

Realistic mathematics education combined with guided discovery for improving middle school students' statistical literacy

Titi Adriani Hakim^{*}, Wahyu Setyaningrum

Universitas Negeri Yogyakarta, D.I Yogyakarta, Indonesia.

^{*} Correspondence: titiadriani.2022@student.uny.ac.id

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Abstract

Statistical literacy is essential for students to evaluate and mitigate the spread of biased information critically and to make well-informed decisions grounded in data. Despite its recognized significance, many students face challenges in grasping statistical concepts. While Realistic Mathematics Education (RME) has demonstrated efficacy in enhancing overall mathematics learning outcomes, its specific influence on statistical literacy remains underexplored. This study sought to evaluate the effectiveness of integrating RME with guided discovery and Quizizz to enhance statistical literacy among middle school students. This approach utilized real-world contexts, facilitated active exploration, and provided personalized feedback to foster deeper understanding and engagement. Employing a pre-experimental design, the study involved 26 eighth-grade students and utilized a one-group pretest-posttest framework. The results indicated that post-test scores met the established passing criteria, with over 85% of students achieving classical completeness in learning. These results highlight the effectiveness of combining RME with guided discovery and Quizizz in advancing statistical literacy among middle school students. This research offers valuable insights into effective instructional strategies for promoting statistical literacy and provides practical implications for educators and curriculum developers aiming to innovate educational practices.

Keywords: guided discovery, Quizizz, realistic mathematics education, statistical literacy

Introduction

Society encounters a vast array of information, often supported by statistical data, across various domains such as economics, education, public opinion, and social behavior. This

information is commonly disseminated through news media on a daily basis. Consequently, adopting a critical perspective towards encountered information is imperative (Bailey & McCulloch, 2023) to avoid succumbing to misleading data (Hidayati et al., 2019) and to make informed decisions essential for sustaining one's livelihood (Setiani & Suyitno, 2021). A critical stance towards information serves as a key indicator of statistical literacy.

Statistical literacy encompasses the ability to interpret, critically evaluate, and effectively communicate statistical information (Gal, 2002). This competence enables students to identify biases and make data-driven decisions. Developing statistical literacy allows students to analyze data and draw insightful conclusions (Carter et al., 2011), thereby fostering their engagement as informed citizens in decision-making processes. Nevertheless, research by Aksoy & Bostan (2021) reveals that students often struggle with concepts such as variation and face difficulties in critically evaluating averages. Current middle and high school curricula frequently lack emphasis on these critical skills (Callingham & Watson, 2017), underscoring the necessity of incorporating comprehensive statistical literacy into mathematics education (Sharma, 2017).

To address this issue, educators can enhance students' statistical literacy through innovative teaching strategies, including new approaches, models, or methods. One such innovation is the implementation of Realistic Mathematics Education (RME), which is particularly well-suited for teaching statistical literacy due to its principles emphasizing real-world contexts. RME initiates learning with meaningful problem situations rather than abstract formulas, allowing students to develop mathematical concepts through the resolution of real-world problems (Fauzana et al., 2020). Additionally, RME conceptualizes mathematics as a human activity, thereby actively engaging students in the learning process and improving their statistical literacy (Listiwati et al., 2023).

The objective of RME is to utilize real-life experiences or scenarios relatable to students as a foundation for developing mathematical concepts and applying this knowledge to future situations (Uyen et al., 2021). Heuvel-Panhuizen & Drijvers (2020) suggest that "realistic" encompasses a broad spectrum, including real-world, imaginative, or formal mathematical contexts, as long as the problems are perceived as experientially real by students. RME is characterized by five key features: 1) contextualization in real-world scenarios; 2) development of models to convert situations into mathematical problems; 3) student-formed guided mathematical concepts; 4) interaction between students and teachers; and 5) viewing mathematics as an integrated subject (Tong et al., 2022).

Extensive research supports the effectiveness of RME in enhancing students' mathematical abilities. Juandi et al. (2022) demonstrated that RME significantly improved mathematical literacy compared to traditional learning methods, particularly in smaller sample sizes across various educational levels. Additionally, Andriani & Fauzan (2019) highlighted that RME positively impacts students' mathematical communication, especially in statistics.

