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Empowering students' critical thinking through the integration of statistical board teaching aids and problem-based learning

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Empowering students' critical thinking through the integration of statistical board teaching aids and problem-based learning

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Abstract

This study explores the impact of integrating a Statistics Board teaching aid within a Problem-Based Learning (PBL) model to foster students' critical thinking skills in learning statistics, specifically in the topic of single data. Employing a qualitative case study approach, the research involved prospective mathematics teachers and undergraduate students enrolled in an Offering E class of a Mathematics Education Program. Data were obtained through classroom video recordings, observational notes from the lecturer, and the use of the Statistics Board during learning sessions. The collected data were analyzed using an interactive analysis technique, encompassing data condensation, data display, and conclusion drawing. Findings demonstrate that the incorporation of the Statistics Board within a PBL setting significantly enhances students' engagement and conceptual understanding while promoting the development of higher-order thinking, particularly critical thinking. The tangible and visual nature of the teaching aid enabled students to navigate abstract statistical concepts more intuitively and collaboratively solve contextual problems. This research affirms the pedagogical value of integrating concrete teaching aids and student-centered learning models in mathematics instruction. It recommends the use of the Statistics Board as an effective instructional resource for both practicing teachers and teacher candidates, offering a pathway toward more innovative, engaging, and cognitively enriching mathematics classrooms.

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1. Introduction

Statistics is one of the branches of mathematics. Single data central tendency is a sub-topic within the broader domain of statistics. When solving problems related to single data, students often make errors in determining the mean, primarily due to the large volume of data, which leads to miscalculations. Additionally, students sometimes misidentify the median and mode, especially when the data presented is extensive. Moreover, statistics is often perceived as a difficult and less favored subject by students, as they find it tedious and challenging to compute large sets of data, which frequently results in calculation errors (Rosyidah & Mustika, 2021). In line with this, students tend to be less meticulous when analyzing statistical problems. Mistakes often arise from rushing through problems, forgetting the appropriate formulas, or lacking a solid understanding of the underlying concepts, all of which contribute to their difficulty in solving statistical tasks (Amalia, 2020).

Based on the data collected, it was evident that many students face considerable challenges in understanding fundamental statistical concepts, particularly those related to measures of central tendency in single data sets. A significant number of students exhibited difficulties in accurately calculating the mean and median, and frequently misunderstood the procedures for identifying the mode. Moreover, they struggled with interpreting and solving word problems, often committing computational errors—a tendency that is exacerbated by the typically large volume of data involved in statistical tasks. These persistent challenges contribute to students' negative perceptions of statistics, reinforcing the notion that it is a complex and intimidating subject. Statistics, in fact, can be viewed as a tool for solving real-life problems encountered in everyday life, the workplace, and various scientific fields (Yusuf, 2017). Broadly speaking, statistics is a discipline that develops techniques for processing numerical data and provides methods for analyzing information (Inayah, 2017). Today, statistics is widely applied across multiple fields, including economics, sociology, psychology, medicine, pharmacy, and many others. Therefore, it is essential for students to understand and master statistical concepts, given their broad and practical applications in life. Students are expected to develop a strong understanding of the definitions and distinctions among mean (average), median (middle value), and mode (most frequently occurring value) in single data sets, and be able to calculate them accurately. Furthermore, they should be able to apply these concepts to solve real-world problems. However, in reality, many students still encounter challenges in learning statistics. For this reason, it is necessary to develop a learning medium known as the Statistics Board to assist students in solving problems related to statistics, particularly in calculating the mean, median, and mode for single data sets. The Statistics Board teaching aid encourages students to be more active and engaged in the learning process and fosters their interest in the subject (Fauji et al., 2019). An illustration of the Statistics Board is presented in Figure 1.

Figure 1

Statistics Board



In the 21st century, education plays a highly important and strategic role in building a knowledge-based society equipped with the following skills: (1) technological and media literacy; (2) effective communication; (3) critical thinking; (4) problem-solving; and (5) collaboration (Agustina, 2019). Through mathematics learning, it is expected that students' critical thinking abilities can be fostered and developed. This aligns with the view of Putra & Amalia (2020), who state that mathematics emphasizes students' reasoning abilities, thus critical thinking—which is one level of higher-order thinking—can be cultivated through mathematics instruction.

