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# The Effect of Technology-Based PBL Learning on Junior High School Students' Mathematical Representation Ability in Data Centralisation Material

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***Abstract:*** *The low level of students' mathematical representation ability became the background of this study. The research aimed to analyse the effect of implementing the Problem-Based Learning (PBL) model assisted by interactive PowerPoint media and Microsoft Excel on students' mathematical representation ability. The research method used was a quasi-experiment with a pretest-posttest control group design. The sample consisted of 40 eighth-grade students divided into an experimental group and a control group. The research instrument was a mathematical representation ability test that had been validated and proven reliable. Data were analysed using a t-test and N-Gain calculation. The results showed that the N-Gain score in the experimental class reached 0.82 (high category), while in the control class it was only 0.22 (low category). The difference was statistically significant ($t = 20.316$; $p < 0.000$). Thus, it can be concluded that integrating PowerPoint and Excel into the PBL model is effective in improving students' mathematical representation ability, particularly in presenting data in the form of graphs and tables. This research implies that a PBL model supported by digital media can serve as an innovative alternative for mathematics learning.*

***Keywords:*** *Problem Based Learning (PBL);* Microsoft Excel; Mathematical Representation; Data Centralization; Quasi-Experiment

## INTRODUCTION

Mathematics is one of the branches of science that plays a crucial role in education (Sofiyah et al., 2025). As a fundamental discipline, mathematics serves as the foundation for various other fields of study. Therefore, this subject is considered essential to be taught at all levels of education. The goal of mathematics learning is to equip students with the ability to think logically, critically, and systematically, as well as to solve problems effectively and efficiently (Husnul Fauzan & Khairul Anshari, 2024). To achieve these objectives, students need to master a set of mathematical competencies. The National Council of Teachers of Mathematics (Beyers II, 2000) recommends five key competencies that students should acquire in the process of learning mathematics, namely: problem-solving, communication, making connections, reasoning and proof, and representation.

These five process standards cannot be separated from mathematics learning, as they support one another and form an integral part of the teaching and learning process. In mathematics instruction, students are required not only to perform calculations but also to understand concepts and relate them to various contexts. One of the essential competencies to be developed is representation, since through representation, students can express mathematical ideas and concepts in forms that are easier to comprehend. The Representation Standard is not merely a way of conveying ideas or concepts in mathematics, but rather a fundamental ability in building a deeper understanding of problems. By employing different forms such as symbols, diagrams, tables, or visual models, learners are not only translating information but also constructing meaning, identifying relationships among concepts, and evaluating solutions more systematically (Rahmadian dkk., 2019).

In line with this, Sabirin (2014) states that representation is a way for students to understand and interpret a problem, serving as a tool to help them find solutions. Forms of representation may include words, written text, diagrams, tables, graphs, mathematical symbols, or concrete objects. Meanwhile, Rangkuti (2014) defines representation as the depiction, translation, or symbolisation of mathematical ideas, concepts, and their interrelationships. Students express these in various forms to gain clarity of meaning, demonstrate understanding, or seek solutions to the problems they face. Referring to both perspectives, mathematical representation can be understood as students' way of comprehending, interpreting, and communicating mathematical ideas, concepts, and relationships through multiple forms such as words, symbols, diagrams, graphs, tables, or concrete models. Representation is not only a tool for visualisation but also plays a crucial role in developing conceptual understanding, explaining thought processes, as well as searching for and evaluating solutions to mathematical problems.

The results of preliminary observations at a junior high school in one of the provinces of West Nusa Tenggara, Indonesia, revealed that mathematics learning is still dominated by conventional methods, such as lectures and assignments, without being complemented by varied and contextual approaches. Although the school has adopted the Merdeka Curriculum, its implementation has not been fully optimised. Teachers tend to act merely as passive facilitators, without providing active guidance that encourages students to explore and deeply understand concepts. As a result, students encounter difficulties in comprehending abstract concepts, particularly in terms of symbolic, graphical, and verbal representations. This result indicates that students' mathematical representation ability at the school remains low.

