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Evaluating the Influence of Problem-Based Learning on High School Students' Mathematics Performance

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Abstract

This research examines the influence of the Problem-Based Learning (PBL) model on the mathematics learning outcomes of Grade X students at SMAN 71 Jakarta. The study was conducted in response to students' low achievement in mathematics and the learning difficulties commonly associated with conventional, teacher-centered instruction. A quantitative method with a quasi-experimental design was employed, involving two Grade X classes selected through purposive sampling: one experimental class (X-B) and one control class (X-C), each comprising 36 students. Students' learning outcomes were measured using expert-validated pretest and posttest instruments. The collected data were analyzed using a series of statistical procedures including validity, reliability, normality, homogeneity tests and independent samples t-test using SPSS version 26. The analysis showed a significance value of 0.004 ($p < 0.05$) and the calculated t-value was 2.946 which is greater than the critical t-value of 1.994. These results indicate that the use of PBL model has led to a statistically significant improvement in the learning outcomes of students in mathematics. Furthermore, students who learned through PBL showed greater engagement and achieved higher scores than those who received conventional instruction.

Keywords: Problem-Based Learning, mathematics learning outcomes, quasi-experimental.

1. Introduction

Education in Indonesia is a conscious and planned effort to develop the potential of students as stipulated in the National Education System Law. According to the Republic of Indonesia (2003), education is "a planned and intentional effort to create learning conditions and processes so that learners may actively develop their potential." Mathematics is a fundamental subject that is important for achieving this goal as it develops analytical reasoning, logical thinking and problem-solving skills. Besides, mathematics is seen as a universal science and becomes the foundation for the advancement of modern technology (Susanto, 2013). Mathematical ideas are important, but many students still have difficulties in understanding them, which leads to comparatively poor learning outcomes.

One of the main factors contributing to these difficulties is the dominance of teacher-centered instructional approaches. Mathematics learning should develop students' ability to think critically and solve problems systematically, yet in practice, students often act as passive recipients of information (Ibrahim & Suparni, 2012). Such approaches limit students' opportunities to construct knowledge actively, leading to superficial understanding and low achievement (Sanjaya, 2010). This condition indicates the need for instructional models that promote active engagement and meaningful learning experiences.

Problem-Based Learning (PBL) is widely recognized as an instructional model that can address these challenges. PBL encourages students to learn through collaborative problem-solving and inquiry, enabling them to develop both conceptual understanding and higher-order thinking skills (Arends, 2012). In addition, PBL stimulates critical and analytical thinking by presenting students with authentic problems that require investigation (Wena, 2009). Previous studies also report positive impacts of PBL, such as increased motivation and improved ability to analyze and present solutions (Arends, 2012; Siswantoro, 2016). These findings suggest that PBL has strong potential to enhance mathematics learning outcomes compared to conventional approaches.

Preliminary observations conducted during the researcher's teaching internship at SMAN 71 Jakarta revealed that students' mathematics achievement remained relatively low, with scores ranging between 50 and 70, and classroom participation was limited. Students often struggled to solve contextual problems, and instruction was still predominantly lecture-based. Although previous studies have demonstrated the effectiveness of PBL, its implementation in this specific context has not been thoroughly examined. Therefore, this study aims to investigate the effect of the Problem-Based Learning model on the mathematics learning outcomes of Grade X students at SMAN 71 Jakarta. The findings are expected to contribute to the development of more effective instructional practices and support improved learning outcomes in mathematics education.

2. Methods

This study employed a quantitative research approach using a quasi-experimental method, specifically the pretest–posttest control group design. This design was selected to examine the effect of an instructional intervention by comparing learning outcomes between groups through statistical analysis (Sugiyono, 2019). A quasi-experimental approach was appropriate because random assignment of students was not feasible in the school setting, while still allowing the investigation of causal relationships (Fraenkel & Wallen, 2009). Through this design, the effectiveness of the Problem-Based Learning (PBL) model was compared with conventional instruction under authentic classroom conditions.