Another promising approach is guided discovery, which can synergistically complement RME. Guided discovery involves students actively exploring mathematical concepts (Putri et al., 2020), aligning with RME's emphasis on rediscovering mathematical ideas. This method

requires teachers to proactively guide students towards discovering concepts that meet mathematical standards (Fauzana et al., 2020). Guided discovery enables students to explore and uncover concepts with teacher support, fostering inquiry-based learning (Hidayati et al., 2019). The teacher's role as a facilitator in guided discovery enhances students' engagement and concept development (Ishartono et al., 2019; Tayibu & Faizah, 2021).

Previous studies have demonstrated that guided discovery effectively enhances learning outcomes. Hidayati et al. (2019) found that students utilizing guided discovery outperformed those using traditional expository methods in mathematics learning. Ishartono et al. (2019) noted that guided discovery reduced students' reliance on rote memorization in geometric transformations, promoting meaningful learning. Tayibu & Faizah (2021) observed that cooperative guided discovery methods effectively engaged students in mathematics learning.

To further enrich these innovations, integrating online-based learning media can enhance classroom experiences. Quizizz, an interactive assessment application, allows students to participate actively in enjoyable and educational activities (Azzahra & Pramudini, 2022; Khasanah & Lestari, 2021). Quizizz facilitates monitoring of learning progress, repetition of quizzes, and leaderboard tracking, thus enhancing user engagement and motivation (Feladi et al., 2021; Munfarikhatin et al., 2021). It also includes features such as time allocation and points, which bolster participation and task completion (Agustia et al., 2021; Yunus & Hua, 2021). This tool serves not only as an evaluation mechanism but also as an engaging platform that can enhance students' cognitive abilities (Heckie et al., 2022).

Given the effectiveness of RME in mathematics education and its potential to improve statistical literacy, this study investigates the impact of combining RME with guided discovery and Quizizz on middle school students' statistical literacy. By assessing the effectiveness of this integrated approach, the study aims to provide practical strategies for educators to enhance students' statistical understanding. The findings are expected to reveal the benefits of incorporating interactive digital tools into mathematics education to foster critical thinking and problem-solving skills, offering valuable insights for curriculum developers and policymakers. Additionally, the research advocates for innovative instructional methods that cater to diverse learning styles and boost student engagement, ultimately aiming to improve the quality of mathematics education and better prepare students for real-world statistical challenges.

Methods

This pre-experimental study was conducted at a private middle school in Yogyakarta, utilizing existing study groups. The research employed a one-group pretest-posttest design. An eighth-grade class was randomly selected from a pool of two classes. The selection process involved random sampling from the two available eighth-grade classes, ensuring that all students had an equal opportunity to be chosen (Cohen et al., 2007). Among the 51 students in the eighth grade, 26 voluntarily participated in the study. These participants were enrolled in the 2013 curriculum and had previously received instruction in statistical concepts during their seventh-grade year. The students were classified as having low to medium abilities based on the school's ranking

within the private middle schools of Sleman Regency, Yogyakarta. Specifically, the school was ranked 45th out of 63 institutions, with an average score of 49.68.

The implementation of this research was structured into three distinct stages: 1) the preliminary stage, which involved administering the pretest; 2) the implementation stage; and 3) the concluding stage, which involved administering the posttest. Detailed information regarding the research implementation is provided in [Table 1](#).

Table 1. Implementation of the research

First meeting (60 minutes)	Preliminary Stage	Administration of Pretest on Statistical Literacy
Second Meeting (60 minutes)	Implementation Stage	Understanding the concept of averages and data presentation through problem-solving related to students' heights.
Third Meeting (60 minutes)		Understanding the concepts of median and mode through problem-solving related to runners' race times.
Fourth Meeting (60 minutes)		Understanding the concepts of range and quartiles through problem-solving related to a restaurant's monthly profits over a year.
Fifth Meeting (60 minutes)	concluding stage	Administration of Posttest on Statistical Literacy.

The study was conducted across five sessions. The first session commenced with a pretest to evaluate students' initial levels of statistical literacy before the application of Realistic Mathematics Education (RME) and guided discovery methods, supplemented by Quizizz. The second session focused on understanding averages and data presentation through contextual problem-solving involving students' heights. The third session addressed the concepts of median and mode through problem-solving activities related to runners' race times. The fourth session explored range and quartile concepts using a case study of a restaurant's monthly profits. The final session included a posttest to measure improvements in statistical literacy. This approach combined contextual problem-solving with teacher guidance and group discussions, promoting active student engagement and enhancing statistical understanding through real-life applications.

