Exploring student's conceptual understanding of statistics towards the problem-based learning model

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Abstract

This study aims to explore Grade XI students' concept understanding of statistics at SMA Negeri 1 Insana through the implementation of the Problem Based Learning (PBL) model. A qualitative case study approach was employed through classroom observation, concept-understanding tests, LKS analysis, and student interviews. The findings showed that PBL encouraged active engagement in understanding the concepts of mean, median, and mode through real-world problem exploration. Students' conceptual understanding improved based on test results: 1 student achieved very good, 26 good, and 3 fair. The average conceptual understanding score was 78.31 (good category). Teacher activity reached 70% (fairly good), while student activity reached 68% (fair). These findings indicate that PBL supports students in independently and contextually constructing their conceptual understanding. In conclusion, the PBLmodel effectively enhances students' conceptual understanding of statistics, as shown by the dominance of students in the good category. The implications of this study indicate that PBL can be applied as an alternative instructional approach to improve conceptual understanding and learning engagement in statistics. Teachers are encouraged to strengthen the reflection and feedback stages to further support students' mastery of concepts.

Keywords: conceptual understanding, exploration, mathematics learning, problem based learning, statistics

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INTRODUCTION

Education is a continuous process of growth and development (Aprilita & Handican, 2023). One of its key goals is to develop students' conceptual understanding of mathematics so they can solve problems, apply concepts in real-life contexts, and build other essential skills (Handayani et al., 2015). Without adequate conceptual understanding, mathematics learning objectives cannot be achieved effectively.` Moreover, conceptual understanding serves as the foundation for meaningful learning, enabling students to connect new knowledge with prior experiences, reason mathematically, and transfer their learning to unfamiliar situations. Students who possess strong conceptual understanding are more

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likely to demonstrate flexibility in problem-solving, make logical connections among mathematical ideas, and develop higher-order thinking skills necessary for lifelong learning.

Previous studies reveal that students' conceptual understanding remains low (Nuraeni, 2018) found that students struggle due to low reading motivation and limited effort in seeking references. (Febiwanti et al., 2023) also noted that students tend to follow the teacher's examples mechanically without deeper exploration of concepts, resulting in confusion when faced with unfamiliar problems. This concern continues to be reported in recent studies. (Abakah & Brijlall, 2024) emphasized that conceptual misconceptions hinder students' ability to develop meaningful mathematical understanding and rational reasoning. Likewise, (Sandra, 2025) reported that students frequently experience difficulties in understanding mathematical concepts because of weak prerequisite knowledge, leading to poor performance in applying concepts across different problem contexts. In addition, a literature review by (Yatri et al., 2025) concluded that students' difficulties in conceptual understanding are strongly influenced by cognitive factors, particularly their inability to connect basic mathematical concepts with new situations and real-world applications.

A similar situation occurs at SMA Negeri 1 Insana which is located in the Insana District, North Central Timor Regency (TTU), East Nusa Tenggara Province (NTT), where observations show students' difficulties in understanding basic mathematics concepts, representing concepts in multiple forms, and applying them logically. Many Grade XI students made errors in determining data values, writing procedures, and interpreting averages, indicating low conceptual understanding particularly in restating, connecting, and applying statistical concepts.

These conditions are consistent with findings reported in earlier studies. Yulia and Natalia (2020) emphasized that low conceptual understanding is often rooted in students' lack of motivation to read and search for additional references. Likewise, Husna (in Yulia and Natalia, 2020) explained that students frequently struggle when confronted with problems that differ from teacher-provided examples due to weak foundational understanding. Ratnasari and Yulia (2018) further highlighted that students tend to rely solely on teacher explanations without independently exploring concepts, limiting their ability to build deeper and more flexible understanding. These findings align with issues observed in SMA Negeri 1 Insana and show that students need learning conditions that support active engagement, exploration, and conceptual construction.

