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Meta Analysis: The Effect of Problem Based Learning (PBL) Model on Student Mathematics Learning Outcomes

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ABSTRACT

This study aims to determine whether or not there is an effect of the *problem-based* learning model on students' mathematics learning outcomes and the difference in the amount of influence *based* on level. Due to the variety of research results on this topic, a meta-analysis research was conducted to evaluate as a whole. This research analyzed 14 data studies consisting of articles and theses at the junior high school and high school levels, with the help of Ms Exel and JASP *software*. The results of this study indicate that the *problem-based learning* model has an effect on students' mathematics learning outcomes, as evidenced by the *p-value* <0.001 with a significant level of 0.05. In addition, the combined *effect size* value is 1.46 which means the impact is very large based on Cohen's scale. Meanwhile, when viewed from the perspective of the level of education, there is a big difference in the effect between junior high school and senior high school. With an average *effect size* value of junior high school of 1.194 while high school is 2.008. If the two are compared, the effect is greater at the senior high school level than junior high school. Therefore, based on this research, the *problem-based learning* model is considered an effective learning model to improve students' mathematics learning outcomes compared to conventional learning models.

Keywords: *problem-based learning* model, math learning outcomes, and meta-analysis.

INTRODUCTION

Education is a deliberate and planned effort to create an effective learning environment, where students actively develop their potential in various aspects such as personality, noble character, religion, intelligence, self-control, and skills that are relevant for personal, social, and national interests. (Darlin & Fathonah, 2021). Education, especially formal education, must have a learning system that prioritizes a dynamic process, aims to stimulate curiosity and overcome any problems faced by students. (Susila, 2017). One of the subjects studied in the world of formal education is mathematics.

Mathematics according to (Nasution, 2019) is the foundation of thinking and reasoning that is essential for solving various challenges in the scientific, administrative, and industrial worlds. Meanwhile, according to James, mathematics includes logical studies related to magnitude, shape, arrangement, and number concepts that break down into three main domains: algebra, geometry, and analysis. (Efriyani, 2021). As a key subject, mathematics continues to develop along with the human

thought process, making logic an integral foundation in the construction of this science. (Nasution, 2019).

In Indonesia, one of the indicators of success and failure in learning mathematics is measured by student achievement in the subject. In this case, the real form of student learning outcomes can be seen in the form of scores from questions, assignments, exams, and understanding manifested in answers. When students achieve good learning outcomes, this indicates the success of the learning process, otherwise unsatisfactory learning outcomes indicate challenges in the learning process that need to be overcome. (Butar et al., 2022).

PISA (*Program for International Student Assessment*) conducted a study in 2018 which showed that student learning outcomes in mathematics in Indonesia are still low. The data shows that in 2015, Indonesia achieved 386 points in math learning competency, but in 2018 this number decreased to 379 points, a decrease of 7 points. Nonetheless, Indonesia's average points are still below the OECD (*Organisation for Economic Co-operation and Development*) average of 478 points, indicating that mathematics competency in Indonesia is quite low compared to some other countries. (Efriyani, 2021).

In addition, several experimental studies state that students' interest and learning outcomes in mathematics are low, as seen from the scores of students, the majority of which are still below the minimum completeness criteria (KKM). This is motivated by the learning model used which is still teacher-centered / conventional learning model. So that learning becomes boring, monotonous, less interesting and students become passive, bored, and lazy. (Andriasa et al., 2020; Manoka et al; Kusumawati et al; Pratiwi et al; Surat & Jayani, 2019).

Improving student learning outcomes requires the right learning models, techniques and methods. An alternative learning model that can be applied is the *problem-based* learning (PBL) learning model. PBL is a learning model that emphasizes the active participation of students and uses real-world problems as a learning context. PBL has several characteristics, namely: (1) learning begins with the identification of one specific problem; (2) ensuring that the problem is relevant to the real situation faced by learners; (3) structuring subject matter around existing problems, not related to certain disciplines; (4) giving great responsibility to learners in organizing and implementing the learning process directly; (5) using learning in small groups; (6) demanding learners to demonstrate their understanding through concrete products or performance. (Jalaluddin, 2019).

