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The Effect Of Problem-Based Learning Model Assisted By Live Worksheets On Students' Mathematical Reasoning Ability

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ABSTRACT

This study aims to determine the effects of using the problem-based learning (PBL) model and live worksheet media on students' mathematical reasoning skills. The research method used was quantitative and quasi-experimental. The study included all Grade X students from a private high school in Jakarta who had relatively balanced math skills. The study sample comprised four classes (X.1, X.2, X.4, and X.6), which were randomly selected using random sampling technique and each received a different learning treatment; X.1 was taught using the TCL method with PPT, X.2 received PBL with PPT, X.4 received PBL assisted by Live Worksheets, and X.6 was taught using the TCL method assisted by Live Worksheets. A descriptive test, validated and pre-tested by experts, served as the instrument. The results of the ATS showed that there were no significant differences in the initial abilities between the classes. A mathematical reasoning ability test was conducted after the treatment and the data analysis was performed using non-parametric tests, as the data did not meet the requirements of parametric tests. The test results yielded an Asymp. Sig value of 0.000 <0.05, which implies the rejection of H0. This means that there is a difference in the students' mathematical reasoning ability between the four classes. The class that applied the PBL and live worksheet model achieved the best average result. This indicates that the combination of these methods effectively improves students' mathematical thinking ability.

Introduction

Mathematics plays an essential role in education because it can develop a systematic, logical and creative way of thinking in understanding information and knowledge (Hermawati et al., 2021; Hjelte et al., 2020). In the implementation of the mathematics learning process, the focus is not only on the teaching of material by the teacher, but the active participation of the students is also emphasized. This is important so that they can develop a way of thinking that promotes their understanding of concepts and improves their mathematical skills (Kurnia Putri et al., 2019; Ramadhani et al., 2024).

Logical thinking is a thought process in which conclusions or statements are formulated whose truth can be verified and proven in advance (Kurnia Putri et al., 2019). Mathematical thinking is not only important for solving academic problems, but also for coping with various everyday problems. (R. P. Khotimah, 2022; Samsudin et al., 2022). Recognizing the importance of this skill, the Indonesian government has stipulated in the Decree of the Head of BSKAP No. 008/KR/2022 that one of the objectives of mathematics education in the Merdeka curriculum is to develop students' logical thinking skills. This includes recognizing patterns and features, performing mathematical operations, making generalizations, proving and logically expressing mathematical ideas or statements. (Agusantia & Juandi, 2022).

Various studies show that the mathematical reasoning skills of students in Indonesia are still relatively low. Lesmana, (2022) examined one of the high schools in Meureubo and found that the students' logical reasoning ability only reached 73.66% of the unmet indicators. Tambunan & Siregar, (2023) also came to similar conclusions. They found that the average mathematical reasoning ability score of students at a vocational school in East Angkola was 57.3 and thus fell into the “poor” category. Selain itu, Savitri et al., (2020) also found that the average reasoning ability of Padangsidimpuan Private Junior High School students was only 48.80, which falls into the “low” category. Increasing student engagement and motivation has been found to be effective in overcoming these problems, based on the learning model of problem-based learning (PBL) (Gulo, 2022). PBL represents an approach to learning that focuses on collaboratively tackling complex problems and aims to foster students' intrinsic motivation, flexible knowledge, independent learning and critical thinking skills (Lee & Jo, 2023). The research findings of Ramdani et al., (2022) support this effectiveness by showing that the application of the PBL model can increase student interactivity and engagement and has a positive impact on learning outcomes. With an average score of 73.02, these were higher than those of the control group, which only achieved an average score of 65.21.

According to research by (Madden et al., 2023), the use of live worksheets in online learning significantly increases learner engagement, promotes learner autonomy and provides immediate feedback that deepens their understanding of the material. These results support the use of interactive technology as a component of innovative learning. Liveworksheet is a digital platform that aims to simplify learner electronic worksheets (LKPD) and transform traditional worksheets into interactive digital exercises with auto-correction features (Ranindita et al., 2024; Retno, 2022). Liveworksheet is a technology-based learning tool that provides support to students in self-learning activities through instant feedback. Its incorporation into the PBL model is expected to increase overall learning effectiveness (Retno, 2022).

