The Effect of a Problem-Based Learning Model Incorporating the Bintang Ajaib Manipulative on Student Learning Outcomes and Activities

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Abstract

This study aims to determine the effect of implementing the Problem-Based Learning (PBL) model, supported by the Bintang Ajaib manipulative, on student learning outcomes and activities related to sequences and series. This study employs a quantitative, quasi-experimental design, specifically a Nonequivalent Pretest-Posttest Control Group Design. The research sample consisted of an experimental class that used the PBL model, supported by the Bintang Ajaib manipulative, and a control class that used conventional instruction. Data collection techniques included observation, documentation, and pretest and posttest assessments. Data analysis utilized the Shapiro-Wilk normality test, homogeneity test, and Independent Samples t-Test using SPSS version 27.0. The results showed a significance value (Sig. 2-tailed) of $0.007 < 0.05$, so H_0 was rejected, and H_1 was accepted. The average learning achievement of students in the experimental class was 85.90, higher than that of the control class (79.39). In addition, student activity in the experimental class increased because students were more engaged in discussing, solving problems, and understanding concepts through concrete, engaging manipulatives. Thus, the Problem-Based Learning model, supported by the Bintang Ajaib manipulative, is an effective alternative to mathematics instruction that improves student learning outcomes and engagement.

Keywords: Problem-Based Learning, Bintang Ajaib Manipulative, Mathematics Learning Outcomes, Student Engagement, Sequences and Series.

Introduction

Mathematics education plays a crucial role in developing students' logical, analytical, critical, and systematic thinking skills. Mathematics serves not only as a tool for calculation but also as a means to develop problem-solving skills essential to daily life (Mathematics, 2020). However, in school classroom practice, mathematics is still often perceived as a difficult, abstract, and uninteresting subject for students. This perception results in low student motivation, limited learning activities, and poor academic performance in mathematics (Mertayasmini, 2023). Furthermore, mathematics instruction that remains dominated by lecture-based and teacher-centered methods tends to make students passive and less engaged in the learning process (Widyastuti et al., 2025). Another common problem is students' limited ability to understand mathematical concepts in depth. Many students simply memorize formulas without understanding the underlying concepts, so they struggle to solve problems when faced with slightly different scenarios. This situation indicates that mathematics instruction still tends to emphasize procedural mastery over conceptual understanding (Rahmawati et al., 2022). As a result, students struggle to apply mathematical concepts to new situations, which ultimately leads to low achievement in mathematics (Halawa & Heksa, 2021). Research indicates that low student engagement in learning is directly correlated with low academic achievement (Antari, 2024). Additionally, a lack of student involvement in the learning process also contributes to poor mathematical problem-solving skills (Setiawan, 2019). According to Rahmat (2022), students' active engagement during the learning process influences mathematics learning outcomes. Low student engagement in learning also results in students' suboptimal understanding of mathematical concepts. As a result, students tend to memorize formulas without understanding their meaning or the relationships between concepts, causing them to struggle when faced with problems that require reasoning and the application of concepts.

To address these issues, a learning model is needed that can encourage students to be active, think critically, engage directly in the learning process, and build meaningful conceptual understanding. Low levels of mathematical conceptual understanding cannot be addressed through teacher-centered instruction alone; rather, they require a learning approach that provides students with opportunities to explore, discover, and construct concepts independently. One relevant instructional model is Problem-Based Learning (PBL). The PBL model is a learning approach centered on solving real-world problems as the context for learning, thereby training students to develop critical thinking and problem-solving skills (M. Rusman, 2018). In PBL, students do not merely receive information from the teacher but actively seek out, process, and construct their own knowledge. Research by Hidayah (2024) indicates that implementing PBL has a significant impact on elementary school students' mathematics learning outcomes. Another study by Fauziah (2023) found that the PBL model significantly increases student learning activity. Furthermore, Zetriuslita's (2023) research indicates that problem-based learning can enhance students' critical thinking skills in mathematics.