Many studies have been conducted to evaluate the effect of *problem-based* learning (PBL) on students' mathematics learning outcomes in Indonesia. The results vary, some studies state that it has an effect (Haqkiky & Hadi, 2023; Jayantika et al; Kapoh et al; Pardede et al; Aniswita et al; Noervadila & Astidari, 2019). While other studies show no effect (Kurniawan et al., 2022).

Therefore, research is needed to thoroughly evaluate the impact of *problem-based* learning (PBL) models on students' mathematics learning outcomes in Indonesia. This aims to reduce inconsistencies and verify the results of several previous studies. A suitable method for this analysis is meta-analysis, a research approach that systematically and quantitatively examines existing studies to gain a deeper understanding of something. (Rahmawati et al., 2023)..

MATERIALS & METHODS

This study uses *standard operating procedures* (SOP) *preferred reporting items for systematic for systematic review and meta analysis* (PRISMA). PRISMA SOP is a procedure used in conducting meta-analysis to make it easier to review the *roadmap* structure of research objectives. (Nugraha et al., 2020).. PRISMA SOP is carried out through three stages, namely

searching and retrieving articles, filtering and analyzing. The first two stages produced 14 primary study data to be analyzed. For better understanding, the PRISMA flow diagram is presented in Figure 1 while information from the 14 studies is presented in Table 1.

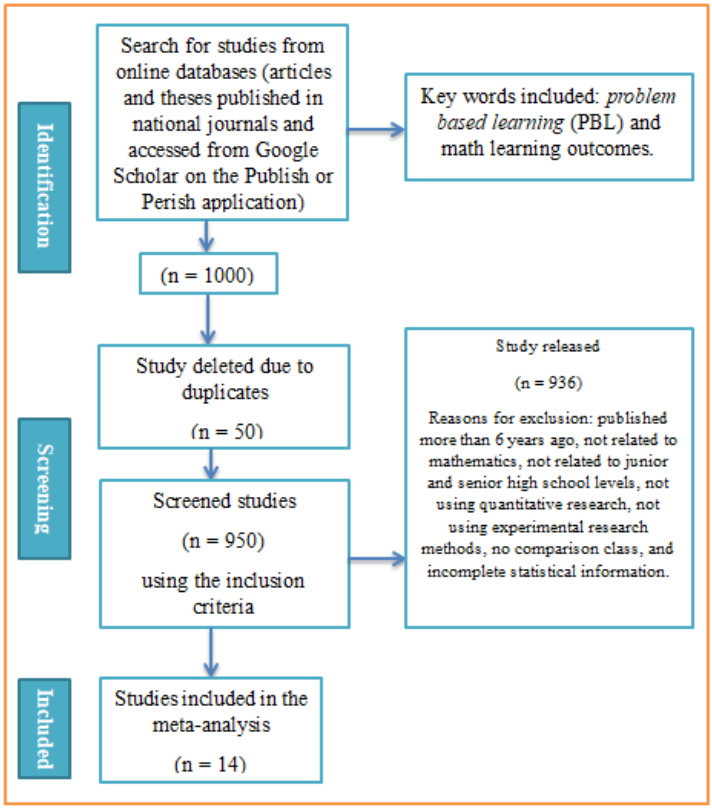


Figure 1. PRISMA Flow Diagram

Table 1. List of articles used in the study

No.	Code	Year	Author Name	Title	Journal
1.	A101	2023	Annisa Putri Haqkiky, Susilo Hadi	The Effect of Problem Based Learning Model (Pbl) on Mathematics Learning Outcomes of 7th Grade Students of Smp Hang Tuah 2 Surabaya	National Seminar on Mathematics, PGRI Adi Buana University Surabaya
2.	A102	2020	I Gusti Agung Ngurah Trisna Jayantika, Nyoman Parmithi, Desak Nyoman Diah Purwaningsih	The Effect of Problem Based Learning Model on Anxiety and Mathematics Learning Outcomes	Emasains Journal: Journal of Mathematics and Science Education Volume IX
3.	A103	2023	Lingkan C. Kapoh, Sylvia J.A. Sumarauw, Aaltje S. Pangemanan	Students Using PBL Model and DI Model Assisted by Geogebra Software on SPLD Material	MARISEKOLA: Journal of Mathematics Research Education and Collaboration
4.	A104	2024	Windi Pratama Putri, Elita Zusti Jamaan	The Effect of Problem Based Learning Model on Learning Outcomes of Class VIII Students of Smp Negeri 25 Padang	Journal of Mathematics Education and Research
5.	A105	2021	Aniswita, Yogi Saputra, Gema Hista Medika	Effect of Learning Model Problem Base Learning on Student Mathematics Learning Outcomes in Class VII SMP N 1 V Koto	Juring (Journal For Research In Mathematics Learning)