These findings are in line with previous studies that have highlighted the low level of students' mathematical representation ability. Suningsih & Istiani (2021) reported that visual representation only reached 65.2%, while expression and verbal forms were each below 45%. Similarly, Wahidah & Masrukan (2021)found that many students did not meet the minimum mastery criteria due to difficulties in constructing mathematical models and solving conceptual problems. Furthermore, Rahmatika dkk (2022) emphasised that conventional teaching models tend to make students accustomed to imitating rather than engaging in independent thinking. These conditions indicate the need for a shift in instructional approaches to improve students' mathematical representation ability.

To address the low level of students' mathematical representation ability, an interactive, meaningful, and contextual learning approach is required. This statement is supported by the study of Rahmita et al. (2020), which demonstrated that the use of the interactive GeoGebra software had a significant effect on improving mathematical representation skills. In addition, Septianingsih et al. (2020) found that a contextual approach assisted by environmental media not only increased student mastery to 80% but also fostered nationalism through positive student responses. Furthermore, Aisyah & Madio (2021) reported that both contextual and realistic mathematics approaches through Problem-Based Learning (PBL) were effective in improving mathematical representation ability at a moderate level. However, no significant difference was found between the two. Therefore, one relevant model to apply is PBL, as it encourages students to actively solve real-world problems, think critically, and construct knowledge through collaboration and exploration. In the context of mathematics learning, PBL has the potential to enhance students' representation skills, since they are trained to present solutions in multiple forms, whether symbolic, graphical, or verbal, according to their understanding.

Furthermore, the use of technology as a supporting medium in the PBL model can enrich students' learning experiences. Technology enables the presentation of material in visual and interactive formats, such as through mathematics applications, simulations, or instructional videos, which can help students develop their mathematical representation skills. This statement is supported by the findings of Tralisno & Alfi (2023), who showed that simulation-based multimedia in geometry topics was able to improve students' psychomotor skills with an N-gain score of 0.73 (high category). Similarly, Winarni et al. (2021)demonstrated that mathematics instructional videos were effective in enhancing students' numeracy and digital literacy through significant quasi-experimental results. Thus, the utilisation of technology in the form of simulation-based multimedia and instructional videos has the potential to serve as an effective means of supporting mathematical representation, fostering learning interest, and developing 21st-century skills. Nevertheless, interviews with teachers at SMP Islam Al-Maliki Woha revealed challenges in its implementation, as neither the PBL model nor the use of technology had ever been applied in mathematics instruction. Teachers perceived that students were not yet ready and were concerned that such approaches might cause greater confusion, given that students still struggled even with conventional methods.

The results of classroom observations and teacher interviews reinforce these concerns. The observations revealed that only about 4–5 students were able to accurately represent mathematical concepts, while most others appeared confused or merely pretended to understand the material. Teacher interviews further confirmed this condition, noting that students tended to struggle even with conventional instruction. This situation underscores the need for an intervention through a more effective learning approach. By implementing a technology-based PBL model in a structured and gradual manner, it is expected that students will become more actively engaged, gain a deeper conceptual understanding, and develop stronger mathematical representation skills.

Problem-Based Learning (PBL) is an instructional model that emphasises students' active engagement in solving real-world problems, fostering critical, collaborative, and exploratory thinking (Sudarti, 2024; Ramadhani et al., 2024). Several studies, such as those conducted by Silviana & Maryati (2021) dan Herdiana et al. (2019), have shown that PBL is effective in enhancing students' mathematical representation skills, particularly in presenting data visually and solving problems using mathematical expressions.

In addition to instructional models, the integration of technology has also been proven to enhance the quality of learning. Educational technology functions not only as a tool but also as a systematic process to address learning challenges through interactive and flexible media (Subroto et al., 2023). Studies by Habibah et al. (2022) and Rosida et al. (2019) demonstrated that technology, including instructional videos and digital platforms, can improve students' understanding of abstract concepts as well as their critical thinking and problem-solving skills.