However, implementing a learning model alone is not enough to address students' difficulties in understanding abstract mathematical concepts. Various studies show that the use of media or manipulatives can bridge the transition from concrete experiences to an understanding of abstract concepts through visual representations and hands-on activities. Manipulatives allow students to build connections between concrete objects, visual representations, and mathematical symbols, making conceptual understanding more meaningful and easier to transfer to new situations (Laski et al., 2015). Therefore, appropriate media or manipulatives are needed to ensure that the learning process, including the Problem-Based Learning (PBL) model, proceeds more effectively in helping students understand abstract mathematical concepts. In PBL, students are presented with problems that require them to investigate, discover, and construct concepts independently. For this investigative process to proceed effectively, manipulatives are needed to help students visualize abstract concepts more concretely.

Through hands-on manipulation of objects, students can more easily connect real-world experiences with mathematical representations, so that the problem-solving process in PBL not only yields solutions but also builds a deeper conceptual understanding. Thus, the use of manipulatives supports the implementation of PBL by facilitating students' active construction of knowledge. Manipulatives play a crucial role in bridging abstract concepts, making them more concrete and easier for students to understand (Sundyana, 2016). The use of manipulatives in mathematics instruction has been proven to enhance conceptual understanding, learning activities, and student learning outcomes (Ratna Wahyu Srisakti et al., 2025). Additionally, manipulatives can increase student engagement in learning by providing a more interactive and enjoyable learning experience (Sobri & Khaeroni, 2016)

One teaching aid for mathematics education is the Bintang Ajaib manipulative. This tool is designed to help students understand mathematical concepts visually and systematically, allowing them to see patterns and relationships between concepts more clearly. Unlike conventional learning, which generally relies on verbal explanations and procedural problem-solving, the Bintang Ajaib gives students the opportunity to manipulate objects directly, making abstract concepts more concrete. These characteristics support knowledge construction, increase student engagement, and facilitate students' discovery of relationships among mathematical concepts (Hidayah, 2018). Research by Khaerani et al. (2024)also shows that using the Bintang Ajaib manipulative tool can enhance students' learning activities and understanding of mathematical concepts. Therefore, when integrated with the Problem-Based Learning (PBL) model, the Bintang Ajaib serves not only as a visual aid but also as a tool that supports students in exploring, testing, and verifying problem-solving strategies, thereby making the learning process more active, meaningful, and focused on conceptual understanding.

Based on a review of previous studies, most research still focuses on applying the Problem-Based Learning (PBL) model as a learning strategy without integrating manipulatives specifically designed to support each stage of the PBL syntax. In some studies, the learning media used serve only as aids for delivering content; they have not been utilized as tools for students to independently explore, manipulate, and construct mathematical concepts during the problem-solving process. Consequently, the potential of manipulatives to enhance students' conceptual understanding through inquiry and discussion, key characteristics of PBL, has not been fully realized. Research by Yuliana (2019) suggests that the Problem-Based Learning model has a positive impact on the mathematics learning outcomes of elementary school students. Another study by Maulana (2025) found that implementing PBL can increase student engagement in mathematics instruction. Additionally, research by Agusdianita (2021) indicates that the use of mathematical manipulatives can enhance conceptual understanding and student engagement during learning. Research by Anggraini (2023) also indicates that the use of concrete learning media has a significant impact on students' mathematics learning outcomes. Furthermore, Ayu's (2024) research found that implementing a PBL model, supported by learning media, can significantly increase students' motivation and engagement in learning activities.

However, these studies were still conducted separately, focusing on the Problem-Based Learning model and the use of learning aids. Research integrating the Problem-Based Learning model with concrete learning aids such as Bintang Ajaib remains very limited. In fact, the combination of innovative learning models and appropriate learning media has the potential to exert a more significant influence on student learning outcomes and engagement (Arends, 2012). Therefore, research on the effects of the Problem-Based Learning model, combined with the use of the Bintang Ajaib manipulative, on student learning outcomes and activities is important. Based on the above discussion, research is needed to determine the effect of implementing the Problem-Based Learning model using the Bintang Ajaib manipulative on students' learning outcomes and activities in mathematics. Therefore, this study was conducted under the title "The Effect of the Problem-Based Learning Model with the Use of the Bintang Ajaib Manipulative on Student Learning Outcomes." This study is expected to contribute to the development of more effective, innovative, and meaningful mathematics learning strategies.