A person's critical thinking ability is closely related to the process of critical thinking and its indicators. Therefore, an individual can be said to possess critical thinking skills if they meet the relevant indicators. The critical thinking indicators proposed by Karim & Normaya (2015) are presented in Table 1.

Table 1

Critical Thinking Indicators

Critical Thinking Criteria	Indicator
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Interpretation	Understanding the problem as demonstrated by accurately writing down the known information and the question being asked.
Analysis	Identifying the relationships between statements, questions, and concepts presented in the problem, as demonstrated by accurately creating a mathematical model and providing the correct explanation.
Evaluation	Using appropriate strategies to solve the problem, with complete and correct calculations.
Inferential	Being able to draw accurate conclusions based on what is being asked.

One of the keys to successfully developing students' critical thinking skills is the ability to select and apply appropriate learning models. The problem-based learning (PBL) model is one of the innovative instructional models that can facilitate students' direct involvement in the teaching and learning process (Afifah et al., 2019). The combination of the problem-based learning model and the statistics board teaching aid forms a learning model that is designed based on real-life problems. Students are then guided to systematically formulate alternative solutions, allowing them to develop their knowledge independently with the aid of the teaching tool. The steps of the problem-based learning model according to Ardianti et al. (2022) are presented in Table 2.

Table 2

Steps of the Problem-Based Learning Model

Phases in PBL	Teacher's Behavior
Phase 1 Provide directions about the problem to the students.	The teacher explains the learning objectives, outlines the essential requirements that need to be provided, and motivates students to engage in problem-solving activities.
Phase 2 Organize students to learn.	The teacher helps students define the problem and organize learning tasks related to the problem.
Phase 3 Investigation or research is conducted by individuals or groups.	The teacher encourages students to gather information, engage in appropriate experimental behavior, and search for explanations and solutions.
Phase 4 Presentation of the work results.	The teacher assists students in planning and preparing appropriate works, such as reports, videos, models, and helps students share tasks with other students.
Phase 5 Analysis and evaluation of the problem-solving process.	The teacher helps students reflect on the investigation and the process used.

The problem-based learning (PBL) model, when combined with the statistics board teaching aid, can help develop students' critical thinking skills. This aligns with research conducted by Wulandari (as cited in Arif et al., 2019), which found that the use of the problem-based learning model can train critical thinking, problem-solving, collaboration, and the ability to express ideas both orally and in writing. This is because the learning process in problem-based learning, such as gathering information, analyzing problems, and identifying possible solutions, encourages students to think critically.

The Statistics Board has proven to be a valuable instructional tool in facilitating students' understanding of statistical concepts, particularly measures of central tendency in single data sets. Its use becomes especially effective when integrated with contextualized learning, such as through story problems that mirror real-life situations. After engaging with these problems, students are encouraged to transfer the information into a tangible visual format using the Statistics Board. This process of data actualization enables students to organize, represent, and interpret data more concretely. The physical manipulation and visual layout of the board allow for clearer identification of patterns, which in turn simplifies the process of determining the mean, median, and mode. Additionally, this hands-on interaction fosters deeper conceptual understanding by bridging the gap between abstract numerical representations and real-world applications. The Statistics Board thus not only enhances procedural fluency but also promotes meaningful learning experiences that support the development of critical

thinking and problem-solving skills in statistics. This teaching aid has several advantages, including its ability to help students better understand statistical concepts, particularly in determining the mean, median, and mode of single data sets. It also helps teachers introduce variation in instructional methods and increases student engagement during the learning process. However, the statistics board also has limitations, such as being usable only for calculating the mean, median, and mode of single data sets, and not suitable for processing large datasets.