Data collection for this study was carried out using written pretests and posttests designed to assess statistical literacy. These tests were administered in an essay format to evaluate students' abilities in writing, organizing information, and explaining concepts (Nitko & Brookhart, 2011). Content validity of the tests was ensured through expert validation, confirming their relevance to the study objectives. The reliability coefficients for the pretest

and posttest were 0.687 and 0.704, respectively. The tests assessed various statistical concepts including data concentration, distribution, and presentation. They also evaluated skills in reading, understanding, interpreting, communicating, and evaluating data within personal and socio-cultural contexts, as detailed in [Table 2](#).

Table 2. Statistical Literacy Ability Test Instrument Content Outline

No	Indicator	Question
1.	Reading data	1, 2
2.	Understand statistical concepts	2
3.	Interpreting data	1, 2
4.	Communicate and evaluating the results of data processing	1, 2

During the learning process, teachers utilized an observation sheet to monitor both teacher and student activities, based on the Realistic Mathematics Education (RME) and guided discovery methods supplemented by Quizizz. This observation tool ensured that the learning procedures adhered to the planned instructional design. Observations encompassed preliminary activities, core activities involving contextual problem-solving and discussions, and concluding activities. The core activities included understanding, solving, comparing, discussing, and drawing conclusions from contextual problems.

The data analysis comprised both descriptive and inferential techniques. Descriptive analysis involved calculating statistical measures such as the mean, standard deviation, maximum, and minimum scores obtained by students. Inferential analysis tested hypotheses using a one-sided test (right-sided test). This included performing an average test using a one-sample t-test and a proportion test utilizing the z-test (Cohen et al., 2007).

Statistical literacy learning outcomes were assessed at two levels: individual and classical. Individual learning completion was based on achieving a minimum score of 70 and demonstrating an average normalized gain greater than 0.3 from pretest to posttest. Classical completeness required that at least 85% of students meet the minimum score criterion. Additionally, data from teacher activity observations were analyzed using both quantitative and qualitative methods.

Results and Discussion

The implementation of Realistic Mathematics Education (RME) combined with guided discovery and Quizizz occurred over five sessions. This included two sessions dedicated to pretesting and posttesting, and three sessions focused on learning statistics, specifically data presentation and measures of central tendency. The instructional process followed five key steps in the classroom: understanding contextual problems, solving these problems, comparing and discussing findings, and drawing conclusions. The Quizizz application used in this study allowed students to track their learning progress, retake quizzes, and view their rankings on a leaderboard during classroom quizzes (Feladi et al., 2021; Munfarikhatin et al., 2021).

The research results were analyzed using both descriptive and inferential methods. Descriptive analysis revealed significant improvements in students' statistical literacy test scores from pretest to posttest, with normalized gain values provided in [Table 3](#).

Table 3. Description of Statistical Literacy Ability Test Results

Description	Pretest	Posttest	Normalized Gain
Mean	38,88	78,92	0.6565
Standard Deviation	11,98	6,91	0,0899
Variance	143,706	47,834	0,008
Theoretical maximum score	100	100	
Theoretical minimum score	0	0	
Maximum Score	59	90	
Minimum Score	14	66	

[Table 3](#) indicates that the average pretest score for students' statistical literacy did not meet the school's minimum criterion of 70 prior to the implementation of Realistic Mathematics Education (RME) and guided discovery methods with Quizizz. However, the average posttest score increased to 78.92, surpassing the minimum criterion.

Subsequently, we conducted an inferential analysis to evaluate whether the integration of RME and guided discovery with Quizizz led to significant improvements in students' statistical literacy. This analysis involved hypothesis testing and an assessment of data normality using the Shapiro-Wilk test, with detailed results presented in [Table 4](#).

Table 4. Normality Test Results

Data	<i>p-value</i>
Pretest	0,584
Posttest	0,652
Normalized Gain	0.195

[Table 4](#) presents the *p*-values for the pretest (0.584), posttest (0.652), and normalized gain (0.195), all of which are greater than 0.05. These results support the acceptance of the null hypothesis (H_0) and indicate that the data follow a normal distribution. The study aimed to evaluate the effectiveness of Realistic Mathematics Education (RME) combined with guided discovery and Quizizz in enhancing middle school students' statistical literacy. This evaluation was based on three hypotheses: 1) posttest scores are equal to or greater than 70; 2) more than 85% of students achieve learning mastery; and 3) the average normalized gain is greater than 0.3.