Method

The research method used in this study was quantitative, with a quasi-experimental design. The quasi-experimental design was chosen because the researcher could not fully randomize subjects (random assignment) but could still compare the treatment effects between the experimental and control groups under real-world learning conditions (Creswell & Poth, 2016). This study aims to determine the effect of the Problem-Based Learning (PBL) model, integrated with the Bintang Ajaib manipulative, on learning outcomes and student engagement in the topic of sequences and series among 10th-grade students. The experimental class used the Problem-Based Learning model with the Bintang Ajaib manipulative, while the control class used conventional teaching methods.

The research design used was the Nonequivalent Control Group Pretest-Posttest Design. According to Fraenkel as cited in A'yun (2023) quasi-experimental designs are widely used in educational research when researchers are unable to randomize subjects. In the nonequivalent control group design, both the experimental and control groups are administered pretests and posttests to evaluate the effect of the treatment given to the experimental group. The population in this study consisted of all 10th-grade students. The study sample comprised two classes: an experimental class and a control class, selected using purposive sampling. Purposive sampling is a nonprobability sampling technique conducted based on specific considerations or criteria established by the researcher in accordance with the research objectives (Sugiyono, 2021). In this study, this technique was implemented by selecting two classes with relatively comparable academic characteristics and student numbers, based on recommendations from the mathematics teachers. This technique was chosen because both classes were considered to have relatively similar initial conditions, making them suitable as the experimental and control classes.

Data collection techniques in this study included observation, documentation, and testing. The use of multiple data collection techniques was intended to obtain more comprehensive data so as to fully describe both the learning process and outcomes (Creswell & Poth, 2016). The research instruments included student activity observation sheets, documentation sheets, and test instruments. Observation sheets were used to monitor student engagement during learning sessions using the Problem-Based Learning model aided by the Bintang Ajaib manipulative. Documentation was used to gather supporting data, such as student rosters, learning materials, photos of activities, and other documents related to the research implementation. The test instrument, consisting of essay-type questions, was used as a pretest and a posttest to measure student learning outcomes on sequences and series. Before being used in the study, the test instruments were evaluated for quality through analyses of validity, reliability, difficulty, and discriminative power. These analyses aimed to ensure that the instruments met the criteria for good measurement tools, thereby producing valid and reliable data (Arikunto, 2021).

Data analysis was conducted after first performing prerequisite tests, namely a normality test using the Shapiro-Wilk test and a homogeneity test using Levene's test. If the data were normally distributed and homogeneous, the analysis would proceed using the independent-samples t-test. However, if the data are not normally distributed, the nonparametric Mann-Whitney U test is used to assess differences in learning outcomes between the experimental and control groups.

This study uses the Bintang Ajaib manipulative as a learning medium integrated into the Problem-Based Learning model. The use of manipulatives in mathematics instruction can help students visualize abstract concepts more concretely, thereby making it easier for them to develop a more meaningful understanding of those concepts (Khaerani et al., 2024). The Bintang Ajaib manipulative serves as scaffolding to support students in building conceptual understanding during the inquiry process within the Problem-Based Learning model. According to Ang, Zheng, Tan, & Lajoie (2023) scaffolding is support that helps students improve their problem-solving skills and self-regulation until they can work more independently. During the inquiry phase, the Bintang Ajaib manipulative is used to help students observe number patterns, visually identify differences in arithmetic sequences, and verify the formula for arithmetic sequences through hands-on activities, thereby making the learning process more meaningful. In addition to enhancing conceptual understanding, the use of manipulatives is also known to increase learning activity, critical thinking skills, and student engagement in the mathematics learning process (Asmiatun et al., 2021). An image of the Bintang Ajaib manipulative is shown below.