The participants consisted of two Grade X classes selected through purposive sampling based on recommendations from the mathematics teacher to ensure similar academic characteristics (Arikunto, 2013). Class X-B was assigned as the experimental group, while Class X-C served as the control group. Each class consisted of 36 students. This sampling technique ensured that the selected participants were appropriate for examining the impact of the instructional model (Sugiyono, 2019).

The research instrument was a mathematics achievement test comprising ten multiple-choice items that were aligned to curriculum indicators and learning objectives. Content validity of the instrument was validated by expert reviewers. To determine the reliability, the internal consistency of the instrument was analysed by using Cronbach's Alpha, which is supposed to be above the acceptable level of 0.70, meaning that the instrument is reliable to measure students' learning outcomes (Riduwan, 2015; Purwanto, 2012).

Data collection was conducted in three steps, pretest, treatment and posttest. Both groups were pre-tested to determine their level of understanding. In the same teaching period, the experimental group was taught using the PBL model and the control group was taught using traditional lecture methods. A posttest was administered after the treatment under the same conditions to maintain the fairness and consistency of data collection (Arikunto, 2013).

The data collected were analyzed using SPSS version 26. Before the test of the hypothesis, the prerequisite analyses such as normality test and homogeneity test were conducted to ensure the data met the assumptions for parametric testing (Sudjana, 2005). Then an independent samples t-test was used to determine if there was a statistically significant difference between the posttest scores of the two groups.

In addition, the magnitude of the treatment effect was described using Cohen's d effect size, which provides information about the practical significance of the results in addition to testing for statistical significance. The size of the effect was calculated by taking the average scores of the experimental group minus the average scores of the control group and dividing by the pooled standard deviation.

The decision to reject or accept the null hypothesis was based on both the significance value ($p < 0.05$) and the magnitude of the effect size. When these criteria were satisfied, the null hypothesis was rejected, indicating that the Problem-Based Learning model had a statistically and practically significant effect compared to conventional instruction.

3. Result and Discussion

The descriptive analysis summarizes students' performance in mathematics before and after the instructional treatment. The pretest results show that both the experimental and control groups started the study with similar levels of math skills. This similarity means that the two groups were equivalent at the beginning. Any differences in achievement later can be linked to the learning model used. After the intervention, the posttest results showed that the experimental group had higher average scores than the control group. This improvement suggests that using the Problem-Based Learning model positively affected students' math learning outcomes.

Table 1.
Pretest descriptive statistic for control class and experiment class

	Control	Experiment
Mean	48.56	53.61
Median	50	50
Range	70	60
Mode	60	50
Min	10	20
Max	80	80
Sum	1730	1930

Table 2.
Posttest descriptive statistic for control class and experiment class

	Control	Experiment
Mean	65.56	80.83
Median	70	80
Range	70	50
Mode	70	90
Min	30	50
Max	100	100
Sum	2360	2910

The posttest results demonstrated distinct outcome patterns between the two groups after the instructional period ended. The experimental group which used Problem-Based Learning instruction reached better mathematical concept understanding through their mean scores than the control group. The PBL model demonstrated superior student achievement and understanding when compared to standard classroom teaching methods. The research team performed initial data analysis before testing their hypothesis to verify all data points met the requirements for parametric statistical analysis. The research team performed normality tests to determine if the pretest and posttest score distributions followed a standard distribution and they performed homogeneity tests to determine if the experimental group and control group showed similar variance patterns.
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requirements for parametric statistical analysis. The research team performed normality tests to determine if the pretest and posttest score distributions followed a standard distribution and they performed homogeneity tests to determine if the experimental group and control group showed similar variance patterns.

