A systematic literature review on developing students' statistical literacy skills

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Abstract. Statistical literacy is crucial for preparing students to become part of a modern society that is continuously bombarded with arguments that are derived from data-based decisions. In this regard, the teaching of statistics is a fundamental aspect of the mathematics curriculum at any educational level. Therefore, this study presents a systematic literature review of 36 articles that examine statistical literacy skills among students. Specifically, this study focused on identifying teaching methods that influence the development of statistical literacy among students. It was found that four dominant factors influence the development of statistical literacy among students: the learning environment, students' attitude, teaching method, and students' basic knowledge. Some studies have focused on students' demographic factors, including their age, gender, and grade level; however, there are no conclusive findings on their role in influencing the development of statistical literacy. The study also revealed the three most common teaching methods in statistical literacy studies were teacher-centered teaching methods, student-centered teaching methods, and materials-based teaching. Out of these methods, materials-based teaching was the most commonly used to develop statistical literacy among students. Based on the findings, implications for teaching and learning statistics were discussed.

1. Introduction
The integration Living in the 21st-century world is reflected through the widespread dissemination of information through printed mediums such as books, billboards, or newspapers, as well as through digital platforms including social media sites such as Facebook, Twitter, and YouTube. The advances in technologies have increased society's exposure to different meanings that require careful interpretation and statistical analysis. It has indirectly made statistical literacy skills an essential aspect of knowledge development [1].

Statistical literacy is defined as the ability to critically understand, interpret, evaluate, and communicate statistical data through various forms of media [2]. On the other hand, the argued statistical literacy is needed to understand and assimilate statistical information [3]. Thus, an individual should not only possess the ability to read a report but also understand the primary statistical data, evaluate the usefulness of the data and, most importantly, analyze and make critical interpretations of the data. This shows the importance of instilling statistical literacy skills among members of society to help them develop critical thinking skills so that they can distinguish between false and true information. In meeting 21st century educational needs, these skills are incorporated into every level of learning statistics.
The subject of statistics is not something new to many students as they have been learning it in both primary and secondary schools, and its application can be seen in everyday life [2]. Learning about statistics at the school level provides students with early exposure and knowledge that could help them to face real-life challenges, which signifies the importance of statistical literacy. The developing statistical literacy in school is crucial for preparing students to become part of a 21st-century society that is continuously bombarded with a myriad of information that involves statistical data-based arguments [4]. Thus, teaching statistics in data science has become a fundamental aspect of the mathematics curriculum at the school level, making statistical skills a vital goal in mathematics education. Therefore, this systematic literature review has been conducted to examine and synthesize empirical research on the development of statistical literacy skills among students to answer the research questions: What is the teaching method that impacts the development of statistical literacy among students?

2. Methods
The present study adopts a survey analysis research design. The selection of articles was searched and retrieved between February and March 2020. The articles reviewed were published between January 2010 and December 2019 and were available through one database, which was the Education Resources Information Centre (ERIC), the biggest database for educational research papers. A systematic literature review involves collecting, identifying, analyzing, summarizing, and critically evaluating the issues being studied [5]. The initial step is to define specific keywords to ensure that the articles found are relevant to the research questions set by the researcher. The keywords in this study are "statistical literacy," AND "students," "statistical literacy," AND "factors," and "statistical literacy," AND "learning." The connection word "AND" was used to find articles on statistical literacy, focusing on issues related to students, factors, and learning.

During the article search, four criteria were set to guide the article selection process and to ensure that the selected articles met the research requirements. The four criteria were: (1) The research articles should be published within the last ten years, mainly between 2010 and 2019, (2) The research articles had undergone peer review, and the researcher could retrieve the full-text version, (3) The research articles were related to statistical literacy development among students across all levels of education—primary, secondary, and tertiary, and (4) The research articles were only published in journals or as proceedings. The selected articles should not be part of any book, dissertation or thesis, conference paper, manuscript, concept paper, or any other source of reference.

The first step in the article collection process was to identify the articles that fit the first and second criteria in the guideline. The predefined keywords were keyed into the database, and there were 127 articles listed in the ERIC. The research articles were then reviewed to prevent redundancy, and subsequently, 42 articles were excluded. Hence, out of 127 articles, only 85 articles were retained.

Each article was reviewed to ensure that first, the papers focused on statistical literacy in the field of education only, and second, they discussed the influence of factors and teaching methods that affects the development of students' statistical literacy skills. Based on the third and fourth criteria, a total of 48 articles were excluded from the review process, and only 36 research papers were retained for further review.

3. Result and Discussion
From the 36 articles analyzed, several significant findings could be discussed in this study. The analysis was conducted based on the research question that focused on teaching methods that impacted the development of statistical literacy among students. It was found that most articles focused on three main teaching methods, namely teacher-centered teaching, student-centered teaching, and materials-based teaching. Seventeen articles highlighted the use of a materials-based teaching method to develop statistical literacy, ten articles focused on student-centered teaching methods, and only one focused on teacher-centered teaching methods.

The analysis in each article also looked into the educational level of the respondents. In this regard, all of the articles chosen involved students as respondents based on one of the conditions set during the
article selection process, namely, the studies must focus on the development of statistical literacy among students. This was to ensure that the analysis could examine the factors influencing students' acquisition of statistical literacy skills. Based on the review conducted, the results show that 20 statistical literacy studies involved university students or adult students, 11 studies involved secondary school students, and five studies included primary schools. Out of the 36 articles reviewed, none involved pre-schoolers.