Figure 1. Bintang Ajaib Manipulative

Results and Discussion

The research results obtained after implementing instruction using the Problem-Based Learning (PBL) model, aided by the Bintang Ajaib manipulative, on the topic of sequences and series are presented in this section. The presentation of the research results begins with a description of the research subjects, followed by the results of the research instrument quality testing, which includes validity and reliability tests. The instruments were tested to meet the requirements for valid and reliable measurement tools, thereby ensuring accurate and consistent data. Once the instruments were deemed suitable for use, the study was conducted by administering pretests and posttests to determine the effect of implementing the Problem-Based Learning model, aided by the Bintang Ajaib manipulative, on student learning outcomes.

Based on the results of the research instrument testing, the test instruments used met the criteria for validity and reliability. The validity test was conducted to determine the instrument's accuracy in measuring student learning outcomes in sequences and series. In contrast, the reliability test was conducted to assess the instrument's consistency and ensure it is suitable for use as a data-collection tool in the research. The instrument was tested using 5 essay questions given to students outside the research sample. The results of the instrument's validity and reliability tests showed that all items were suitable for use in the research. The results of the instrument's validity and reliability tests are presented in the following table.

1. Validity

   The instrument's validity was tested with students on the topic of Sequences and Series. The instrument consisted of five essay questions designed in accordance with the learning indicators and research objectives. The validity test was conducted using IBM SPSS Statistics 27 to determine the suitability of each item before it was used in the study. Based on the analysis, all items were deemed valid and suitable for use as data collection tools in this study.

2. Reliabilitas

   The reliability test was conducted using Cronbach's alpha in IBM SPSS Statistics 27.0. The reliability test results showed that the Sequences and Series test instrument had a reliability index of 0.927. This value falls into the "very strong" category, indicating that the instrument used is reliable and suitable for measuring the learning outcomes.

After the instrument was deemed valid and reliable, the study administered pretests and posttests in the experimental class. Based on the study conducted in the experimental class, data on student learning outcomes were collected through pretest and posttest activities. These results indicate a difference in student scores before and after the implementation of the Problem-Based Learning model assisted by the Bintang Ajaib manipulative on the topic of sequences and series. A summary of student learning outcomes in the experimental class was used to assess the improvement in learning outcomes following the intervention. The summary of the research findings on the experimental class's learning outcomes is presented in the following table.

Table 1. Summary of Research Findings on Learning Outcomes in the Experimental Class

No	Student's Initials	Pretest	Posttest		No	Student's Initials	Pretest	Posttest
1	A.I.A.S	45	78		16	M.K.T	74	98
2	A.N.A	50	85		17	M.H	42	79
3	A.N	72	95		18	M.N.A	64	91
4	A.S.S	55	88		19	N.S	76	100
5	A.L.A	48	80		20	N.M	44	77
6	A.Z	55	75		21	N.H	48	83
7	B.S	70	96		22	P.R.S	40	76
8	C.F.M	38	72		23	S.N.P	69	95
9	D.I.R	68	94		24	T.A.M	73	97
10	F.N.S	52	86		25	V.F.Z	71	99
11	F.S.P	60	90		26	Y	43	78
12	F.D.C	50	84		27	A.B.A.S	39	74
13	H.W.A	46	82		28	A.A.K	56	89
14	I.N.S	58	88		29	N.F	41	75
15	M.I.F.S	54	87					

Table 2 presents a summary of the test results for students in the control group, the class group that received conventional instruction using lecture methods and practice problems, without the application of the Problem-Based Learning model or the use of the Bintang Ajaib manipulative for the topic of sequences and series.