To assess students' statistical literacy, researchers used school-specific criteria, taking into account factors such as student intake, the complexity of the material, and the support available (Mardapi et al., 2015). Results from the inferential analysis, utilizing a one-sample *t*-test, are detailed in [Table 5](#).

Table 5. Realistic Mathematics Education and Guided Discovery Effectiveness Test Results

Data	Mean	t_{count}	p-value
Posttest	78,92	58,187	0,000
Normalized gain	0,6565	37,229	0,000

Table 5 shows that the calculated t-value for the posttest data was 58.187, which exceeds the critical t-value of 1.706, with a p-value less than 0.05. This result leads to the rejection of the null hypothesis (H_0), indicating that the average statistical literacy score of the experimental class students met the minimum criterion of 70. Similarly, the calculated t-value for the normalized gain was 37.229, also surpassing the critical t-value of 1.706, with a p-value less than 0.05. This finding leads to the rejection of H_0 and demonstrates a significant improvement in statistical literacy from the pretest to the posttest, as reflected in the average normalized gain.

Additionally, a Z-proportion test was conducted to evaluate the classical learning mastery of students who engaged in the Realistic Mathematics Education (RME) approach combined with guided discovery and Quizizz. The results of this test showed a p-value less than 0.05, indicating the rejection of the null hypothesis (H_0). This suggests that the proportion of students achieving learning mastery with the RME and Quizizz approach exceeded 85% of all students who participated in the statistical literacy test.

**Figure 1.** Students' Use of Quizizz

The statistical analysis indicates that the use of Realistic Mathematics Education (RME) combined with guided discovery methods, supported by Quizizz, effectively enhances students' statistical literacy. Over 85% of students achieved mastery, and the average posttest scores surpassed the pretest scores. This educational approach demonstrates its effectiveness and aligns well with constructivist learning theories, suggesting its broader applicability in improving statistical literacy and other mathematical domains.

In this study, the researchers examined the integration of RME with guided discovery learning to bolster students' understanding of statistics. Ulandari et al. (2019) highlight that RME allows students to explore mathematical concepts with adult guidance through real-world problem-solving. This perspective supports Simamora et al.'s (2019) view that in guided discovery learning, the teacher plays a facilitative role. Consequently, combining RME with guided discovery learning merges the core principles of both innovative educational methods to enhance students' statistical literacy. The integration of RME and guided discovery learning can be implemented through various strategies, such as applying real-world contexts (Heuvel-Panhuizen & Drijvers, 2020), reconstructing mathematical knowledge, and providing teacher guidance (Ishartono, 2019).



Figure 2. The learning process using RME and Guided Discovery, along with the administration of the posttest

The learning activities were structured into four primary steps: 1) understanding contextual problems, 2) solving contextual problems, 3) comparing and discussing solutions, and 4) summarizing findings. This study investigated mathematics learning through a combined

approach of Realistic Mathematics Education (RME) and guided discovery learning, situated within personal and socio-cultural contexts.

Teachers utilized the guided discovery method, which involved posing directed questions to assist students in identifying mathematical patterns within real-world scenarios (Tayibu & Faizah, 2021). For instance, students engaged in tasks such as measuring heights, determining eligible school representatives for elections, and calculating monthly restaurant profits. The implementation of guided discovery significantly enhanced students' statistical literacy.

Quizizz was employed as an assessment tool to evaluate students' learning achievements following the lessons. It served to gauge student progress and understanding after the instructional activities.

The results of the students' posttest performance are illustrated in Figure 3 and Figure 4.

