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The effectivity of problem-based learning to improve the HOTS: A meta-analysis

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Abstract: This study aims to determine the effect of problem-based learning on higher-order thinking skills (HOTS) through meta-analysis. Data is collected by research documentation generated from various sources collected through the Internet. These articles were published from 2019 to 2022. The themes discussed the effect of PBL to HOTS on students' skill abilities, analysed quantitatively, described data in sample sizes, standard deviations, and averages, and published in journals and indexed on Google Scholar. The analysis design used a contrast group with a random effects model that corrected for effect sizes. The analysis used JASP software to calculate mean aggregate differences, plot forest plots, and publication bias. The study results show a significant difference between groups using control and experimental in the learning process (SE = 1.00); students who use PBL in learning have better learning outcomes than those who do use conventional. Based on the analysis results, the urgency of implementing PBL is evident in supporting the problem-based learning process with HOTS skills.
Keywords: HOTS, PBL, effect, improve

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INTRODUCTION

The millennial era has brought significant changes in various fields of life, one of which is in the world of education (Arlinwibowo, Mustaqim, et al., 2021; Marsigit et al., 2020). Education is a form of embodiment of dynamic and developing human culture (Zurqoni et al., 2018). Education can support future development education that can set students to help with the difficulties that occur in life (Syarifah & Ritonga, 2020). In addition, education in the era of the industrial revolution 4.0 is marked by the emergence of new literacy, namely data literacy, technological literacy, and human literacy (Yurniwati & Soleh, 2020). To face challenges and problems that increasingly require technology and science in this global community (Arlinwibowo, Retnawati, Hadi, et al., 2021), the world of education must be oriented to preparing the younger generation to have 21st Century Skills (Arlinwibowo et al., 2020; Arlinwibowo, Retnawati, & Kartowagiran, 2021b).

21st-century skills are the answer to the challenges of the industrial revolution era 4.0 (Arlinwibowo, Retnawati, & Kartowagiran, 2021a; Arlinwibowo et al., 2022). In which the State needs to change three things in the world of education to answer the challenges of the indus-

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trial revolution 4.0, namely first: changes in the nature and mindset of today's children (character), second: schools must be able to hone and develop children's talents (critical and creative), third: educational institutions can change the learning model according to the needs of the times (communication, collaboration and networking) (Ahmad et al., 2022).

HOTS is a thinking process that memorises and conveys already known information and the skills to connect existing knowledge and experience into creative thinking in making decisions and solving problems in new situations. Students with high-order thinking skills in learning will cause them to get used to analysing and thinking creatively in solving problems found in everyday life (Simanjuntak et al., 2021).

HOTS has a vital role when it comes to 21st-century skills. However, the facts on the ground show that the capacity of HOTS students is still relatively low. Students are still learning at the level of remembering, understanding and applying and are not accustomed to being trained in the ability to analyse, evaluate, and create. Based on the research results, Saido et al. showed that previously teachers learned to remember students; in contrast, teachers still did not carry out innovative learning, such as project learning, problem-based learning, collaborative learning and research. This is reflected in the PISA Study results, which ranked 64th in 65 countries in 2012, and 2015 was rated 64th out of 72 countries (Gurria, 2012). The ranking shows that Indonesian students are still at a low level of proficiency.

The implementation of the education system in Indonesia currently uses the revised 2013 Curriculum, which aims to make students have higher-order thinking skills in Higher Order Thinking Skills (HOTS). One learning model that is expected to increase HOTS ability is Problem Based Learning (PBL). The Problem Based Learning (PBL) model is designed in real-world problems as a context for students to gain essential knowledge, learn critical thinking methods and problem-solving skills, and connect knowledge and experience to critical and creative thinking to make decisions. And solve problems in new situations (Prastiwi et al., 2019).

Thus, this study aims to determine the effectiveness of applying the PBL model for students' problem-solving skills in HOTS ability enhancement content. It is hoped that the results of this meta-analysis can be used as an overview of problem-based learning in improving students' HOTS abilities to be used as a basis for critical and creative thinking in solving problems.