To address these issues, an effective learning model is required. PBL has been proven to improve learning performance and problem-solving skills. (Utami & Mardhiyana, 2023) found that PBL significantly enhances students' understanding of statistics. The model encourages exploration, discussion, and student-driven concept construction. (Wibawa et al., 2023) reported that students who learned through the PBL model showed a greater improvement in mathematical conceptual understanding than those who experienced conventional learning. Similarly, (Nurlaili et al., 2023) found that PBL has a significant effect on students' understanding of mathematical concepts because it promotes active participation and encourages students to connect new knowledge with prior learning experiences. Therefore, this study was exploring students' conceptual understanding of statistics through the PBL Model in Grade 11.

METHODS

This study employed a qualitative case study design to explore students' conceptual understanding of statistics within the PBLmodel. Qualitative research, as described by (Bogdan & Taylor,

Quoted in Moleong, 2018), emphasizes detailed descriptions of written or spoken data and observed behavior, making it suitable for investigating phenomena that cannot be analyzed through statistical procedures. This approach was selected because the research problem required an in a depth interpretation of students' learning experiences, conceptual difficulties, and meaning making processes during PBL implementation.

The subjects of this research were Grade 11 students at SMA Negeri 1 Insana who participated in PBL based statistics lessons, while the object of the study was their conceptual understanding after the learning process. Data were collected using several instruments: observation sheets to assess teacher and student activities, concept-understanding tests based on validated indicators, student worksheets (LKPD) to capture learning exploration, and semi-structured interviews to obtain deeper insights from selected students and the teacher. Supporting documentation such as lesson modules, student work, and photos or videos of classroom activities was also gathered to reinforce the findings.

Data collection techniques consisted of observation, testing, interviews, and documentation. The data were analyzed through data reduction, data display, and conclusion drawing. Observation results were converted to percentages to evaluate implementation levels, test responses were scored according to conceptual understanding indicators, worksheets were qualitatively examined for procedural and conceptual errors, and interview transcripts were analyzed thematically. Triangulation across observation sheets, tests, worksheets, and interviews ensured the validity and consistency of the findings.

$$\text{Ni} = \frac{\text{Total Indicator Score}}{\text{Maximum Score Of Class Indicator}} \times 100$$

Maximum score of indicators (questions) = 3
Number of students = 30
Maximum score of class indicators = 3×30 = 90

The research procedure consisted of planning, data collection, data analysis, and conclusion drawing. The planning stage included constructing the background, research questions, instruments, and obtaining expert validation and school approval. Data collection was carried out through the implementation of PBL lessons, followed by conducting observations, administering tests, distributing worksheets, interviewing participants, and gathering documentation. The analysis stage involved organizing and interpreting all collected data, while the final stage drew inductive conclusions to answer the research questions and classify students' conceptual understanding based on predetermined criteria.

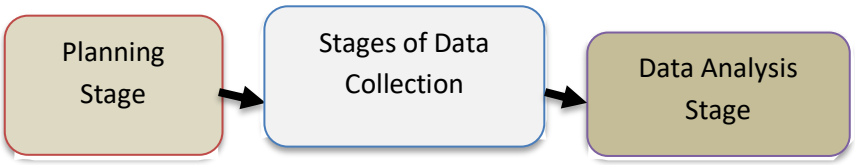


Figure 1. Research Procedure

RESULTS AND DISCUSSION

During the data collection stage, the researcher implemented the PBLmodel as the main strategy to explore students' conceptual understanding of statistics. The learning process followed the five PBL

phases, each serving as a key source of data to observe how students constructed and developed their understanding of mean, median, and mode. The lesson began with greetings, prayer, and attendance checking, followed by having the observer monitor the implementation of the model and student activity throughout the lesson. The researcher then oriented students to a contextual problem related to real life situations, which served as a trigger question to elicit students' initial conceptual understanding, identify important information, and connect the problem to statistical concepts before group discussion. After a student successfully answered the trigger question and no further questions arose from the class, the lesson proceeded to the next stage.