The research by (Khikmiyah, 2021) shows that the implementation of live web worksheets based on the problem-based learning (PBL) model can maximize student participation in online mathematics classes, with an average student activity level of 84%. Also (Ramdani et al., 2022), came to similar conclusions by stating that the use of live worksheets in the PBL model can increase student interactivity and engagement and has a positive impact on learning outcomes. The average score of 73.02 outperformed that of the control group (65.21), while at the same time increasing students' enthusiasm in completing problem-based tasks.

This study examines the effects of the live worksheet-based PBL model on students' mathematical thinking skills, taking into account the importance of mathematical thinking in mathematics learning and the relevance of innovative learning models. Therefore, this study aims to determine the effect of the Problem-Based Learning (PBL) model and Live Worksheets, both independently and in combination, on students' mathematical reasoning ability through a 2×2 factorial design.

Research Methods

This study employed a quasi-experimental design, which is appropriate when the researcher is unable to randomly assign participants to groups, yet still intends to compare the effect of a treatment across different groups. According to (Creswell, 2022), quasi-experimental research allows the researcher to examine cause-and-effect relationships while maintaining practical feasibility in educational settings. The design used in this study involved a pretest-posttest control group, where the experimental group received instruction through the PBL model assisted by Live Worksheets, and the control group received conventional instruction. In this type of research, a quantitative approach with a quasi-experimental method was applied. To examine the effects of the PBL learning model supported by Live Worksheets on students' mathematical reasoning skills, the study employed a 2×2 factorial design, which allows the researcher to investigate both the main effects of each independent variable and the interaction effect between them. As (Creswell, 2022) explains, factorial designs are used in experimental research to simultaneously examine the impact of two or more independent variables on a single outcome.

Table 1. Factorial Design

	Live Worksheet (B_1)	PPT (B_2)
PBL (A_1)	PBL + Live Worksheet (A_1B_1)	PBL+PPT (A_1B_2)
TCL (A_2)	TCL+ Live Worksheet (A_2B_1)	TCL + PPT (A_2B_2)

Table 1 shows the 2×2 factorial design used in this study, which involved two independent variables: learning model (PBL and TCL) and learning media (Live Worksheets and PowerPoint). The combination of these two variables resulted in four treatment groups, namely: (1) PBL with Live Worksheets, (2) PBL with PowerPoint, (3) TCL with Live Worksheets, and (4) TCL with PowerPoint.

The target population of this research included all students in Grade X of PKP Jakarta Islamic School whose math ability was relatively balanced. The research sample included classes X.1, X.2, X.4, and X.6, each of which received a different treatment. Class X.1 served as the control class in which the TCL was used via PPT; class X.2 was the experimental class in which the PBL model was applied using PPT, and class X.4 implemented PBL with Live Worksheet. In contrast, class X.6 used a TCL model together with Live Worksheet media.

The implementation of the PBL model in the experimental classes followed five core stages: problem orientation, student organization, investigation, presentation, and evaluation (Khoirudin & Rizkianto, 2018). These stages were designed to foster students' mathematical reasoning skills such as logical argumentation, appropriate use of formulas, and constructing direct proof.

This study used random sampling technique in sampling to ensure that every member of the population has an equal chance of being selected. The sample in this study consisted of four groups, with 35 and 36 students in each group. The demographic characteristics of each sample group, including the gender distribution and average age of the students, are presented in the following Table;

Table 2. Demographic Information ftom the Research Sample

Class	Gender	Number of Students	Average Age (Years)
TCL + PPT	Man	24	16,4
	Woman	11	16,54
TCL+ Live Worksheet	Man	2	16,4
	Woman	14	16,5
PBL + Live Worksheet	Man	20	16,15
	Woman	16	16,4
PBL+PPT	Man	14	16,21
	Woman	21	16,19

Table 2 shows the demographic information of the four sample groups in this study. Each group consisted of male and female students with ages ranging from 16 to 17 years. There were fewer female students than male students in each group. All participants were grade X students from one of the high schools in East Jakarta. This data shows that the composition of the participants is quite balanced and can represent the student population at that level.