Based on these findings, the research problem formulated in this study is how the implementation of a technology-based Problem-Based Learning (PBL) model utilising interactive PowerPoint and Microsoft Excel can enhance students' mathematical representation ability. Accordingly, this study aims to apply a technology-based PBL model through the use of interactive PowerPoint, which presents material engagingly and dynamically to create a more lively learning experience, as well as Microsoft Excel, which helps students visualise data in the form of graphs or tables, thereby making conceptual understanding more concrete. Through the combination of these two media, this research is expected to increase students' engagement, motivation, and mathematical representation ability, while also providing empirical contributions to the development of more innovative mathematics learning strategies aligned with the demands of 21st-century education.

## RESEARCH METHODS

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The research method employed in this study was a Quasi-Experimental design with a Pretest-Posttest Control Group. This design was chosen to identify the effect of specific variables in addressing the research problem and to achieve the objectives of the study systematically and measurably. The study was conducted at SMP Islam Al-Maliki Woha during the even semester of the 2025 academic year. The population consisted of all eighth-grade students at SMP Islam Al-Maliki Woha. At the same time, the sample comprised two classes selected through purposive sampling, namely one experimental class and one control class, each consisting of 20 students. The research instrument was a mathematical representation ability test in the form of open-ended questions, which had been tested for validity, reliability, difficulty level, and discriminating power, ensuring its feasibility for data collection. The data collection procedure consisted of three stages: administering a pretest to assess students' prior ability, implementing the treatment by applying a technology-based Problem-Based Learning (PBL) model in the experimental class and conventional instruction in the control class, and administering a posttest to measure improvements in mathematical representation ability after the treatment. The test results were analysed through prerequisite tests, namely normality and homogeneity tests, followed by hypothesis testing using an independent t-test to determine differences in learning outcomes between the experimental and control classes.

The following table presents the research design employing a quasi-experimental approach.

**Table 1**. Research Design with a Quasi-Experimental Approach

| Group | Pretest | Treatment | Posttest |
|---|---|---|---|
| Eksperimental | $O_1$ | X | $O_2$ |
| Control | $O_1$ | - | $O_2$ |

Notes:
$O_1$ : Result before treatment

X: Class receiving treatment

$O_2$ : Result after treatment

This research was carried out in the even semester of 2025 at a junior high school located in Woha District, Bima Regency. The population consisted of all eighth-grade students, distributed across two classes. From this population, two classes were selected as the sample, namely class VIII A as the experimental group and class VIII B as the control group, with 20 students in each class. The sample selection was conducted using purposive sampling, based on specific criteria considered relevant to the needs and objectives of the study.

The pretest and posttest questions were used as instruments to collect data. These instruments were designed to evaluate the extent to which students were able to reorganise mathematical concepts (mathematical representation) in a structured manner when solving mathematical problems. Each instrument was developed in accordance with the research objectives, allowing for an unbiased and methodical analysis of the collected data to determine the effect of the applied treatment. The data analysis process involved three stages: hypothesis testing, prerequisite testing, and evaluation of the research instruments.

The instrument testing was carried out to ensure the feasibility of the test items used in this study as a tool for measuring students' understanding of mathematical representation. The evaluation process included validity testing, reliability testing, difficulty level, and item discrimination. The validity test aimed to confirm that the instrument truly measured students' mathematical representation ability on the topic of data centralisation. Meanwhile, the reliability test was used to examine the consistency of measurement results. The difficulty index was applied to determine the level of challenge of the items, and the discrimination index was intended to assess the ability of the items to distinguish between high- and low-ability students. According to Magdalena et al. (2021), the product-moment correlation formula can be used to evaluate the validity of a test item. The decision regarding the distribution test (r table) is based on the significance level $\sigma$=0,05 and degrees of freedom. ($df$= n-2). The rule is that if the calculated $r_{hitung} \geq r_{table}$ The item is considered valid.

Meanwhile, to calculate the reliability of the test items used in the data analysis, the Alpha formula was applied. This formula is particularly suitable for instruments

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with scores in the form of scales or open-ended responses, where the scoring is not limited to dichotomous values such as 1 or 0. The following table presents the criteria used as the basis for determining the conclusion regarding the reliability of the test instrument employed in this study.