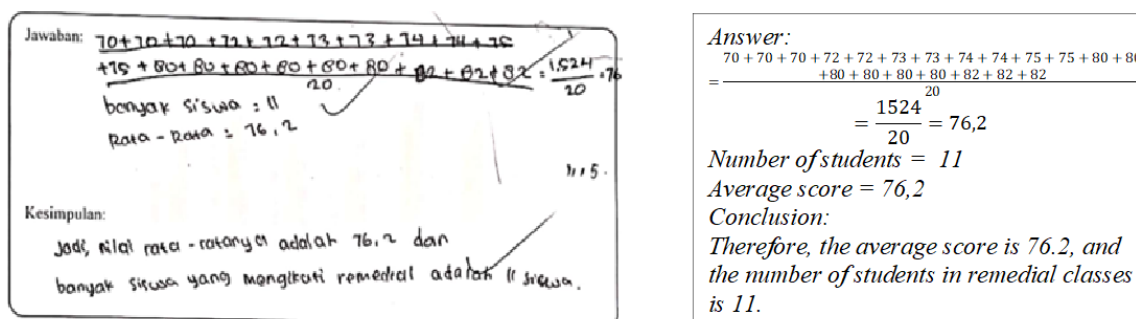
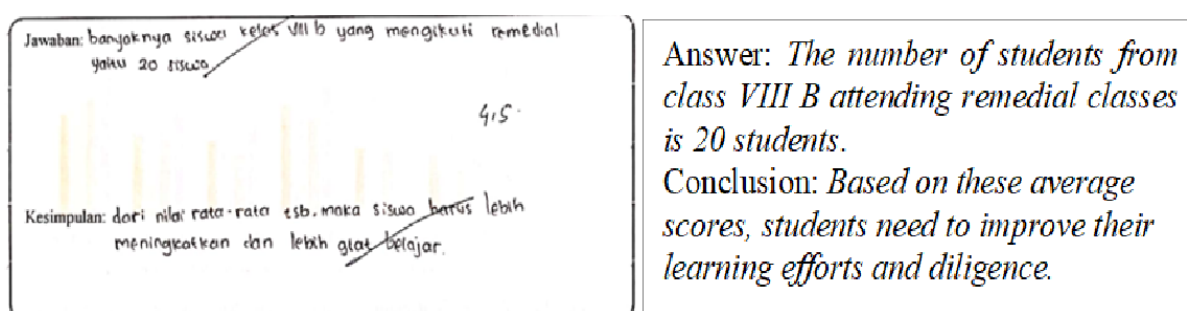


Figure 1 illustrates that prior to the implementation of Realistic Mathematics Education (RME) and guided discovery supported by Quizizz, students faced difficulties in understanding averages and drawing conclusions from the given problems. Conversely, Figure 2 indicates that after applying RME and guided discovery with Quizizz support, students demonstrated improved comprehension of the questions, enhanced ability to calculate averages, and greater proficiency in drawing conclusions based on the provided problems. This improvement reflects a significant enhancement in students' capabilities to understand and solve statistical problems. For additional results related to the range material, please refer to Figures 5 and Figure 6.