The instrument used in this study is a written descriptive test designed to measure students' mathematical reasoning ability after treatment. In one of the secondary schools in West Java, the instrument was tested and validated by mathematics education professionals and class X high school teachers. In addition, reliability testing of the instrument was conducted to ensure that it is consistent and reliable in measuring the variables under study.

To ensure that each item in the instrument is suitable for use, a validity test is carried out using Pearson Product Moment correlation analysis. This validity test aims to determine the extent to which each item can measure the intended indicator. The results of the instrument validity test are shown in the following table.

Table 3. Reliability Statistics

Cronbach's Alpha	N of Items
0.752	12

Table 3 shows the result of the reliability analysis conducted using Cronbach's Alpha. The coefficient obtained was 0.752 for a total of 12 items, which indicates that the instrument has high internal consistency and is considered reliable for measuring students' mathematical reasoning ability.

Table 4 Item Total Statistics

	Scale Mean If Item Delated	Scale Variance if Item Delated	Corrected Item-Total Correlation	Cronbach's Alpha if Item Delated
A1	34.4750	16.615	0.408	0.732
B1	34.5750	16.969	0.302	0.746
C1	34.3000	17.036	0.399	0.734
A2	34.3750	16.394	0.575	0.716
B2	34.4500	17.536	0.258	0.750
C2	34.3000	17.395	0.448	0.732
A3	34.4500	16.100	0.654	0.708
B3	34.2250	16.846	0.380	0.736
C3	34.3500	15.669	0.580	0.710
A4	34.2000	17.190	0.368	0.737
B4	34.5500	17.126	0.234	0.758
C4	34.2500	17.115	0.239	0.757

Table 4 shows the item-level reliability results. Most Corrected Item-Total Correlation values are above 0.30, and the Cronbach's Alpha if item deleted ranges from 0.70 to 0.75, indicating that the instrument is internally consistent and reliable.

The research hypotheses used in this study are:

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4$ (The mathematical reasoning ability of the first sample population does not differ from the second, third and fourth sample populations)

H_1: $\mu_1 \neq \mu_2 \neq \mu_3 \neq \mu_4$ (There is a difference in mathematical thinking ability between the first sample population and the second, third and fourth sample populations)

The data obtained was analyzed using descriptive and inferential statistical methods. The descriptive analysis made it possible to determine the mean value, the standard deviation and the minimum and maximum values of the pupils' results in mathematical thinking. The prerequisites for the inferential analysis were checked using normality and homogeneity tests. The test results showed that the data did not fulfill the requirements of normal distribution and homogeneity. The data did not meet the parametric assumptions, so the analysis was continued using a non-parametric statistical approach to test whether there was a significant difference between the treatment groups. The results of the tests showed a statistically significant difference ($p < 0.05$) in the posttest results between the compared groups.

Findings

The ATS results of the individual classes in the sample were used for the preliminary tests of this study. Before the inference test is carried out, a descriptive test of the data is performed to determine the maximum, minimum, mean, standard deviation and variance values. The results of the descriptive data test in the study can be seen in Table 2 below:

Table 5. Descriptive Test Results of Pre-Research Data

	N	Minimum	Maksimum	Mean	Std. Deviation	Variance
X.1	35	25	93	69.37	20.517	420.946
X.2	36	20	95	72.05	18.780	352.707
X.4	36	30	95	78.17	15.023	225.971
X.6	35	23	92	72.89	16.813	282.692
Valid N (listwise)	35					

Table 5 shows the results of the Midterm Assessment (ATS) scores of the four sample classes used in the study as pre-research data. The data shown includes the minimum, maximum, average, standard deviation, and variance of each class. These results are used as an initial reference to determine the basic abilities of students before being given different learning treatments. Based on the data in the table, it can be seen that the initial abilities of the four classes are at a relatively comparable level, although there are small variations in the average value and distribution.