				Kampung Dalam Padang Pariaman 2019/2020 Academic Year	
6.	A106	2020	Wa Ode Andriasa, Mohamad Salam, Utu Rahim	The Effect of Problem-Based Learning Model on Mathematics Learning Outcomes of Students of Class VII Smp Negeri 1 Wadaga	Journal of Mathematics Education Research
7.	A107	2022	Greiselah Manoka, Rosiah J. Pulukadang, Patricia V. J. Runtu	The Effect of Problem-Based Learning Model on Student Learning Outcomes on Pythagorean Theorem Material	World Inspiration: Journal of Education and Language Research
8.	A108	2019	Juriah Nasution	The Effect of Problem Base Learning (Pbl) Model on Student Learning Outcomes of Class VII Smp Negeri 13 Pekanbaru	Riau Islamic University Library
9.	A109	2019	Nuradilah Jalaluddin	The Effect of Problem Based Learning Model (Pbl) on Students' Mathematics Learning Achievement on SPLDV Class VIII Smp Negeri 1 Matakali Material	Journal Peqguruang: JPCS Conference Series
10.	A201	2022	Friska Esrawaty Butar Butar, Ropinus Sidabutar, Golda Novatrasio Sauduran	The Effect of Problem Based Learning (PBL) Learning Model on Mathematics Learning Outcomes	Journal of Science and Computer Education
11.	A202	2019	I Made Surata, Ni Luh Lian Jayani	The Effect Of Problem Based Learning Model With E-Learning To Creativity And Learning Result Of Mathematics The Effect Of Problem Based Learning Model With E-Learning To Creativity And Learning Result Of Mathematics	Emasains Journal: Journal of Mathematics and Science Education P-ISSN 2302-2124
12.	A203	2022	Arie Kurniawan, M. Ikhsan, Mukhlis Hidayat	The Effect of Geogebra-assisted Problem Based Learning Model on the Equation of Tangent Curve on Learning Outcomes of High School Students	Scientific Journal of Mathematics Education Students
13.	A204	2019	Irma Noervadila, S.Pd, M.Pd, Tri Astidari, S.Pd, M.Pd	The Effect of Problem Based Learning (Pbl) Learning Methods and Metacognition Skills on Student Learning Outcomes of Smk Negeri 2 Situbondo	Ika's Journal
14.	A205	2023	Nyimas Inda Kusumawati, Rica Oktasari, Hussein Fattah, Refi Elfira Yuliani, Luvi Antari	Experimental Study of Problem Based Learning Model on Mathematics Learning Outcomes of Students of Grade XI Row and Sequence Material	Journal of Mathematics Education Research

STATISTICAL ANALYSIS

This study uses a meta-analysis technique whose statistical analysis refers to the opinion of Retnawati et al (2018). The first step is to calculate the *effect size* and *standard error*. The calculation of *effect size* and *standard error* begins with calculating the sample estimation parameters (d), combined standard deviation (S_{within}), variand d (V_d), free degree (df), correction factor (J), effect size grub contrast (g), variant of effect size grub contrast (V_g), and standard error (SE_g) with the formula:

$$d = \frac{\overline{X}_E - \overline{X}_c}{S_{within}} \quad , \quad S_{within} = \sqrt{\frac{(n_1-1)S_1^2+(n_2-1)S_2^2}{n_1+n_2-2}} \, , V_d = \frac{n_1+n_2}{n_1\, n_2} + \frac{d^2}{2(n_1+n_2)} \, ,$$

$$df = n_1 + n_2 - 2 \quad , \quad J = 1 - \frac{3}{4df-1} \quad , \quad g = J \times d \, , V_g = J^2 \times V_d \, , SE_g = \sqrt{V_g}$$