METHODS

This study is a meta-analysis that summarises the results of similar studies and ends with global conclusions. The theme of this research is the impact of problem-based learning in improving higher-order thinking skills (HOTS). Thus, the population of data in this article is a study of all studies comparing the results of problem-based learning through the control class (no treatment) and the experimental style (treated). The analysed articles were published in journals from 2019 to 2022 in English. The engineering article collection uses Google Scholar as a search engine that links to various journal portals and indexing institutions. This strategy is used to collect the broadest possible data to obtain many data to represent global conditions and avoid bias comprehensively.

The inclusion criteria in this study based on articles published from 2019 to 2022 were: (i) Articles published in the United Nations Language; (ii) This article discusses problem-based learning to improve higher-order thinking skills (HOTS); (iii) Articles are analysed quantitatively; (iv) The article describes the data in the form of sample size, standard deviation, and average; (v) Articles published in journals indexed in Google Scholar.

Articles that do not meet the six inclusion criteria will be included in the pool of pieces that fall under the exclusion criteria. Papers that fall within the exclusion criteria will not be included in the meta-analysis process. Finally, the researchers collected 28 articles that included data on sample size, the standard deviation of data, and the mean of study results. These three data are the basis for finding global conclusions. If these data are unavailable, the article will be omitted from the sample set to be analysed. So, from the final collection of research results, 28 themes will be explored using meta-analysis techniques.

This study uses a random effect model to generalise the research results to the population (not only valid for concluding data findings). The requirement for selecting the random effects model is heterogeneity information I^2> 25%. The type of meta-analysis in this study is a contrast group that will show whether there is a difference between the control and experimental classes in higher-order thinking skills (HOTS). The data obtained have varying intervals (difference between the minimum and maximum values), so the data must be standardised. The estimated mean/effect sample size (d) is normalised by (1):

$$1(oned) = \frac{\underline{x}_1 - \underline{x}_2}{S_{within}},\ 1S_{within} = \sqrt{\frac{(n_1-1)S_1{}^2+(n_2-1)S_2{}^2}{(n_1-1)(n_2-1)}} \quad \text{.........(1)}$$

The formula used to find the standard error d (SEd) is (2):

$$SubscriptSE_d = \sqrt{V_d}, \text{ where } V_d = \frac{n_1+n_2}{n_1 n_2} + \frac{d^2}{2(n_1+n_2)} \quad \text{.........(2)}$$

Hedges Retnawati et al. (2018) shows that the resulting d has a slight bias. To minimize bias, Hedges changed to (3) and (4).

$$g = J \times d, \text{ with } J = 1 - \frac{3}{4df-1} \quad \text{.........(3)}$$

$$df = degree\ of\ freedom\ (n_1 + n_2 - 2)$$

$$SE_g = \sqrt{V_g}, \text{ with } V_g = J \times V_d \quad \text{.........(4)}$$

Then, the analysis process is carried out using JASP software. The data entered is g as a practical measure and generates predictive plots in which there are value intervals and standard errors for each study and conclusion. In addition, JASP also helps in calculating heterogeneity and publication bias (funnel planning). Thus, it can be concluded that the effect of problem-based learning on higher-order thinking skills (HOTS).

RESULTS AND DISCUSSION

Result

This study analyzed 28 research results taken from 40 articles. Several studies have produced several research results. Several studies, Liana et al. (2020a) shared interactive mobile learning media to improve students' hots skills supported by a problem-based learning model. Liana et al. (2020b) share Learning Media with Problem Solving Approach: Its Effect on Higher Order Thinking Skills. Tumanggor et al. (2020) share students' higher-order thinking skills through problem-based learning in Bandung.

The selected research generally finds the effect of problem-based learning in improving higher-order thinking skills (HOTS). In this study, what is meant by analysis are students who can think critically and creatively in solving problems? The study compared the control group with the experimental group (ICT-based). Based on the data sample size, mean, and standard deviation, researchers can produce an effect size and standard error, as presented in Table 1. Based on the data in Table 1. A heterogeneity test will be conducted to show the model's suitability with the data. The results of the heterogeneity test are shown in Table 2.