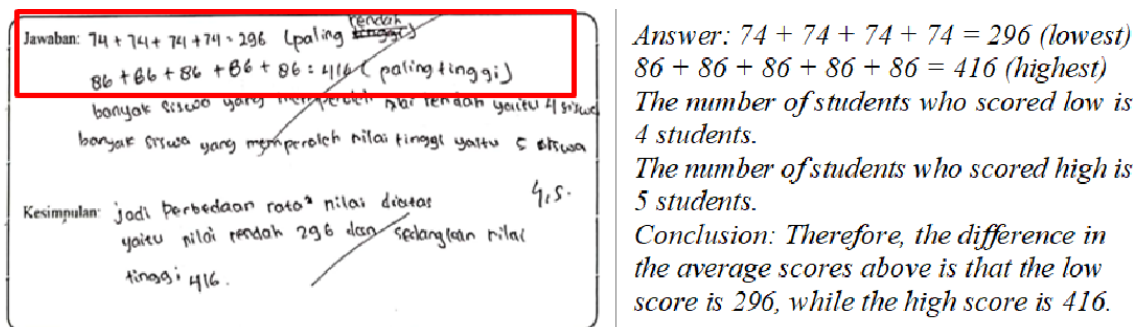


Figure 5. Pretest Results of Students on the Topic of Range

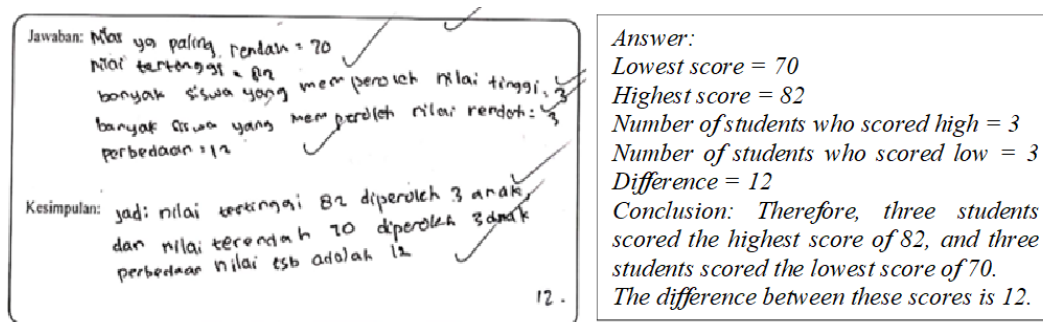


Figure 6. Posttest Results of Students on the Topic of Range

Figure 3 illustrates that prior to the learning intervention, students exhibited a fundamental misunderstanding of the concept of range. Specifically, they incorrectly used high values to determine the maximum and low values to determine the minimum. In contrast, Figure 4 demonstrates a marked improvement in students' comprehension of the range concept. They are now capable of accurately identifying the maximum and minimum values and calculating their difference.

The enhanced statistical literacy observed can be attributed to the implementation of Realistic Mathematics Education (RME) in conjunction with guided discovery methods, supported by the Quizizz platform. This approach is effective due to its structured learning process. Students participate in contextual problem-solving activities (Uyen et al., 2021) that facilitate a deeper understanding of statistical concepts. Initially, students investigate real-life statistical problems with guidance from teachers who stimulate critical thinking through targeted questioning (Hidayati et al., 2019). Collaborative discussions among students further consolidate their ability to interpret data.

Subsequently, group problem-solving sessions, led by teachers using structured worksheets, foster precise problem-solving strategies that enhance both conceptual understanding and the practical application of statistical principles. The final stage involves summarizing the learning experience with the teacher, followed by the administration of quizzes via the Quizizz platform. Quizizz plays a crucial role in assessing students' understanding, creating engaging learning experiences, and providing immediate feedback. In the realm of statistical education, Quizizz evaluates students' grasp of concepts such as mean, median, and range through interactive and challenging questions that encourage real-world

application of these concepts. Additionally, Quizizz enables teachers to monitor student progress in real time, facilitating the identification of areas that require further attention (Feladi et al., 2021; Munfarikhatin et al., 2021). The data derived from quiz results are utilized to conduct a comprehensive analysis of students' understanding, ensuring a robust comprehension of statistical concepts. Furthermore, Quizizz's features enhance student motivation and engagement, fostering a more enthusiastic approach to learning statistics (Azzahra & Pramudini, 2022; Khasanah & Lestari, 2021).

In conclusion, the integration of Realistic Mathematics Education and guided discovery methods, supported by Quizizz, significantly improves students' statistical literacy. The findings of this research suggest innovative learning strategies for enhancing statistical literacy among middle school students, offering practical applications for educators. Specifically, combining realistic mathematics education with guided discovery and Quizizz can increase student engagement and motivation, facilitating their ability to solve real-life problems involving data and information.

Conclusion

The integration of Realistic Mathematics Education (RME) with guided discovery, complemented by interactive learning platforms such as Quizizz, has demonstrated promising results in enhancing students' statistical literacy and deepening their understanding of complex mathematical concepts. The interactive nature of Quizizz engages students in contextual problem-solving activities, which effectively reinforces their grasp of statistical concepts. Research findings highlight significant improvements in student outcomes, affirming the effectiveness of this pedagogical approach.

To optimize learning outcomes, it is advisable for educators to implement well-structured classroom management techniques and to make optimal use of educational tools to sustain student engagement and focus throughout learning activities. However, this study acknowledges several limitations, including the small sample size from a single class, which affects the generalizability of the findings, and the use of a pre-experimental design, which constrains causal inferences. Additionally, relying predominantly on essay tests to assess statistical literacy may not encompass all relevant aspects of the construct. Future research should address these limitations by employing larger sample sizes, more rigorous experimental designs, and diverse evaluation methods to ensure a comprehensive assessment of statistical literacy.

Conflicts of Interest

No conflict of interest regarding the publication of this manuscript.

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