After all the first step processes have been carried out, then the g andSE_g values that have been obtained are input to the JASP *software*. Where the correction factor (J) always has a value less than 1.0 and g is always smaller than d. However, J will always be close to 1.0 unless the df is always small (less than 10) and the difference is usually. After determining the *effect size* and *standard error* for each study, the next step is to test for heterogeneity by checking the $Statistic$ - Q value and the p - value. In addition to determining the estimation model, this test also aims to determine the combined *effect size of* all primary studies. If the p-value <0.05, then H_0 is rejected, meaning that the *effect size of* each study is different (heterogeneous) and the selected estimation model is the *random effect model*.

Then compile the *forest plot* obtained from the JASP *software* and interpreted. The criteria used for the interpretation of *effect size* are Cohen's opinion (Rahmawati et al., 2023) as follows:

Small effect $= 0{,}2 = ES$
Medium effect $= 0{,}21 = ES = 0{,}50$
Big effect $= 0{,}51 = ES = 1{,}00$
Effect is huge $= ES > 1{,}00$

Next is the bias test. Bias correction can be done if the sample size is small, n < 20. Bias is corrected with the fail-safe N (FSN) test using the formula$\frac{N}{(5k+10)} > 1$ where k = number of samples. If the formula is met, it means that the primary study analyzed is free of publication bias. In addition, it can also be seen in the JASP *funnel plot* with the condition that it must be symmetrical, but if it is not symmetrical, the FNS test is sufficient.

Furthermore, hypothesis testing is carried out by testing the p - $value$ value of the Z statistic. The criterion for rejecting H_0 if p - $value$ < 0.05, indicating an effect. The last test is the assessment of study characteristics by examining the average *effect size* value for each education level to determine the effect based on education level**.**

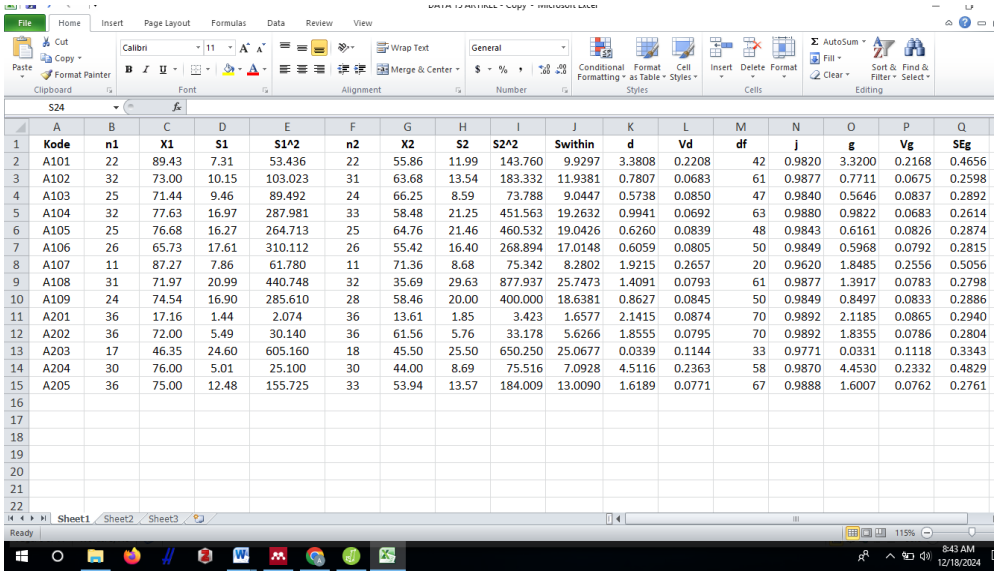
RESULT

The researcher extracted the statistical information contained in 14 study data, where the data was divided into 2 groups based on education level, namely: junior high school study group with the code A101, A102, A103, A104, A105, A106, A107, A108, A09 and senior high school study group with the code A201, A202, A203, A204, A205. The following is a recapitulation of the extraction results.