Following the descriptive data check, the preliminary data was tested for normal distribution. The result showed that the data was not normally distributed (sig <0.05), which is why a non-parametric test was used. The results of the non-parametric test data pre-research in this study are shown in Table 4 below:

Table 6. Nonparametric Test Results of Pre-Research Data

	Value
Kruskal-Wallis H	4.110
df	3
Asymp. Sig.	0.250

Table 6 shows the results of the Kruskal-Wallis test of students' mathematical reasoning ability scores from the four classes using different learning models, with a value of 4,110 and a significance of 0.000 ($p < 0.05$). In comparison, the nonparametric analysis of the baseline data yielded an asymptotic significance value of 0.250 ($p > 0.05$), indicating that there was no statistically significant difference in the initial ability of the four sample classes. Previously, normality and homogeneity tests were conducted on the posttest data of students' mathematical reasoning ability from the four sample classes. Based on the normality test results, the data in each class has a significance value of more than 0.05, so it can be concluded that the data is normally distributed. However, the homogeneity test results show a significance value of less than 0.05, which means the data is not homogeneous. Therefore, inferential analysis cannot be done with parametric tests such as ANOVA, but instead uses nonparametric tests as an alternative.

The next stage after conducting descriptive data tests and inference tests on pre-research data, treatment was carried out to 4 sample classes. The results of the treatment using the mathematical reasoning ability test that has been carried out to 4 sample classes. The results of the mathematical reasoning ability test will then be calculated descriptive test data and inference test to see the effect of the treatment applied to mathematical reasoning ability.

The results of the descriptive test data from the post-test results in the 4 sample classes are shown in Table 7 below:

Table 7. Data Descriptive Test Results from post-test results

	N	Minimum	Maksimum	Mean	Std. Deviation	Variance
X.1	26	21	100	74.31	21.925	480.702
X.2	25	44	92	61.24	10.576	111.857
X.4	27	58	100	79.48	12.617	159.182
X.6	21	60	90	76.24	9.055	81.990
Valid N (listwise)	21					

Table 7 shows the descriptive statistics of the posttest results of students' mathematical reasoning ability from the four classes that became the research sample. Class X.1 which used TCL model assisted by PowerPoint had an average score of 74.31. Class X.2 that used the Problem-Based Learning (PBL) model assisted by PowerPoint obtained an average of 61.24. Class X.4 that applied the PBL model assisted by Live Worksheets showed the highest average of 79.48. Meanwhile, class X.6 that received TCL assisted by Live Worksheets had an average of 76.24. This data shows that the class with PBL model assisted by Live Worksheets has the highest result compared to other classes. Other information presented in this table includes the minimum, maximum, standard deviation, and variance values of each class.

The next stage after the descriptive test of the data was to test the post-test results for normal distribution. The result was sig 0.20 > 0.05, indicating a normal distribution of the data. However, the homogeneity test showed a result of sig 0.000 < 0.05, meaning that the requirements for the t-test were not met. A non-parametric test was then carried out to investigate the effects of using Live worksheet with PBL on mathematical reasoning ability. The results of the non-parametric tests in this study are shown in Table 8 below;

Table 8. Nonparametric test results from post-test data results

	Value
Kruskal-Wallis H	23.014
df	3
Asymp. Sig.	0.000

Table 8 shows the results of the Kruskal-Wallis test on student mathematical reasoning ability test data from four sample classes. This nonparametric test uses samples from the four classes that received different learning treatments. The Kruskal-Wallis statistical value (H) of 23.014 with a degree of freedom (df) of 3 and a significance value of 0.000 ($p < 0.05$) indicates that there is a statistically significant difference between the four classes after the treatment is given. Thus, the null hypothesis (H_0) is rejected, which means there is a difference in mathematical reasoning ability between classes. This result indicates that the learning model used has a different effect on improving students' mathematical reasoning ability. In particular, the class that applied the PBL model assisted by Live Worksheets obtained the highest average score compared to the other classes, which indicates the effectiveness of the approach in supporting the development of students' reasoning skills.