Table 3.
Normality Test

Test of Normality			
	Shapiro-Wilk		
	statistics	df	Sig.
Pretest (Control)	0.941	36	0.056
Posttest (Control)	0.943	36	0.069
Pretest (Experiment)	0.942	36	0.063
Posttest (Experiment	0.948	36	0.089

Figure 1.
Homogeneity Test with SPSS

Test of Homogeneity of Variance

		Levene Statistic	df1	df2	Sig.
Posttest	Based on Mean	1,287	1	70	,260
	Based on Median	1,280	1	70	,262
	Based on Median and with adjusted df	1,280	1	68,154	,262
	Based on trimmed mean	1,286	1	70	,261

The prerequisite test results confirmed that all data requirements for parametric analysis were fulfilled which allowed the use of independent samples t-test for inferential statistical analysis. The researchers performed t-test analysis to determine if the experimental group showed different posttest results than the control group. The research findings showed that the Sig. (2-tailed) value dropped below 0.05 which proved the two groups differed significantly and showed that the Problem-Based Learning approach produced substantial improvements in students' math learning results.

Figure 2.
Independent sample t-test with SPSS

Independent Samples Test

	Levene's Test for Equality of Variances				
	F	Sig.	t	df	Sig. (2-tailed)
Equal variances assumed	1,287	,260	-2,946	70	,004
Equal variances not assumed			-2,946	67,994	,004

Since the calculated significance value was 0.004<0.05, the alternative hypothesis (H_1) was accepted.

The research findings showed that students who learned through Problem-Based Learning (PBL) achieved better mathematics results than their classmates who followed conventional teaching methods. The development emerged because PBL students worked together to solve problems while learning through real-world situations and actively participating in their education which resulted in deeper understanding of concepts. The research findings support theoretical models which demonstrate that students need hands-on learning activities to develop their advanced thinking abilities. The research findings prove that students achieve better math learning results through PBL than through traditional teacher-led instruction because the experimental group showed better results than the control group.

The research data shows positive results but multiple factors need to be taken into account when scientists analyze these findings. The research study used two school classrooms for its research which limited the number of students who participated thus restricting the ability to apply results to different learning situations. The assessment of student learning outcomes depended on a multiple-choice test which contained only a few questions so it failed to show how students understood concepts deeply and their complete problem-solving methods. The research team conducted their study during a brief period which prevented them from studying how students would remember their learning after the PBL intervention and their overall development. The study outcomes show potential benefits but we need to analyze these results with caution because of the study's present limitations.

The current assessment of this topic has revealed multiple unexamined research areas which scientists should investigate. Researches need to include bigger groups of students from various backgrounds for their future studies because this approach will help scientists apply their findings to different student populations and teachers should use PBL for all mathematical subjects and students from various educational backgrounds. The assessment system needs to include additional instruments which should consist of open-ended problems and performance-based tasks to reveal students' complete problem-solving and reasoning abilities. The study of PBL requires additional research to determine its effects on students throughout their educational journey while scientists should investigate how digital technology can enhance its implementation process. Addressing these open problems will contribute to a more robust understanding of the effectiveness of Problem-Based Learning in mathematics education.

4. Conclusion

The research study shows that students at SMAN 71 Jakarta will achieve better mathematics learning results through the PBL educational model implementation. Students who received PBL-based instruction performed better on their posttest assessments than students who received conventional teacher-directed instruction. The research findings support the idea that students achieve better learning outcomes through their active participation in building knowledge instead of receiving information in a passive manner according to Sanjaya (2010).

The PBL learning approach functions well because it supports the constructivist educational framework which teaches students to build knowledge through active participation in problem-solving activities. Students learn to develop their learning abilities through PBL according to Arends (2012) because they need to solve actual problems which require teamwork for successful resolution. Students achieve meaningful mathematics learning according to Ibrahim and Suparni (2012) through their ability to perform critical thinking and use mathematical concepts in an organized way. The study used contextual problems together with group work activities which helped students build better conceptual knowledge and develop their mathematical problem-solving abilities.

The research findings support the theory which states that students develop better higher-order thinking abilities through authentic learning experiences and inquiry-based educational settings. Wena (2009) explains that students develop better learning results when they handle real and important problems because these situations drive them to apply analytical thinking which leads to critical thinking development. The study results show that the PBL model achieves statistical success while proving its theoretical value to support student-led learning activities through active learning methods. The research recommends teachers should start using Problem-Based Learning as their standard method to teach mathematical concepts in their classrooms. Researchers need to study this method further because they should investigate its performance in various educational settings and different academic subjects while testing its effectiveness with technological tools.

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