**Table 2**. Interpretation of the Correlation Coefficient (r)

| Absolute Value of r | interpretation |
|---|---|
| 0,800-100 | Very High |
| 0,600-0,800 | Adequate / Sufficient |
| 0,400-0,600 | low |
| 0,200-0,400 | Rather Low |
| 0,000-0,200 | Very low |

Source: (Magdalena et al., 2021)

Based on the explanation of Magdalena et al. (2021), the formula for determining the power of discrimination of questions is $D = P_A - P_B$ By following the discrimination value, the test items can be analysed and their categories determined according to the following criteria:

**Table 3**. Interpretation of the Discrimination Index of Each Item

| Differentiating Power | Interpretation |
|---|---|
| 0,70-1.00 | Very Satisfactory |
| 0,40-0,69 | Adequate |
| 0,20-0,39 | Good |
| 0,00-0,19 | Unsatisfactory |
| Negative Sign | Very Poor |

Source: (Magdalena et al., 2021)

To ensure the validity and reliability of the analysis results, prerequisite tests were conducted before testing the hypothesis. The normality test and homogeneity test were applied as prerequisite methods in this analysis.

In this study, data analysis was carried out using the Statistical Package for the Social Sciences (SPSS) version 25.0. The analysis process began with normality testing (Shapiro-Wilk) and homogeneity testing as the basis for deciding whether to accept or reject the hypothesis. The data were considered normally distributed if the significance value was greater than $\alpha = 0.05$, and homogeneous if the significance value was also greater than $\alpha = 0.05$. Subsequently, hypothesis testing was conducted to determine differences in learning outcomes between the experimental and control classes after receiving different treatments, employing the

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t-test and the N-Gain Score test. The t-test was used to identify significant differences in student learning outcomes and to analyse the degree of influence of the independent variable on the dependent variable through simple linear regression. According to Hariyono et al. (2005), the decision rule in the t-test is that if the significance value is less than α, then the alternative hypothesis is accepted. Meanwhile, the N-Gain Score test was applied to measure the extent of students' score improvement from pretest to posttest, with interpretation conclusions referring to the predetermined criteria of improvement levels.

**Table 4**. N-Gain Value Benchmark

| Score | Category |
|---|---|
| 0,70≤n≤1,00 | High |
| 0,30≤n<0,70 | Medium |
| 0,00≤n<0,30 | Low |

Sumber:(Oktavia dkk., 2019)

## RESULTS AND DISCUSSION

### Research result

This study involved two classes, namely class VIII A as the experimental class and class VIII B as the control class, each consisting of 20 students. Prior to the treatment, both groups were given a pretest to measure students' initial abilities. After the treatment, a posttest was administered to assess the learning outcomes achieved. In addition, prerequisite tests (normality and homogeneity), hypothesis testing using the t-test, and N-Gain analysis were conducted to determine the effectiveness of the treatment.

**Table 5**. Descriptive Pretest in Experimental and Control Classes

<table>
<tr><th>Group</th><th colspan="2">Statistic</th><th>Standar Error</th></tr>
<tr><td rowspan="7">Eksperimental</td><td>Mean</td><td>50.00</td><td>1.291</td></tr>
<tr><td rowspan="2">95% Cinfidence Interval For Mean</td><td>47.32 Lower Bound</td><td></td></tr>
<tr><td>52.68 Upper Bound</td><td></td></tr>
<tr><td>Median</td><td>50.00</td><td></td></tr>
<tr><td>Range</td><td>20</td><td></td></tr>
<tr><td>Interquartile Range</td><td>11</td><td></td></tr>
<tr><td rowspan="4">Control</td><td>Mean</td><td>48.95</td><td>1.159</td></tr>
<tr><td rowspan="2">95% Cinfidence Interval For Mean</td><td>46.54 Lower Bound</td><td></td></tr>
<tr><td>51.37 Upper Bound</td><td></td></tr>
<tr><td>Media</td><td>48.50</td><td></td></tr>
</table>

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| | | |
|---|---|---|
| | Range | 19 |
| | Interquartile Range | 9 |