The next aspect analyzed is the study location. Fourteen articles reported studies conducted in the United States of America (USA), followed by Australia with six articles, Turkey with four articles, the United Kingdom (UK) with three articles, and New Zealand with two articles. Studies on the factors and methods of teaching that influence the development of statistical literacy were also conducted in the following countries: Portugal, Ireland, Indonesia, Greece, Germany, China, and Brazil, with an article from each country.

3.1. teacher-centered teaching methods
The analysis found only one article, [6], which discussed the influence of teacher-centered teaching methods on the development of statistical literacy. The study found that traditional teaching methods showed better results in improving students' performance, attitude, and perception of statistical literacy compared to virtual and flipped lessons.

3.2. student-centered teaching methods
The analysis indicated that 10 out of 36 articles focused on the use of student-centered teaching methods in teaching statistical literacy. There are three forms of student-centered teaching implemented in teaching statistics, which are a project-based learning, group-based learning, and model-based learning. The reviewed articles show that project-based learning can help to improve statistical literacy among students [7-12]. For instance, the conducted project-based learning in their study, and it was found that the implementation of gardening activities in statistic lessons could increase students' science and mathematics skills, ranging from asking questions to analyzing and interpreting data [12]. The project-based statistics courses enhance students' confidence and interest in applying their statistic skills while conducting research [8].

Moreover, [9], which is a continuation of the study conducted by [8], shows that a project-based learning environment could meet the needs for statistical literacy as it creates meaningful engagement in research, problem-solving and professional development. The project-based learning helps students solve problems as it encourages them to communicate and use the information [7]. This indirectly increases their confidence in their ability to apply statistical knowledge when presenting and facing judgment from the public.

It is believed that it demonstrated the great pointers that could be used to improve students' statistics literacy [13]. The study focused on developing students' ability to understand and apply statistical concepts in the classroom and went on to suggest that this would help to support students' development of statistical literacy skills. The use of model-based learning, such as using flipped classroom models [14], Collaborative Problem Solving Model (CLP-ALM) [15] and Technical–Conceptual–Pedagogic–Practical Model (TCP Model) [16] have also been found to have a positive impact on the development of statistical literacy among students.

Based on the analysis, material-based teaching is the most widely studied teaching method in statistical literacy studies. Seventeen out of 36 articles discussed the influence of material-based teaching. Based on the analysis, studies showed different materials used for teaching statistics to observe their impact on the development of statistical literacy. These materials included Robot Bioglyphs [17], table construction templates [18,19], data from actual information [20,21,22,23], interactive songs [24], computer and internet [1,25,26,27,28], Mturk application [29], guidance questions or questionnaires [30,31], and Freakonomics books [32].

The teachers incorporated real-life statistical information, such as breakfast cereal boxes in the classroom discussions, as it enhanced students' understanding of the context of the statistical data being presented, and consequently, supported the development of statistical literacy among students [20].
Another study used newspaper articles as a source for statistical information [22]. It was found that a student-centered learning environment provides students with an opportunity to develop their understanding of statistical concepts and practice critical thinking in solving problems related to real-life situations. The studies focused on the use of technology such as computers, the internet, and visualization software in learning statistics [1,25,27]. These studies found that such approaches help students to enhance their conceptual understanding of statistics and reduced interference for them to fulfill the following statistics learning objectives. In contrast, compared the use of virtual learning and hybrid learning and found that the use of different learning formats did not affect the development of statistical literacy among graduate students [28]. Similarly, students who experienced virtual learning had similar pass rates, achievement in exams, and performance in statistical literacy assessment in comparison to students who learned statistics through hybrid methods [26].

4. Conclusion
In conclusion, this systematic literature review was conducted to explore issues about students' statistical literacy skills. The issues being studied were the factors influencing the students' statistical literacy development, as well as the teaching methods that influence the development of students' statistics literacy. These two issues served as a guideline throughout the process of article research, and subsequently, a total of 36 articles were selected for analysis. The study found that several factors affect the development of statistical literacy among students. These factors are demographic, learning environment, students' attitude, teaching methods, and basic statistical knowledge and skills. It was found that most articles focused on teaching methods, which refer to the learning medium applied by the teacher and the teaching styles that they adopt while carrying out statistics lessons. In this regard, the results of the analysis show that there are three commonly used methods in teaching statistics, which are teacher-centered, student-centered, and material-based. Out of these three methods, most studies have focused on the influence of material-based teaching on the development of statistical literacy among students.

The findings of this study, as a whole, demonstrate the importance of teachers' planning in teaching statistics at the schools and university level to achieve learning objectives, specifically in developing statistical literacy among students. Referring to teaching methods, the study shows that teachers do not only need to possess excellent statistical skills but also to choose the appropriate materials to conduct learning that captures the interest of the students. Students' statistical literacy skills are essential and need to be developed so that a knowledge of statistics can be applied in solving everyday life problems as part of an organized and intelligent community. It is important to note that this systematic literature review only involved articles that have focused on the development of statistical literacy among students at the primary, secondary, or university levels in a formal setting, specifically during the teaching, learning, and facilitating the process. A follow-up study could be conducted to examine the level of statistical literacy skills among the public to see how these statistical literacy skills are being applied in peoples' everyday lives.

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