Table 2. Recapitulation of data extraction results

Statistical Data						
Code	**Experiment Class**			**Control Class**		
	Mean	**SD**	**N**	**Mean**	**SD**	**N**
A101	89,43	7,31	22	55,89	11,99	22
A102	77,63	16,97	32	58,48	21,25	33
A103	76,68	16,27	25	64,76	21,46	25
A104	87,27	7,86	11	71,36	8,68	11
A105	65,73	17,61	26	55,42	16,398	26
A106	71,97	20,994	31	35,69	29,630	32
A107	63,28	10,47	40	51,97	11,85	39
A108	73,00	10,15	32	63,68	13,54	31
A109	71,44	94,460,796,302	25	66,25	8,593,475,786	24
A201	17,16	1,44	36	13,61	1,845	36
A202	46,35	24,6	17	45,5	25,5	18
A203	75,00	12,479	36	53,94	13,565	33
A204	72,00	5,49	36	61,56	5,76	36
A205	76,00	5,01	30	44,00	8,69	30

All data that has been extracted is calculated using Ms. Exel to get the *effect size* and *standard error* values, then inputted into JASP.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Kode	n1	X1	S1	S1^2	n2	X2	S2	S2^2	Swithin	d	Vd	df	j	g	Vg	SEg
2	A101	22	89.43	7.31	53.436	22	55.86	11.99	143.760	9.9297	3.3808	0.2208	42	0.9820	3.3200	0.2168	0.4656
3	A102	32	73.00	10.15	103.023	31	63.68	13.54	183.332	11.9381	0.7807	0.0683	61	0.9877	0.7711	0.0675	0.2598
4	A103	25	71.44	9.46	89.492	24	66.25	8.59	73.788	9.0447	0.5738	0.0850	47	0.9840	0.5646	0.0837	0.2892
5	A104	32	77.63	16.97	287.981	33	58.48	21.25	451.563	19.2632	0.9941	0.0692	63	0.9880	0.9822	0.0683	0.2614
6	A105	25	76.68	16.27	264.713	25	64.76	21.46	460.532	19.0426	0.6260	0.0839	48	0.9843	0.6161	0.0826	0.2874
7	A106	26	65.73	17.61	310.112	26	55.42	16.40	268.894	17.0148	0.6059	0.0805	50	0.9849	0.5968	0.0792	0.2815
8	A107	11	87.27	7.86	61.780	11	71.36	8.68	75.342	8.2802	1.9215	0.2657	20	0.9620	1.8485	0.2556	0.5056
9	A108	31	71.97	20.99	440.748	32	35.69	29.63	877.937	25.7473	1.4091	0.0793	61	0.9877	1.3917	0.0783	0.2798
10	A109	24	74.54	16.90	285.610	28	58.46	20.00	400.000	18.6381	0.8627	0.0845	50	0.9849	0.8497	0.0833	0.2886
11	A201	36	17.16	1.44	2.074	36	13.61	1.85	3.423	1.6577	2.1415	0.0874	70	0.9892	2.1185	0.0865	0.2940
12	A202	36	72.00	5.49	30.140	36	61.56	5.76	33.178	5.6266	1.8555	0.0795	70	0.9892	1.8355	0.0786	0.2804
13	A203	17	46.35	24.60	605.160	18	45.50	25.50	650.250	25.0677	0.0339	0.1144	33	0.9771	0.0331	0.1118	0.3343
14	A204	30	76.00	5.01	25.100	30	44.00	8.69	75.516	7.0928	4.5116	0.2363	58	0.9870	4.4530	0.2332	0.4829
15	A205	36	75.00	12.48	155.725	33	53.94	13.57	184.009	13.0090	1.6189	0.0771	67	0.9888	1.6007	0.0762	0.2761

Figure 2. Results of Calculation of *effect size* and *standard error* using Ms. Exel

Furthermore, the heterogeneity test was conducted and the estimation model was determined to obtain the overall *effect size* with the help of JASP *software*. From table 4, it is known that the p value <0.001 with a significant level of 95%. Then the value of $p < 0.05$ is met, so H_0 is rejected, which means that the *effect size of* each study is different (heterogeneous) and the selected estimation model is the *random effect model*.