Notes: (i) M = mean of each data presented in the study sample; (ii) n = the number of data displayed in the sample study; (iii) SD = standard deviation indicated in the study sample; (iv)

Esg = Effect size as a quantitative index used to summarise study results in the meta-analysis. That is, the effect size reflects the magnitude of the relationship between the variables in each study which in this study represents the difference between HOTS-based problem-based learning involving ICT and without involving ICT; (v) Seg = Standard Error as the value used as the basis for determining the actual effect size interval.

Table 1. Summary of research data, effect size, and standard error

ID	Researcher code	Based on ICT			Conventional			Esg	Seg
		n	SD	M	N	SD	M		
Study1	(Simanjuntak et al., 2021)	35	14.9	76.62	34	11 .60	44.05	2.41	0.32
Study2	(Muttaqin et al., 2021)	20	20.446	67.50	20	20.007	58.50	0.44	0.32
Study3	(Isnaeni et al., 2018)	36	8.72	76.72	36	7.09	60.72	1 .99	0.29
Study4	(Hasyim et al., 2019)	30	8.46	23.25	30	13.49	56.20	-2.89	0.37
Study5	(Khasanah & Hidayah, 2022)	91	9.14	68.7	91	10.54	38.78	3, 02	0.22
Study6	(Shafira et al., 2022)	32	15,674	76.94	32	17,778	73.84	0.18	0.25
Study7	(Liana et al., 2020a)	36	7.63	82.57	36	3.40	64.82	2.97	0.34
Study8	(Gultom et al., 2021)	34	10,165	73,921	34	10,526	60,980	1.24	0.26
Study9	(Karlina et al., 2008)	20	2.26	6.60	20	2.89	6.05	0.21	0.31
Study10	(Ibrahim et al., 2020)	31	4.884	12.87	32	4.882	20 ,97	-1.64	0.29
Study11	(Tumanggor et al., 2020)	34	688,750	813,23	36	951,50	729,16	0.10	0.24
Study12	(Ibnu et al., 2020)	34	61,647	1,516	32	64,250	64,250	-1.82	0.29
Study13	(Yurniwati & Soleh, 2020)	18	10,799	39,444	18	7,631	27,333	1.27	0.36
Study14	(Syarifah & Ritonga, 2020)	33	5.69	76.73	33	4.78	67.73	1.69	0.29
Study15	(Liu & Mu, 2022)	92	2.15	42.06	92	1.34	31.94	5.63	0.33
Study16	(Pratama & Solehuddin, 2019)	30	11.671	76.93	30	16.993	63.73	0.89	0.27
Study17	(Putra et al., 2021)	23	10.137	78.70	23	6.496	64.76	1.61	0.34
Study18	(Umam et al., 2019)	18	14.61	68.89	18	11, 62	55.56	0.99	0.35
Study19	(Rofik et al., 2022)	34	11.375	138.12	31	8.564	132.16	0.58	0.25
Study20	(Shidiq & Sumiati, 2020)	36	10.658	125.69	36	10.366	119.83	0.55	0.24
Study21	(Masnur & Syaparuddin, 2019)	25	12,069	80.40	25	11,431	71.60	0.74	0.29
Study22	(Desrani et al., 2022)	32	8.375	75.16	32	9.672	60.00	1.66	0.29
Study23	(Komala et al., 2021)	66	8.11	85, 45	66	8.59	78.99	0.77	0.18
Study24	(Darby & Rashid, 2017)	30	1.94	52.36	30	2.61	50.80	0.67	0.26
Study25	(Alsowat, 2016)	33	1.62	7.515	34	1, 95	7.617	-0.06	0.24
Study26	(Djajanto, 2020)	80	7.53506	78.41	80	7.05	72.32	0.83	0.16
Study27	(Hasanah & Malik, 2019)	20	5.806	81.65	20	8.525	71.50	1.36	0.35
Study28	(Yusuf et al., 2021)	29	66.52	22.55	24	17.69	42.01	1.21	0.30