Research on the use of statistics boards as instructional media is not a new topic. This is evidenced by numerous previous studies on the use of the statistics board as a teaching aid across various methods and topics. For instance, research by Safitri et al. (2021) focused on the implementation of problem-based learning supported by statistics board media to improve students' mathematical communication skills; Danial et al. (2022) examined the effectiveness of statistics board media in mathematics learning; and Sintia et al. (2022) studied the effect of the statistics board on learning interest and learning outcomes in mathematics. Based on these studies, it is clear that the statistics board has become an important topic in educational research in recent years.

As a result, the researcher is interested in exploring the use of the statistics board as a teaching medium in mathematics learning. However, the present study differs from previous research in terms of its objective and research subjects. The aim of this study is to investigate the implementation of the statistics board teaching aid in combination with the problem-based learning model to enhance students' critical thinking skills, with the research subjects being students from Offering E of the Mathematics Education undergraduate program at Universitas Negeri Malang.

This study seeks to complement prior research and may serve as a valuable reference for current and future educators in designing classroom instruction—particularly in the topic of single data central tendency—so that mathematics learning becomes more engaging and enables students to clearly understand concepts such as mean, median, and mode. Therefore, this research is important in expanding knowledge and enriching existing literature in this field.

2. Methods

2.1 Research Approach and Type

This study employed a qualitative method with a case study approach. Qualitative research is used to explore phenomena in natural settings where the researcher acts as the key instrument, and the results emphasize meaning rather than generalization (Sugiyono as cited in Astuti, 2017). In this study, the qualitative approach was used to obtain descriptive data in the form of words or images from the teaching practices using the statistics board as an instructional aid. The case study design was chosen to gain a clear understanding of how the statistics board teaching aid was implemented in the learning process. Case study research serves as an effective means to illustrate the relationship between the researcher and the subject or informant (Lincoln & Guba as cited in Rahardjo, 2017).

2.2 Subjects and Procedure

The participants in this study comprised two groups: practitioner students and audience students. The practitioner students, who were prospective mathematics teachers, assumed the role of instructors, while the audience students acted as learners during the teaching sessions. This arrangement provided a simulated yet authentic teaching environment that allowed the practitioner students to apply pedagogical strategies in a controlled classroom setting. As part of the instructional process, the practitioner students delivered mathematics lessons utilizing the Statistics Board as a central teaching aid. The teaching sessions were structured around a Problem-Based Learning (PBL) model, in which real-world problems were presented to stimulate inquiry, exploration, and collaborative problem-solving. The integration of the Statistics Board into the PBL framework enabled the practitioner students to facilitate active learning experiences, encouraging audience students to engage with statistical content both visually and interactively. By guiding their peers through contextual problems and helping them visualize data on the board, the practitioner students not only reinforced their own understanding of statistical concepts but also developed essential teaching competencies such as classroom communication, instructional decision-making, and the ability to scaffold learning. This dual-role structure allowed for meaningful pedagogical reflection and skill-building, offering a unique opportunity to evaluate the effectiveness of instructional tools and approaches in real-time classroom scenarios. The practitioner students

demonstrated how to use the statistics board to solve problems related to the mean, median, and mode of single data sets. They then organized the classroom into small groups and distributed student worksheets (LKPD) to the audience students. The audience students presented their solutions in front of the class using the teaching aid, while the practitioner students facilitated the presentation session. Classroom activities included group collaboration in solving the LKPD, group representatives presenting their work, Q&A sessions between students, and feedback from the course lecturer.

2.3 Data Sources and Research Data

The data sources for this study were the practitioner students (acting as teachers) and the course lecturer. The research data consisted of video recordings of the classroom teaching practices using the statistics board. These videos provided direct insights into the teaching and learning activities, including teacher-student interactions, instructional strategies, and peer interactions among students. In addition, lecture notes from the course instructor offered perspectives on students' progress as prospective teachers, the weaknesses of the statistics board as a teaching medium, and areas of improvement for the practitioner students' instructional delivery. By combining both sources of data, this study aimed to present a comprehensive analysis of the learning process involving students as future educators.