To explore conceptual understanding more deeply, the researcher organized students into five groups of six and distributed the worksheets (LKPD) to be completed collaboratively. This grouping allowed students to explore concepts through interaction, discussion, and exchange of ideas (Fitrah et al., 2022). The researcher explained the group tasks, learning objectives, and problem-solving steps that students needed to investigate, showing how students began to formulate initial strategies and identify statistical concepts. Students then engaged in the investigation stage by interpreting data, calculating the mean, median, and mode, and reviewing their solution steps. The researcher acted as a facilitator, providing guidance when necessaries without reducing student independence. This investigation process became the most crucial part of the exploration, as it showed how students gradually built their conceptual understanding, corrected mistakes, and verified their ideas through peer interaction.

After completing the investigation, each group presented their work in front of the class. These presentations displayed the statistical concepts used, while other groups provided responses in the form of questions or additional explanations. This interaction strengthened the exploration of conceptual understanding by encouraging students to clearly communicate mathematical ideas and defend their reasoning based on correct concepts. The lesson concluded with a reflection session in which students reviewed errors, effective strategies, and the statistical concepts they had learned. This reflection provided deeper insight into how students' conceptual understanding developed during the PBL process and served as the basis for evaluating the consistency of students' understanding both individually and in groups. The results of the student worksheets (LKPD) are presented in the following table.

Table 1. The Classification of Student Worksheets

Group name	N1	N2	N3	N4	Score	Value	Category
Group 1	3	1	1	2	7	58,33	Enough
Group 2	2	1	1	1	5	41,66	Not Good
Group 3	2	2	3	1	8	66,66	Enough
Group 4	3	1	3	3	10	83,33	Good
Group 5	3	1	3	2	9	75,00	Good
Total value						324,98	
Percentage						64,99	

Note: *N1, N2, N3, and N4 refer to the numbering of the test items.*

The table shows that the average LKPD score is 64.99, categorized as fair. Groups 4 and 5 achieved the good category, Groups 1 and 3 were in the fair category, and Group 2 fell into the poor category. During this stage, observers monitored the implementation of the PBL model to evaluate how it supported students' understanding of statistical concepts, particularly measures of central tendency. Observations were conducted throughout the lesson to document the teacher's adherence to PBL steps and students' engagement. The observer examined how the teacher presented problems, guided

discussions, facilitated group work, and provided feedback, while also noting students' participation, collaboration, questioning, and ability to complete LKPD tasks. The results show that the teacher's activity reached an average percentage of 70%, categorized as fair, while student activity obtained 68%, also categorized as fair. These findings indicate that both teacher implementation and student engagement during the PBL process were sufficiently carried out.

At this stage, the concept understanding test was administered after the completion of the PBL learning process. The test aimed to determine each student's level of mastery of statistical concepts. The researcher collected all student answer sheets for evaluation, and the test results are presented in the following table.

Based on the test analysis, the average score was 78.31, calculated from a total score of 2,349.51 divided by 30 students. The results show that 1 student achieved the excellent category, 26 students were in the good category, 3 in the fair category, and none in the poor category. With a mastery percentage of 78.31, students met the predetermined success indicator of 75. Based on the test results that had been examined, the researcher selected three students to be interviewed according to the established categories (Purwanto, 2019). The purpose of the interview was to explore more deeply the students' understanding, difficulties, and the learning strategies they used. abbreviations.

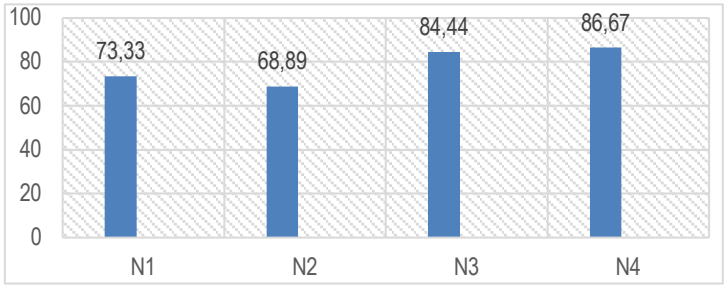


Figure 2. Indicator Value Bar Chart

Based on the analysis of the results of the student concept understanding test, it can be seen that 1 student reached the very good category, 26 students reached the good category, 3 students reached the fairly good category. The score with a percentage of completeness is 78.31, this shows that the completeness of student learning has reached the predetermined success indicator, which is 75. These results are reinforced with a bar chart of concept understanding based on indicators. This shows that the application of the PBL learning model is able to develop an understanding of statistical concepts evenly in each indicator.