Discussion

This study has shown that students' ability to think mathematically is significantly influenced by different learning approaches. Compared to the other classes, the class that learned using the PBL model with live worksheets made better progress. This illustrates that it is possible to create a more meaningful learning process by combining problem-based approaches with interactive digital media.

By using the PBL model with Live Worksheets, students are encouraged to think logically, develop mathematical arguments and use formulas appropriately to solve problems. Real problem solving and active student participation are at the forefront of the learning process, which has been shown to promote the development of higher level thinking skills. Students also receive immediate feedback from the interactive exercises - this is crucial to encouraging their independent understanding of mathematical concepts.

This result is consistent with previous research showing that PBL can help improve students' critical and logical thinking skills (Masek & Yamin, 2011; Tiwari et al., 2006). In addition, the use of digital interactive media such as Live Worksheets has been shown to increase student engagement and understanding of math concepts (H. Khotimah & Hidayat, 2022; Suyono et al., 2024).

Similar support was also provided by the study of (Aryani et al., 2021) who found that the use of PBL-based LKPD using Live Worksheets and Google Classroom had an impact on students' mathematical representation skills. The similarity between this study and the research conducted lies in the use of the PBL model and Live Worksheets, while the difference lies in the number of classes used, with this study using four classes and a factorial design, while Elma Aryani used only two classes.

In addition, the research results of (Ahmar & Soro, 2023) also reinforce these findings. They found that the use of e-LKPD based on Live Worksheets in mathematics learning had a positive impact on students' mathematical reasoning ability, with higher results in the experimental class than the control class. The similarity between this study and Ahmar et al.'s study is in the use of Live Worksheets media and the focus on mathematical reasoning ability, but there are differences in design and education level.

The results of the study conducted by (Wardani & Sugandi, 2024) also corroborate these findings. They found that the live worksheet-based use of LKPD in the context of problem-based learning was effective in improving students' mathematical problem-solving skills. Students demonstrated a significant improvement in their ability to identify problems, generate solutions and make logical deductions after the treatment. The use of the PBL model and the medium of live worksheets represents the similarity of this study to the current study, while the focus of the skills measured and the level of education used differ.

This research is also supported by Nurhasanah and Suryadi's (2021) study, which although it did not use digital media such as Live Worksheets, showed that the PBL model significantly improved students' mathematical reasoning ability. These results indicate that the PBL approach itself is effective, and its use with interactive media such as Live Worksheets can strengthen its impact on mathematics learning.

Thus, the results of this study have a strong foundation in previous studies, and provide additional evidence that a problem-based learning model supported with interactive digital media such as Live Worksheets can significantly improve students' mathematical reasoning skills.

Conclusion

Based on the pre-research test on the four sample classes using ATS data, it was found that the initial ability of students was not significantly different, so the four classes were suitable as research objects. After being treated with various learning methods, the results of the mathematical reasoning ability test show that the class using the PBL model assisted by Live Worksheets has the highest average result compared to other classes. The results of nonparametric statistical tests showed a significant effect of using PBL and Live Worksheets methods on improving students' mathematical reasoning skills. Thus, the combination of PBL and Live Worksheets method proved to be more effective in improving students' concept understanding and mathematical reasoning compared to other learning methods used in this study.

The implication of this study is that teachers can consider the integration of PBL model and interactive media such as Live Worksheets in the mathematics learning process to encourage active involvement and strengthening students' higher order thinking skills. This model can also be an alternative innovative learning strategy in implementing the Merdeka Curriculum.

Suggestions for future research, it is hoped that research can be carried out with a wider scope, at different levels of education, and involve more diverse instruments to test the effectiveness of the PBL model assisted by Live Worksheets in other mathematics learning contexts.

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