Table 3. Heterogeneity Test

Fixed and Random Effects			
	Q	**df**	**p**
Omnibus test of Model Coefficients	25.632	1	< .001
Test of Residual Heterogeneity	116.499	14	< .001
Note. *p* -values are approximate.			
Note. The model was estimated using Restricted ML method.			

The next stage is the calculation of the combined *effect size* seen from the results of the JASP *forest plot*. Figure 3 shows that the combined *effect size* is 1.46, which means the *effect is* very large. While the *effect size of* each study is in a varied classification. There are 7 studies with very large *effect size*, namely A101, A107, A108, A201, A202, A204, A205; 6 studies with large *effect size*, namely A102, A103, A104, A105, A106, A109; 1 study with small *effect size*, namely A203; there are no studies with medium *effect size*.

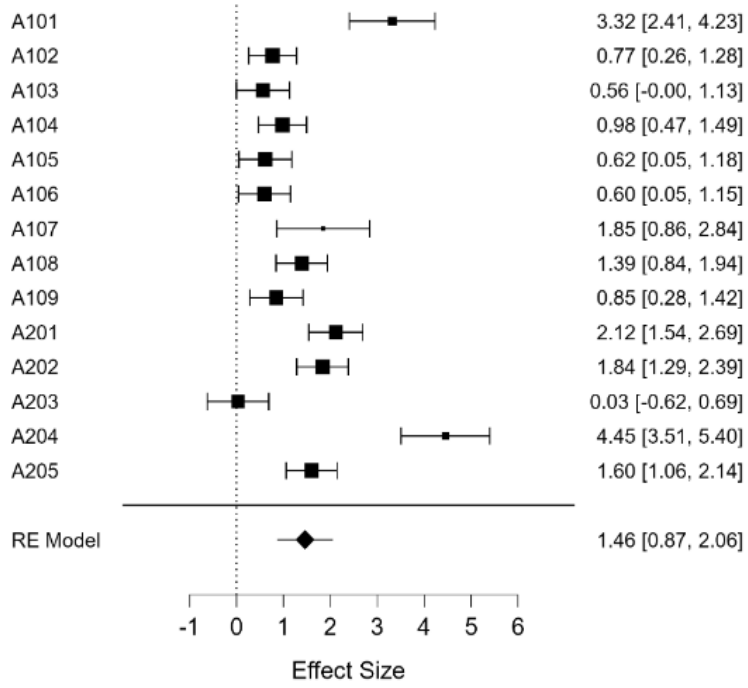


Figure 3. Combined *Effect Size* Calculation *Forest Plot*

Furthermore, the bias test is performed with the fail-safe N (FSN) test because the shape of the funnel plot in Figure 4 is not symmetrical. Substitute the N and k values presented in Table 4. $\frac{1340}{(5.14+10)} > 1$ The result was$16{,}781 > 1$. This means that the 14 primary studies are included in the analysis that is resistant to publication bias and are suitable for use in further analysis.

Table 4. Fail-Safe Test Results N

File Drawer Analysis			
	Fail-safe N	**Target Significance**	**Observed Significance**
Rosenthal	1340.000	0.050	< .001