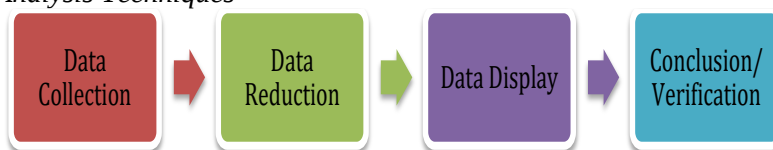
2.4 Data Analysis Technique

The data analysis technique used in this study was interactive analysis. The interactive model formulated by Miles and Huberman (as cited in Puguh & Feby, 2022) begins with data collection from video recordings and lecture notes. Next, data reduction was conducted by simplifying, categorizing, and eliminating irrelevant data from the video recordings in order to extract meaningful insights. After reduction, the data were presented in detail based on the teaching practices observed. Once the key data and categories had been clearly identified during data presentation, conclusions were drawn.

The process of interactive data analysis is illustrated in Figure 2.

Figure 2

Interactive Data Analysis Techniques



3. Results and Discussion

3.1 Results

As previously explained, this teaching practice was carried out by practitioner students acting as teachers and audience students acting as learners. Therefore, in this section, the terms "teacher" and "students" are used to represent the practitioner and audience students, respectively. The learning activity employed the statistics board teaching aid in conjunction with the problem-based learning (PBL) model, aimed at improving students' critical thinking skills. The lesson began with an opening activity, including a prayer, checking student attendance, and delivering a brief apperception to activate prior knowledge. The teacher asked students questions related to mean, median, and mode of single data sets through a PowerPoint presentation, and students actively responded. This can be seen in Figure 3.

Figure 3
Apperception Activity



The main activity continued with the teacher explaining how to use the statistics board teaching aid to solve problems involving mean, median, and mode of single data sets. This is illustrated in Figure 4.

Figure 4
Introduction to the Use of the Statistics Board Teaching Aid



The teacher then oriented students to the problem by dividing them into small groups and distributing student worksheets (LKPD) containing problems relevant to real-life contexts. An example of the LKPD is shown in Figure 5.

Figure 5
Example of a Problem in the LKPD

Permasalahan 1

Pak Eko mencatat pembelian baju di tokonya (dalam potong) selama 7 hari berturut-turut, diperoleh data sebagai berikut: 3, 4, 6, 5, 6, 5, 6. Tentukan mean, median, dan modus dari data tersebut!

Solusi :

After distributing the LKPD, the teacher encouraged students to work together to find solutions to the given problems. Once completed, a representative from each group presented their solutions using the statistics board teaching aid, with the teacher facilitating the presentation session. A representative presenting their group's answer is shown in Figure 6.

Figure 6
Group Presentation Representative



During the presentation, the teacher guided students in reflecting on and evaluating their results. After the presentations concluded, the teacher led the students in drawing conclusions about the lesson, with the help of the teaching aid. Students collaboratively summarized what they had learned. The learning session was concluded with the teacher giving motivation to students to continue learning, followed by a closing prayer.

In this session, students were visibly enthusiastic and actively engaged throughout the learning process. The learning activities closely followed the steps outlined in the problem-based learning model. Students' critical thinking abilities were evident during the lesson. This was demonstrated by their ability to accurately identify known and unknown elements in a problem (interpretation indicator), construct appropriate mathematical models, and provide accurate explanations (analysis). Additionally, students were able to employ proper strategies in problem-solving (evaluation), and draw appropriate conclusions based on the context of the problem.

3.2 Discussion

Based on the results presented, the statistics board is considered an appropriate instructional medium for teaching statistics, particularly in learning about the mean, median, and mode of single data sets. This is because it facilitates students' understanding of how to determine the mean, median, and mode from single data. By using the statistics board as a teaching aid, data visualization becomes clearer, making it easier for students to calculate these statistical measures. Students also find it easier to count the total number of data points, as the data is already visualized through the statistics board. The board's attractive design also prevents students from becoming bored during the learning process.