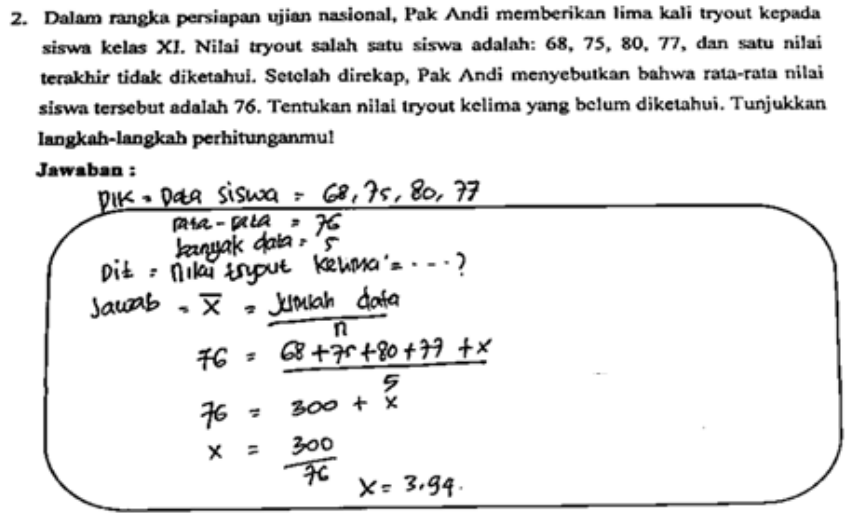
Table 2. Students Selected to Be Interview Subjects

Number	Student Name	Category	Student code
1.	MB	Excellent	Subject 1
2.	ERU	Good	Subject 2
3.	ASN	Enough	Subject 3

This selection aims to obtain a deeper picture of the differences in thinking processes, problem-solving strategies, and obstacles experienced by students at each level of ability. The interview was conducted in a semi-structured manner guided by the steps of the PBL model, namely problem orientation, group organization, investigation, presentation of work results, and analysis and evaluation.

This approach allows researchers to dig into information in detail based on students' hands-on experience during problem-based statistical learning. The following are the results of interviews with 3 subjects selected according to their respective abilities:

MB was able to meet almost all indicators of concept understanding, as evidenced by the success of answering three out of four questions correctly. The only mistake was in question number 2, so the interview was focused on identifying indicators that MB had mastered and that MB had not mastered in the question.


2. Dalam rangka persiapan ujian nasional, Pak Andi memberikan lima kali tryout kepada siswa kelas XI. Nilai tryout salah satu siswa adalah: 68, 75, 80, 77, dan satu nilai terakhir tidak diketahui. Setelah direkap, Pak Andi menyebutkan bahwa rata-rata nilai siswa tersebut adalah 76. Tentukan nilai tryout kelima yang belum diketahui. Tunjukkan langkah-langkah perhitunganmu!

Jawaban :

Dik = Data siswa = 68, 75, 80, 77
rata-rata = 76
banyak data = 5
Dit = Nilai tryout kelima = ...?
Jawab = $\bar{X}$ = $\frac{\text{Jumlah data}}{n}$

$76 = \frac{68+75+80+77+x}{5}$

$76 = 300 + x$

$x = \frac{300}{76}$

$x = 3,94$.