Based on the results of the descriptive statistical analysis of the pretest, it appears that the data profiles between the experimental class and the control class show a striking similarity. The average pretest score in the experimental class was recorded at 50.00, while the control class scored 48.95, indicating only a very slight difference. The score range in both groups was also nearly balanced, namely 20 for the experimental class and 19 for the control class. Meanwhile, the median scores of each class were also not far apart, with 50.50 for the experimental class and 48.50 for the control class. In addition, the 95% confidence intervals for the mean scores in both classes showed considerable overlap, indicating that the data were comparable on a fair basis. Therefore, the similarity in students' initial abilities from both groups can serve as a strong foundation for proceeding to the next stage, namely, the analysis of posttest results to assess the effectiveness of the learning model used in enhancing students' mathematical concept understanding.

After the learning process was completed, a posttest was administered to both groups. The posttest results indicated a difference in learning achievement between the experimental class, which used the technology-based PBL approach, and the control class, which received conventional instruction. Table 6 below presents the posttest scores obtained by each class.

**Table 6**. Posttest Descriptive Statistics of the Experimental and Control Classes

| Group | Statistic | | Standar Error |
|---|---|---|---|
| Eksperimental | Mean | 90.73 | 976 |
| | 95% Cinfidence Interval For Mean | 88.70 Lower Bound | |
| | | 92.76 Upper Bound | |
| | Median | 90.50 | |
| | Range | 16 | |
| | Interquartile Range | 7 | |
| Control | Mean | 48.95 | 1.159 |
| | 95% Cinfidence Interval For Mean | 46.54 Lower Bound | |
| | | 51.37 Upper Bound | |
| | Media | 48.50 | |
| | Range | 19 | |
| | Interquartile Range | 9 | |

The learning outcomes in the two classes differed significantly, according to the findings of the posttest descriptive analysis. Students in the control class obtained an average score of 48.95 with a standard deviation of 5.280, while students in the experimental class recorded an average of 90.73 with a standard deviation of 4.579. Furthermore, the score distribution in the experimental group showed a wider range compared to the control group. Although this gap appears quite evident descriptively, statistical testing is still required to confirm the significance of the difference. Therefore, a series of prerequisite tests, such as the normality test, homogeneity test, t-test, and N-Gain Score analysis, were conducted to ensure the validity of the results. These tests aimed to determine whether the treatment given was truly the main factor influencing the differences in achievement between the two groups.

Before conducting the hypothesis test, the data were analysed using the normality test and the homogeneity test to ensure that the assumptions of parametric analysis were met.

**Table7**. Results of the Analysis Prerequisite Test

| Tests Of Normality | | | | |
|---|---|---|---|---|
| Shapiro-Wilk | | | | |
| | Group | Statistic | df | Sig. |
| Result | Pretest-Eksperimental | 0.966 | 22 | 0.618 |
| | Posttest-Eksperimental | 0.971 | 22 | 0.729 |
| | Pretest-Control | 0.963 | 22 | 0.548 |
| | Posttest-Control | 0.960 | 22 | 0.483 |

The normality test produced a significance value of 0.618. This result indicates that the data distribution of both groups met the normality criteria, as the significance value exceeded the 0.05 threshold. Thus, the normality assumption was fulfilled, allowing the data to be further analysed using parametric tests.

This condition confirms that the data variation in both groups was reasonably distributed and did not significantly deviate from a normal distribution, which is one of the essential prerequisites in hypothesis testing based on parametric statistics

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such as the independent sample t-test. After the normality assumption was satisfied, the next step was to conduct a homogeneity of variance test to ensure that the differences observed between the two groups were not influenced by variance inequality.

**Table 7**. Results of the Homogenity Test

| Test of Homogeneity of Variance | | | | | |
|---|---|---|---|---|---|
| | | Levene Statistic | df1 | df2 | Sig. |
| Result | Based on Mean | 0.292 | 1 | 42 | 0.592 |
| | Based on Median | 0.289 | 1 | 42 | 0.594 |
| | Based on Median and with adjusted df | 0.289 | 1 | 42 | 0.594 |
| | Based on the trimmed mean | 0.292 | 1 | 42 | 0.592 |

The data from both groups showed homogeneous variances, as indicated by the result of the homogeneity test with a significance value in the *Based on Mean* column of 0.592, which is greater than the significance threshold of 0.05. This result confirms that both groups met the homogeneity criteria. With the prerequisite analysis fulfilled, the next stage was to evaluate the significance of the data through hypothesis testing.