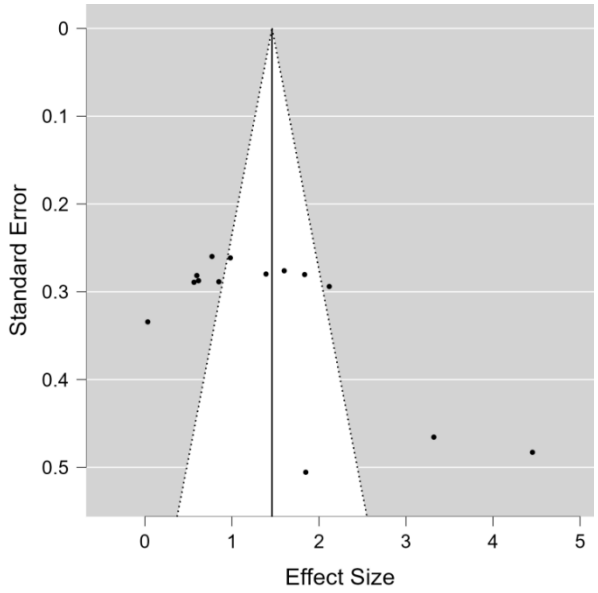


Figure 4. *Funnel Plot*

Then conduct hypothesis testing with a *random effect model*, it can be seen in Table 5 that the *p-value* of the Z statistic is <0.001. Then the criteria for rejecting H_0 if p - $value$ < 0.05 is met, which means that the application of the *Problem Based Learning* (PBL) learning model has an effect on student math learning outcomes rather than conventional learning models.

Table 5. Hypothesis Test

Coefficients				
	Estimate	**Standard Error**	**z**	**p**
intercept	1.461	0.303	4.819	< .001
Notes. Wald test.				

The last step is the characteristic test to evaluate the characteristics of the study focusing on junior high school and senior high school levels. Based on Figure 5, the average ES value at the junior high school level is 1.215, which means there is a very large influence. While the average ES value at the high school level is 2.008 which means, there is also a very large influence.

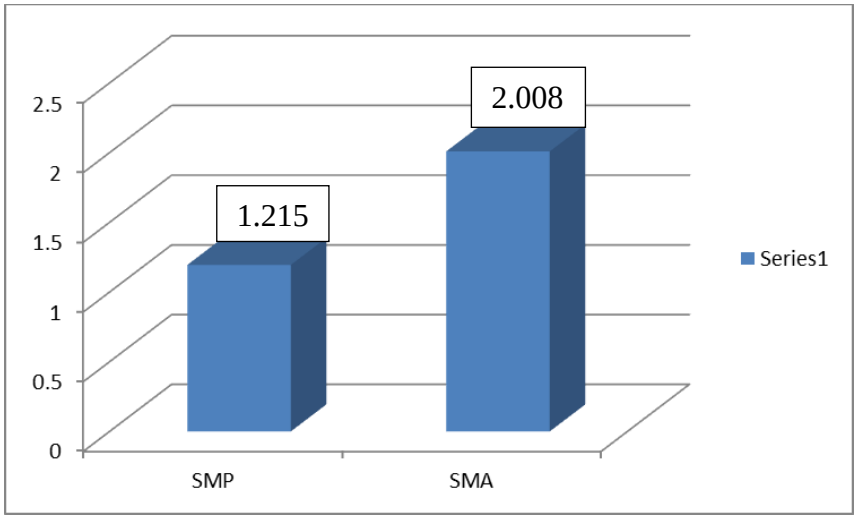


Figure 5. Characteristic Test

DISCUSSION

This study used a quantitative meta-analysis method on 14 articles that met the PRISMA SOP to answer the two objectives of this study.

1. The effect size of PBL model on mathematics learning outcomes: The results of the meta-analysis showed that the average *effect size of* the 14 articles was 1.46, indicating a very large *effect of* the PBL model on students' mathematics learning outcomes. The PBL model is proven to be more effective than conventional learning and more suitable for mathematics learning. This finding is in line with previous research, namely (Robiyanto, 2021).
2. The difference in the effect size of the PBL learning model is based on the level of education: At the junior high school level, the *effect size of the* PBL learning model is 1.194. While at the high school level, the *effect size* reached 2.008. Although both showed a very large effect, there was a difference in the size of the effect. This finding is in line with previous research, namely (Isma et al., 2021).

CONCLUSION

Based on the level of education, the average *effect size* value of junior high school (SMP) is equal to 1.215 while senior high school (SMA) is equal to 2.008, which means that

both at the junior and senior high school levels the *problem-based learning* (PBL) learning model has a very large effect on student mathematics learning outcomes. However, there is a big difference in influence and if the two are compared the influence is greater at the senior high school level (SMA).

While the overall average *effect size* value of 14 study data is 1.46. This means that the *problem-based* learning (PBL) learning model has a very large effect on students' mathematics learning outcomes. So that learning mathematics using a *problem-based learning* (PBL) learning model is very effective and efficient compared to conventional learning models.

Declaration by Authors

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