Figure 3. The Response of MB for Number 2

The interview with MB was conducted to trace the error in question number 2. The analysis based on four indicators of concept understanding shows the parts of the concept that MB has mastered and that MB has not understood. MB understands the concept of mean correctly and is able to identify the wrong data on the question, which is a value of 60 which should be 86. He also knows that a change in one data will affect the mean. The completion step used is correct, namely calculating the initial mean, replacing the wrong data, and then calculating the new mean. However, the error occurred because MB made a mistake when summing the initial data so that the final result did not match.

The ERU meets most of the indicators of concept understanding by answering three correct questions. The mistake is only in question number 4, so the interview is focused on indicators that have not been mastered.

4. **Sebuah toko buku mencatat jumlah buku tulis yang terjual selama 10 hari terakhir: 120, 135, 140, 135, 150, 145, 135, 140, 150, 135.**
   a. **Tentukan modus dari data penjualan tersebut.**
   b. **Jelaskan langkah-langkahmu dalam menemukan modus.**
   c. **Menurutmu, bagaimana informasi modus ini bisa digunakan oleh pemilik toko untuk mengatur stok barang?**

Jawaban :

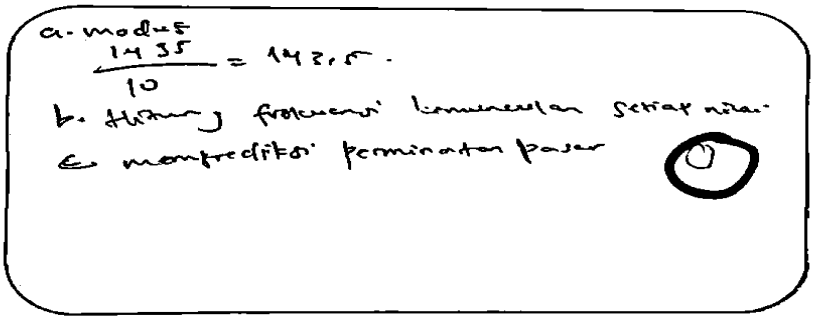


Figure 4. The Response of ERU for Number 4

An interview with ERU was conducted to find out the cause of the error in question number 4 based on four indicators of concept understanding. The ERU knows that the mode is the most frequently occurring value, but it cannot determine the data with the highest frequency of the problem. He is also unable to give examples of using modes, does not know the initial steps to find modes, and does not understand how modes are applied in real world situations such as store sales.

ASN is only able to answer two questions (numbers 3 and 4) correctly, while questions number 1 and 2 cannot be solved, thus showing a low understanding of concepts in this section. Therefore, the interview is focused on tracing the indicators that have been met and those that have not been mastered by ASN in these two questions.