Table 2. Summary of Research Findings on Learning Outcomes in the Control Class

No	Student's Initials	Pretest	Posttest		No	Student's Initials	Pretest	Posttest
1	A.I.A.S	35	65		16	M.K.T	38	70
2	A.N.A	30	55		17	M.H	56	78
3	A.N	50	85		18	M.N.A	50	72
4	A.S.S	40	75		19	N.S	75	95
5	A.L.A	72	92		20	N.M	70	90
6	A.Z	28	78		21	N.H	36	74
7	B.S	32	80		22	P.R.S	52	76
8	C.F.M	55	88		23	S.N.P	58	80
9	D.I.R	48	90		24	T.A.M	60	90
10	F.N.S	35	82		25	V.F.Z	48	72
11	F.S.P	45	75		26	Y	46	70
12	F.D.C	52	86		27	A.B.A.S	50	78
13	H.W.A	50	74		28	A.A.K	62	80
14	I.N.S	42	68		29	N.F	74	94
15	M.I.F.S	54	76					

After collecting the pretest and posttest data from the experimental and control classes, a normality test was conducted as a prerequisite for data analysis. The results of the normality test for the pretest and posttest data are presented in the following table.

1. Test of normality for the experimental group
   A normality test was conducted to determine whether the student achievement data from the experimental class were normally distributed. The normality test in this study was the Shapiro-Wilk test, conducted in SPSS version 27.0. The decision criteria for the Shapiro-Wilk test are as follows: if the significance value (Sig.) is > 0.05, the data are normally distributed; whereas if the significance value (Sig.) is < 0.05, the data are not normally distributed. Based on the normality test results for the student learning achievement data in the experimental class, the results are presented in the following table.

Tabel 3. Hasil Uji Normalitas Kelas Eksperimen

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	,130	29	,200*	,925	29	,061
Postest	,106	29	,200*	,950	29	,178

Based on the Shapiro-Wilk normality test in SPSS version 27.0, the pretest and posttest data are normally distributed. This is evident from the significance value (Sig.) of 0.061 for the pretest data and 0.178 for the posttest data. Both significance values are greater than 0.05, so the data are considered normally distributed.

2. Normality Test for the Control Group

A normality test was conducted to determine whether the student achievement data were normally distributed. The normality test in this study was the Shapiro-Wilk test, conducted in SPSS version 27.0. The decision criteria for the Shapiro-Wilk test are as follows: if the significance value (Sig.) is > 0.05, the data are normally distributed; whereas if the significance value (Sig.) is < 0.05, the data are not normally distributed. Based on the normality test results for the student learning achievement data in the control class, the results are presented in the following table.

Table 4. Results of the Normality Test for the Control Group

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	,086	29	,200*	,962	29	,375
Postest	,108	29	,200*	,970	29	,547

The Shapiro-Wilk test results for the control group indicate that the pretest and posttest data are normally distributed. This is evident from the significance value (Sig.) of 0.375 for the pretest data and 0.547 for the posttest data. Both significance values are greater than 0.05, indicating the data are normally distributed.

Based on the explanation above, the data are normally distributed and homogeneous; therefore, an independent samples t-test was conducted. The hypothesis test was conducted to determine the effect of the Problem-Based Learning model, incorporating the Bintang Ajaib manipulative, on student learning outcomes and activities related to sequences and series. The hypotheses in this study are as follows:

H_0: There was no effect of the Problem-Based Learning model combined with the use of the Bintang Ajaib manipulative on student learning outcomes and student activity.

H_1: The use of the Problem-Based Learning model in conjunction with the Bintang Ajaib manipulative has an impact on student learning outcomes and classroom engagement.

A t-test was conducted to determine whether the Problem-Based Learning model, combined with the Bintang Ajaib manipulative, affected student learning outcomes. Hypothesis testing was performed by comparing the calculated t-value with the table t-value. If the calculated t-value is greater than or equal to the table t-value, the hypothesis is accepted. In contrast, if the calculated t-value is less than or equal to the table t-value, the hypothesis is rejected. Additionally, decision-making can also be based on the significance level (Sig.), such that if Sig. < 0.05, the hypothesis is accepted, and if Sig. > 0.05, the hypothesis is rejected. The Independent Sample t-Test was performed using SPSS version 27.0. The results of the Independent Sample t-Test using SPSS version 27.0 are presented in the following table.

