistical principles.

In addition, resource availability poses a considerable barrier. Studies by Guven et al. (2021) and Özmen & Baki, 2017) indicate that a lack of access to technology and teaching materials significantly impacts the effectiveness of statistical literacy instruction. Instructors often express concerns about their confidence in teaching statistics, which can further detract

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from the learning experience (Heinz, 2020; Monteiro & de Carvalho, 2021). Professional development for educators is also critical yet often insufficient. Kalobo (2016) and Tran et al. (2023) emphasize the necessity for ongoing training and support to help teachers adapt their instructional strategies and lesson plans to promote statistical literacy better. Resistance to adopting new methodologies is frequently noted, suggesting a need for a cultural shift within educational institutions to prioritize statistical literacy training (Syaban et al., 2021).

Moreover, the limitations inherent in study designs, such as the lack of control groups and the quasi-experimental nature of some research, raise questions about the generalizability of findings (Takaria & Talakua, 2018; Van Dijke-Droogers et al., 2017). These methodological constraints highlight the necessity for further research to validate and expand upon existing studies. On the other hand, addressing these challenges—ranging from diverse student knowledge levels and resource constraints to the need for robust professional development—is crucial for enhancing the effectiveness of statistical literacy instruction among prospective teachers. Effective strategies must encompass comprehensive training, resource allocation, and a commitment to fostering an environment conducive to statistical learning.

Implications of findings for more effective development strategies

Developing effective strategies for enhancing statistical literacy skills among prospective teachers is critical for preparing them to teach these concepts effectively in their future classrooms. Research indicates that ongoing professional development is essential for educators to deepen their understanding of statistical concepts and effective teaching methodologies. For instance, Takaria and Rumahlatu (2016) emphasize integrating collaborative learning strategies and creating supportive environments that foster student participation and critical thinking (Tran et al., 2023). Similarly, Kalobo (2016) highlights the necessity for targeted professional development that enhances teachers' perceptions of their students' statistical reasoning abilities, advocating for collaborative efforts among educators to share best practices.

Furthermore, Özmen and Baki (2017) and Van Dijke-Droogers et al. (2017) recommend establishing a standardized curriculum emphasizing statistical literacy across all educational levels. This curriculum should incorporate real-world applications and inquiry-based learning approaches, as suggested by Guven et al. (2021) and Syaban et al. (2021), to ensure that students can apply statistical concepts in practical contexts. Additionally, integrating technology in teaching statistical literacy is crucial, as it facilitates active learning and engagement with data, making statistical concepts more relatable and easier to grasp (Suhermi & Widjajanti, 2020).

Moreover, addressing teacher candidates' varying levels of prior mathematical ability is essential (Almašiová et al., 2021; Bilgin, 2021), as highlighted by Takaria and Talakua (2018), who recommend targeted interventions to support all learners. Using real data in teacher education programs, as Heinz (2020) advocates, further enhances statistical literacy by providing practical experiences that build confidence in handling statistical information. Lastly, continuous feedback and refinement of educational resources, such as mobile applications designed to improve statistical literacy, are necessary to adapt to the evolving needs of students and educators (Bilgin, 2021). A multifaceted approach that includes ongoing professional

development, standardized curricula, technology integration, and practical applications is essential for developing effective strategies to enhance statistical literacy skills among prospective teachers. This comprehensive framework will prepare future educators to teach statistical concepts effectively and foster a culture of statistical literacy in their future classrooms.

Conclusion

The reviewed studies underscore the multifaceted approaches necessary for enhancing statistical literacy skills among prospective teachers. Effective strategies include integrating models like CPS-ALM, using real data, and incorporating technology, all of which have been shown to significantly improve both statistical understanding and self-efficacy in teaching these concepts. Continuous professional development for educators is essential, as it equips them with the necessary skills and methodologies to foster a supportive learning environment that promotes active engagement and critical thinking.

However, challenges such as varying levels of prior knowledge, resource constraints, and the need for robust professional training remain significant barriers to effective implementation. Future research should focus on longitudinal studies that assess the long-term impact of these strategies on both teacher preparedness and student outcomes in statistical literacy. Additionally, exploring the effectiveness of specific technological tools and their integration into diverse educational contexts could provide valuable insights. Addressing these challenges and expanding the scope of research will be crucial for developing comprehensive frameworks that effectively prepare future educators in statistical literacy.

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Conflicts of Interest

The authors declare no conflict of interest regarding the publication of this manuscript. In addition, the authors have completed the ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies.

Author Contributions

Rahma Siska Utari: Conceptualization, writing - original draft, editing, analising the data, and visualization; **Ratu Ilma Indra Putri:** Writing - review & editing, formal analysis,

methodology, and supervision; **Zulkardi:** Validation and supervision; **Hapizah:** Writing - review & editing, supervision.

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