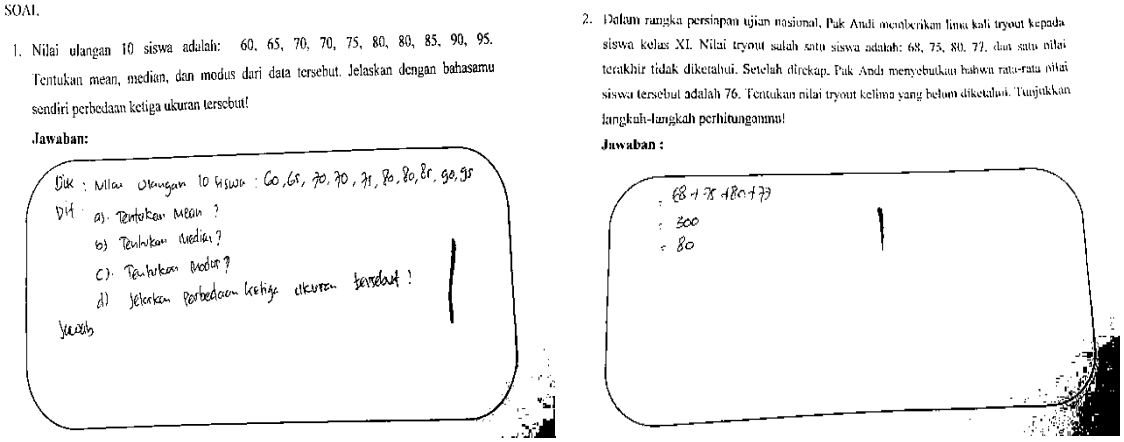


Figure 5. The response of ASN for number 1 and 2

Interviews with ASN were conducted to trace the causes of errors in questions number 1 and 2, with the analysis focusing on fulfilling four indicators of concept understanding. ASN shows a very low understanding of concepts. In question number 1, ASN does not know the definition of mean, median, and mode, and does not understand the basic completion steps. In question number 2, ASN understands that one value is unknown, but does not understand the concept of average or how to use average values to find lost data. ASN only added up four values because they did not understand the correct procedures. Overall, ASN has not mastered the basic steps in solving statistical problems.

Discussion

The results of the study show that the application of the PBLlearning model to statistical materials helps students gradually build understanding of concepts. This can be seen from the results of the LKPD, class observations, concept comprehension tests, and interviews. All of these data complement and reinforce each other, so that the picture of students' abilities can be seen more clearly through triangulation of methods and triangulation of sources. These findings are in line with the research of Aguirre et al., (2022) who concluded that collaborative problem-solving in the PBLlearning model is able to gradually improve conceptual understanding.

For instance, (Yew & Goh, 2016) argued that the student-centered nature of PBL promotes meaningful learning by engaging learners in authentic problem situations that require conceptual reasoning rather than procedural memorization. Similarly, (Andini & Siregar, 2024) reported that students who participated in PBL-based mathematics learning demonstrated better conceptual understanding and greater engagement in the learning process than those who experienced conventional instruction. These findings suggest that the gradual improvement in students' conceptual understanding observed in this study was facilitated by opportunities to collaboratively explore problems, exchange ideas, and construct mathematical meaning throughout the learning process.

In the learning process, students worked in groups to solve problems through LKPD. The results of the LKPD showed an average percentage of 64.99, which falls into the fairly good category. Some groups were able to follow the problem-solving steps appropriately, while others still experienced difficulties because they were not actively involved in asking questions or participating in discussions. These findings are consistent with Kurniawati and Supriyono (2022), who reported that limited participation often hinders students' understanding of statistical concepts. Recent studies have similarly emphasized the importance of active engagement in collaborative learning. (Tang et al., 2025) found that students' participation in mathematical discussions significantly influences the effectiveness of collaborative problem-solving processes, with active interaction facilitating deeper conceptual understanding. Furthermore, (Rohim et al., 2025) reported that the implementation of Problem-Based Learning (PBL) increased both students' conceptual understanding and learning activeness, indicating that active involvement during learning is a key factor in achieving meaningful understanding. Observation of student activities in this study showed a fairly good category. Students were observed cooperating within their groups, although some remained hesitant to ask questions when encountering difficulties. Teacher activities were also categorized as fairly good. The teacher implemented the PBL syntax appropriately, particularly in presenting problems, organizing students into groups, and facilitating the investigation process. These findings are supported by a recent systematic review by (Ayari et al., 2025), which concluded that PBL promotes student engagement, collaboration, and higher-order thinking skills when teachers effectively facilitate inquiry and discussion throughout the learning process.

Based on the results of the observation table of teacher activities, there are 3 aspects that have not been met. This is due to the limited learning time so that teachers or researchers focus more on the delivery of main problems and student assistance in group discussions, as a result of which some supporting activities such as deepening reflection and managing learning follow-up cannot be carried out optimally at the meeting. However, in general, teachers are still able to carry out the main stages of problem-based learning in accordance with the PBL syntax, so that learning goals are still achieved. Only the reflection part at the end of learning has not run optimally so that not all students have a thorough understanding of the concept where reflection activities in learning with the PBL model play an important

role in helping students review the process and results problem solving that has been done. This supports the research results of Fauzi and Widjajanti (2021) which emphasizes the importance of reflection as a final step to deepen the understanding of mathematical concepts. After the learning is completed, a concept comprehension test is given to see the mastery of the concept individually.