Table 5. Independent Sample Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Result	E.V assumed	,003	,954	2,787	55	,007	6,504	2,334	1,827	11,181
	E.V not assumed			2,783	54,3	,007	6,504	2,337	1,820	11,188

Table 6. Results of the t-Test on Student Learning Outcomes

	Class	N	Mean	Std. Deviation	Std. Error Mean
Learning Outcomes	post_eksperimen	29	85,90	8,495	1,578
	post_kontrol	29	79,39	9,122	1,724

Based on the results of the Independent Samples t-test conducted in SPSS version 27.0, the significance value (Sig., 2-tailed) was 0.007. Since this significance value is less than 0.05, H_0 is rejected, and H_1 is accepted. Thus, it can be concluded that the Problem-Based Learning model, using the Bintang Ajaib manipulative, affects the learning outcomes of 10th-grade students in the topics of sequences and series. The results of this study indicate that the Problem-Based Learning model, supported by the Bintang Ajaib manipulative, can improve student learning outcomes compared to conventional learning. This is evident in the

Group Statistics table, which shows that the mean learning achievement of students in the experimental class was 85.90, while that of students in the control class was 79.39. This difference in means indicates that students who learned using the Problem-Based Learning model supported by the Bintang Ajaib manipulative achieved better learning outcomes than those who learned using conventional teaching methods.

Furthermore, student engagement in the learning process in the experimental class was also more active because students were directly involved in problem-solving activities, group discussions, and the use of the Bintang Ajaib manipulative to understand the concepts of sequences and series. The use of the manipulative helped students understand the concepts more concretely and engagingly, making it easier for them to grasp the material. Therefore, the Problem-Based Learning model, when applied using the Bintang Ajaib manipulative, can be considered an effective alternative for improving student learning outcomes. The results of this study are also consistent with Naja et al. (2022), who found that the application of the Problem-Based Learning model, supported by manipulatives, improved students' mathematics learning outcomes compared to conventional learning. That study indicated that students' active use of manipulatives can help them understand mathematical concepts more concretely. Another relevant study by Muqimatussunnah et al. (2024) showed that the Problem-Based Learning model, when combined with learning media, can improve learning outcomes and student engagement, as students are more active in the learning process and find the material easier to understand. Additionally, research by Setiani (2023) found that the Problem-Based Learning model has a positive impact on students' mathematics learning outcomes because the instruction focuses on student problem-solving activities, both independently and in groups.

Based on these relevant studies, this study's results reinforce previous findings that implementing the Problem-Based Learning model, aided by the Bintang Ajaib manipulative, can improve student learning outcomes and engagement in mathematics, particularly in sequences and series.

Conclusion and Suggestion

Based on the research findings, it can be concluded that implementing the Problem-Based Learning model, supported by the Bintang Ajaib manipulative, has a significant effect on 10th-grade students' learning outcomes and engagement in sequences and series. This was supported by the results of the Independent Samples t-Test in SPSS version 27.0, which showed a significance value (Sig. 2-tailed) of 0.007 < 0.05, indicating that H_0 was rejected and H_1 accepted. The research results also showed that students in the experimental class achieved higher learning outcomes than those in the control class. The experimental class, which used the Problem-Based Learning model assisted by the Bintang Ajaib manipulative, achieved an average score of 85.90. In contrast, the control class, which used conventional learning, achieved an average score of 79.39. This indicates that using the Problem-Based Learning model, supported by the Bintang Ajaib manipulative, can improve student learning outcomes more effectively than conventional learning.

In addition to improving learning outcomes, implementing the Problem-Based Learning model, supported by the Bintang Ajaib manipulative, also increased student activity during the learning process. Students became more active in discussing, solving problems, asking questions, and understanding the concepts of sequences and series through the manipulative that helped them visualize mathematical concepts more concretely and engagingly. Thus, the Problem-Based Learning model, supported by the Bintang Ajaib manipulative, can serve as an effective and innovative alternative in mathematics education.

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