Furthermore, this medium can be used by teachers to create variety in instruction. Teachers are not limited to explaining how to determine the mean, median, and mode on the whiteboard; instead, they can utilize the statistics board to make learning more interactive. This aligns with the findings of Devi et al. (2022), who stated that the statistics board aids teachers in delivering lessons on mean, median, and mode more effectively. According to Rosyidah et al. (2022), the use of the statistics board can make mathematics learning more effective and enjoyable, as it helps avoid tedious manual work.

Despite its advantages, the statistics board also has limitations. This tool is only suitable for calculating the mean, median, and mode of single data sets. Additionally, it cannot be used for large data sets, and the colored bars on the board do not represent any specific meanings, which can confuse users regarding the function of the color combinations. Rosyidah et al. (2022) also noted that if the statistics board is used only at the beginning or end of a lesson, students may become less motivated to solve problems manually.

In the learning practice, during the preliminary activity, the teacher provided an apperception activity by asking questions about the concepts of mean, median, and mode of single data to assess students' prior knowledge. Providing apperception at the beginning of a lesson is important, as it promotes student readiness to learn (Agustina, 2019). During this stage, students were observed to be capable of answering questions correctly.

Throughout the lesson, students were actively and enthusiastically engaged in the learning process. Each group appeared to be competing to solve the problems provided in the worksheet (LKPD), and they were able to complete the tasks correctly. Students who have an interest in a subject are more likely to study it diligently (Sholehah et al., 2018). This suggests that using the statistics board as a

teaching aid can foster greater student enthusiasm in learning. This finding is consistent with the study by Nufus & Isyafani (2022), which revealed that students were attracted to the use of the statistics board during the learning process, making it easier for them to understand data processing concepts.

During the group presentations using the statistics board, students also demonstrated enthusiasm in presenting their findings. However, in this learning practice conducted by university students, there was a conceptual misunderstanding regarding the median of an even-numbered data set. According to the researcher's lecturer notes, the median is not necessarily a single value. This is supported by Lee & Max (1992), who explained that if a data set has an even number of elements, the median can be considered any value between the two middle observations Y_k and Y_{k+1} where $k = \frac{n}{2}$, although the book also states that the median is commonly taken as the average of these two values Y_k and Y_{k+1} .

Based on the results of this study, the use of the statistics board teaching aid, combined with the problem-based learning model, was found to be effective in helping students understand concepts related to the mean, median, and mode of single data sets. This aligns with the findings of Danial et al. (2022), who found that the statistics board media successfully aided students in understanding data processing material, thereby encouraging more active participation in class and improving learning outcomes.

Learning with the help of the statistics board and problem-based learning model is also seen as effective in enhancing students' critical thinking skills. Through this approach, students not only gain conceptual understanding of statistics—particularly mean, median, and mode of single data—but are also engaged in solving real-world problems that encourage critical thinking.

4. Conclusion

Based on the research findings and discussion regarding the use of the statistics board teaching aid combined with the problem-based learning model aimed at enhancing students' critical thinking skills, it can be concluded that learning with the statistics board can facilitate students in understanding concepts related to the mean, median, and mode of single data sets. Through the use of the statistics board, students are able to visualize data and grasp statistical concepts effectively. Moreover, implementing the problem-based learning model can improve students' critical thinking skills. Therefore, the integration of the statistics board with the problem-based learning model can serve as an alternative approach to enhance students' critical thinking abilities.

The researcher hopes that the use of the statistics board combined with the problem-based learning model can be adopted as a teaching strategy by teachers to improve the quality of instruction, particularly in statistics, and to foster students' critical thinking. Furthermore, considering the strengths and limitations of using the statistics board as revealed in this study, it is expected that this can serve as a reference for future instructional practices to achieve optimal learning outcomes. The researcher also hopes that this study can be used as a reference for future research, and that subsequent studies may involve larger and more diverse samples to obtain more optimal and representative results.

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The author declares no conflict of interest regarding the publication of this paper.

Ethical Approval

This study did not involve any human or animal experimentation and thus did not require ethical approval.

Informed Consent

All participants involved in the study were informed about the research procedures and voluntarily agreed to participate.

Author Contributions

The author solely designed, conducted, analyzed, and wrote the manuscript.

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