The results of the student concept understanding test showed completeness with an average percentage of 78.31, exceeding the success indicator of 75. The majority of students are in the good category. The results are then presented in the form of a concept understanding bar diagram based on indicators to clarify the distribution of student achievements. The diagram shows that the indicator restates the concept of obtaining a percentage of 73.33, the indicator classifies objects according to the concept of obtaining a percentage of 68.89, the indicator provides examples and non-examples obtains a percentage of 84.44, and the indicator applying concepts or algorithms obtains a percentage of 84.44, and the indicator applying concepts or algorithms obtains a percentage by 86.67. The percentage difference shows the variation in the level of student understanding of each indicator, with the highest achievement in the ability to apply concepts or algorithms and the indicator with the lowest achievement in the ability to classify objects according to concepts. Indicators classify objects according to concepts Being the lowest achievement indicator, based on interviews, students still have difficulty in determining data grouping criteria and distinguishing data types according to statistical concepts. This causes students' ability to classify objects according to concepts is still low. These findings are supported by a study by Megawati et al, (2024) which concluded that the application of the PBLmodel significantly improves students' ability to understand mathematical concepts, especially in students' ability to apply concepts after being actively involved in solving real problems, compared to conventional learning. Overall, these results show that group discussions, presentations, and explanations in the application of the PBLlearning model are able to help students in improving their understanding of statistical concepts as a whole.

Problem solving that has been done. This supports the research results of Fauzi and Widjajanti (2021) which emphasizes the importance of reflection as a final step to deepen the understanding of mathematical concepts. After the learning is completed, a concept comprehension test is given to see the mastery of the concept individually. The results of the student concept understanding test showed completeness with an average percentage of 78.31, exceeding the success indicator of 75. The majority of students are in the good category. The results are then presented in the form of a concept understanding bar diagram based on indicators to clarify the distribution of student achievements. The diagram shows that the indicator restates the concept of obtaining a percentage of 73.33, the indicator classifies objects according to the concept of obtaining a percentage of 68.89, the indicator provides examples and non-examples obtains a percentage of 84.44, and the indicator applying concepts or algorithms obtains a percentage of 84.44, and the indicator applying concepts or algorithms obtains a percentage by 86.67. The percentage difference shows the variation in the level of student understanding of each indicator, with the highest achievement in the ability to apply concepts or algorithms and the indicator with the lowest achievement in the ability to classify objects according to concepts. Indicators classify objects according to concepts Being the lowest achievement indicator, based on interviews, students still have difficulty in determining data grouping criteria and distinguishing data types according to statistical concepts. This causes students' ability to classify objects according to concepts is still low. These findings are supported by a study by Megawati et al, (2024) and (Ramayani & Lubis, 2025) which concluded that the application of the PBLmodel significantly improves students' ability to understand mathematical concepts, especially in students' ability to apply concepts after being actively involved in

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CONCLUSION

The findings of this study indicate that the implementation of the PBL model effectively improved the statistical concept understanding of Grade XI students at SMA Negeri 1 Insana. It also shows that PBL provided opportunities for students to explore problems independently, collaborate in groups, and

construct deeper conceptual understanding. The average concept-understanding categorized as good, demonstrates that most students were able to classify data, provide examples and non-examples, and accurately apply the concepts of mean, median, and mode. PBL also enhanced student activity during the learning process, although participation remained uneven across groups and was still categorized as fair. Teacher activity was rated as fairly good, although the reflection stage and delivery of conceptual feedback require improvement to further strengthen students' understanding. Overall, this study confirms that PBL is an effective instructional model for improving students' statistical concept mastery. It offers meaningful learning experiences, promotes critical thinking, and helps students connect mathematical concepts with real life situations. Therefore, the application of PBL is recommended for mathematics teachers as a strategy to enhance the quality of instruction, particularly in statistics.

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