**Table 8**. Results of Hypothesis Testing (t-test)

| *Independent Sample Test* | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Levene's Test for Equality of Variances* | | | | | | | |
| | | *F* | *Sig.* | *t* | *df* | *Sig. (2-tailed)* | $t_{tabel}$, df=42, two-way with $\alpha = 0.05$ |
| Result | *Equal variances assumed* | 0.544 | 0.465 | 20.316 | 42 | 0.000 | 2.018 |
| | *Equal variances not assumed.* | | | 20.316 | 41.176 | 0.000 | 2.018 |

The posttest results revealed a significant difference between students in the experimental class, which implemented a technology-based PBL learning model, and those in the control class, which used conventional methods. The t-test analysis using SPSS version 25.0 yielded a t-value of 20.316 with a significance level of 0.000 (< 0.05). This proves that the difference between the two groups is statistically significant. Thus, the implementation of technology-assisted Problem-Based Learning (PBL) has a substantial effect on improving students' mathematical representation ability compared to conventional learning methods.

**Table 9**. Results of the N-Gain Score Test

| *Descriptives* | | | | |
|---|---|---|---|---|
| | Group | | *Statistic* | *Std. Error* |
| Result | Eksperimental | Mean | 0.8226 | 0.1556 |
| | | Median | 0.7902 | |
| | | Minimum | 0.71 | |
| | | Maksimum | 0.98 | |
| | Control | Mean | 0.2273 | 0.594 |
| | | Median | 0.2278 | |
| | | Minimum | 18 | |
| | | Maksimum | 27 | |

The N-Gain Score analysis showed that the experimental class achieved an average N-Gain Score of 0.8226, which falls into the effective category, with a score range between 0.71 and 0.98. In contrast, the control class obtained an average N-Gain Score of only 0.2273, which is classified as low or less effective, with the lowest score of 0.18 and the highest of 0.27. These findings confirm that the improvement in students' learning outcomes in the experimental class was significantly higher compared to the control class.

## RESEARCH DISCUSSION

The results of the study revealed a significant difference between the experimental and control classes, both in posttest scores and N-Gain scores. The experimental class achieved an average posttest score of 90.73 with an average N-Gain of 0.8226 (high category). In contrast, the control class only obtained an average posttest score of 60.45 with an N-Gain of 0.2273 (low category). These findings indicate that the implementation of a technology-based PBL model is more effective in improving students' mathematical representation ability compared to conventional learning (Sari, 2024).

The effectiveness of technology-based PBL can be explained through the characteristics of the model. PBL positions students as active subjects who are required to analyse real-world problems, seek information, and construct representations in the form of graphs and tables. The integration of digital media, such as interactive PowerPoint and Microsoft Excel, facilitates visual exploration, enabling students to understand abstract concepts through concrete data representations better. This statement is in line with constructivist theory, which emphasises the importance of active student engagement in building knowledge through learning experiences (Jihan Nurhamidah & Arladia Hafsya, 2024). Therefore, the high N-Gain score in the experimental class can be understood as the result of a learning process that encourages higher-order cognitive activities, such as classification, interpretation, and generalisation of data.

Conversely, the low N-Gain score in the control class (0.2273) indicates that teacher-centred conventional instruction was less effective in fostering the development of representation skills. This method tends to emphasise rote memorisation of procedures and one-way delivery of material, giving students limited opportunities to explore various forms of mathematical representation. The absence of interactive media also restricted the process of data visualisation, thereby hindering students' optimal understanding of data central tendency concepts. This finding is consistent with the findings of Rahayu et al. (2024), which showed that low N-Gain scores reflect the fact that conventional teaching strategies do not have a significant impact on learning outcomes.

These findings are consistent with previous studies. (Sari, 2024) found that the implementation of technology-based PBL made a significant contribution to improving mathematical representation. Similarly, Sutinah et al. (2021) demonstrated that PBL supported by audiovisual media enhanced students' cognitive learning outcomes compared to conventional instruction; furthermore, Jenita dkk. (2017) showed that students' mathematical representation skills improved significantly through PBL, as indicated by increases in average scores and mastery percentages in each learning cycle. The consistency of these findings reinforces the conclusion that technology-based PBL is an effective strategy for developing mathematical representation skills.

The implication of this study is the importance of teachers implementing technology-based PBL in mathematics instruction consistently. Theoretically, these findings support constructivist theory, which emphasises the active role of students in building conceptual understanding through meaningful learning experiences. Practically, the application of technology-based PBL not only enhances students' mathematical representation skills in the topic of data central tendency but also holds potential for application in other subject areas that require deep representation. In addition, this model contributes to the development of 21st-century skills such as critical thinking, creativity, communication, and collaboration (Nurhamidah et al., 2025).

The findings of this study are consistent with those obtained by Puspitasari et al. (2022), who demonstrated that the development of learning tools based on the Problem-Based Learning (PBL) model assisted by PowerPoint media can effectively improve the quality of mathematics instruction in terms of validity, practicality, and effectiveness of the developed tools. Research conducted by supports this conclusion, showing that, unlike conventional teaching, which rarely optimises the use of visual media, the implementation of PBL supported by audiovisual media effectively enhanced students' cognitive learning outcomes. This result was reflected in the increase of learning mastery levels, as well as the validity, practicality, and effectiveness of the learning tools developed through the ADDIE approach. Furthermore, the study reinforces similar findings, showing that students' mathematical representation skills improved significantly through the application of PBL, as indicated by the increase in average scores and learning mastery percentages in each learning cycle.

This model facilitates students to actively think critically, engage in discussions, and solve problems both independently and collaboratively. The Problem-Based Learning (PBL) model integrated with the use of technology offers a learning approach that positions students as active subjects in facing and solving real-world problems. Through the use of digital media such as videos, interactive

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applications, and online learning resources, students are encouraged to explore information, think critically, and develop solutions independently or collaboratively. The use of technology not only enriches the delivery of learning materials but also enhances the attractiveness and effectiveness of the learning process. Thus, technology-based PBL can foster essential 21st-century skills such as creativity, communication, and collaboration, while simultaneously strengthening a deeper and more applicable understanding of concepts in daily life, as evidenced by the comparability of findings from various studies.

Based on the research findings, the technology-based PBL learning model has been proven to have a positive impact on improving students' mathematical representation ability. It is therefore recommended that teachers continue to develop and consistently apply this model, especially in learning contexts that require deep conceptual understanding. In addition, for the sustainable and smooth implementation of this learning paradigm, schools should provide sufficient time, facilities, and teaching resources. The use of technology-based PBL emphasises active student engagement at every stage of learning, which is expected to create more enjoyable learning experiences, increase students' interest in learning, and foster their evaluative thinking skills as well as a deeper understanding of the core mathematical concepts being studied.

## CONCLUSION

Based on the research findings, it can be concluded that the implementation of the technology-based Problem-Based Learning (PBL) model, supported by interactive PowerPoint and Microsoft Excel, has a significant effect on improving the mathematical representation ability of eighth-grade students, particularly in the topic of data central tendency. This improvement is evident from the higher average posttest scores of the experimental class compared to the control class, as well as the N-Gain Value of 0.82 (high category), which was statistically significantly higher than that of the control class (N-Gain = 0.22). The experimental group showed the most significant improvement in visual representation skills, particularly in presenting data through graphs and tables.

Nevertheless, this study has limitations in terms of the relatively small sample size and its scope being confined to a single school; therefore, generalisation of the results should be approached with caution. Accordingly, it is recommended that mathematics teachers consider using the technology-based PBL model as an alternative learning strategy to enhance students' mathematical representation skills. Future researchers may examine the effectiveness of this model in other mathematical topics with a broader sample size, as well as explore its influence on affective aspects such as learning motivation, self-confidence, and student engagement.

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