Table 2. Residual heterogeneity estimation

	Estimate
I^2 (%)	97,058

This study took a random effect model so that the data must meet the heterogeneity assumption. I^2 is one method that can be used to test heterogeneity. I^2 describes the proportion of variation in the summary effect size on a scale of 0% to 100%. The data collected in this study are shown in Table 2 resulting in I^2 = 97.058% > 25%, so it is said that there is heterogeneity so that the selection of the random effect model is by the criteria. Then to conclude, the overall effect can be seen in the prediction plot in Figure 1. The data in the prediction plot shows that the summary effect is 0.95. It can be interpreted that there is a 95% difference in higher-order thinking skills (HOTS) between groups, or students who study with PBL have 100% higher learning outcomes than students who use conventional learning models. In addition, with a confidence interval of 0.95%, it is known that the summary effect range is 0.37 to 1.53, so it does not contain zero. This shows a significant difference between problem-based learning and higher-order thinking skills (HOTS) students with PBL and conventional. Then, there will be an analysis of publication bias in the meta-analysis. This analysis is critical to show the validity of the conclusions in the study because the meta-analysis can be considered biased if it only takes research with the desired results and does not show results that accept the null hypothesis or give negative conclusions (against the theory/not as expected).

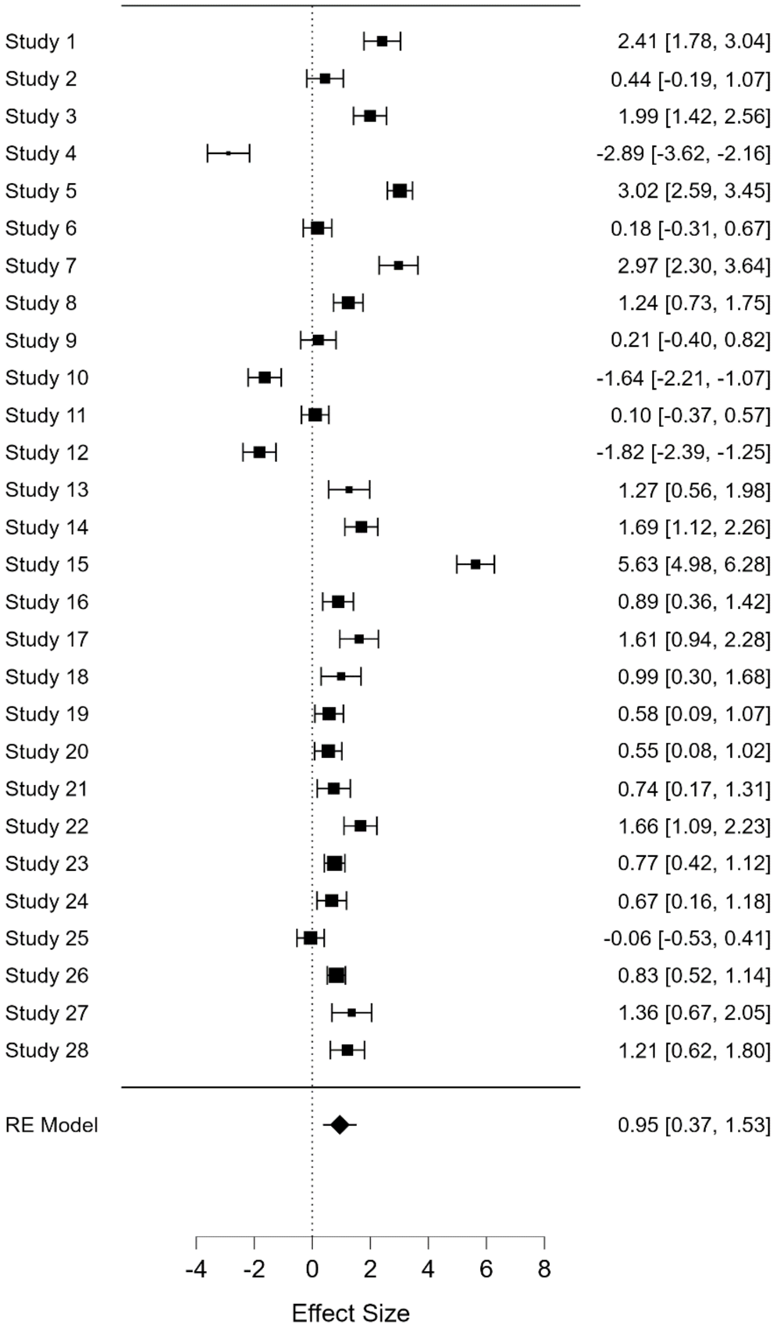

Figure 1. Initial prediction plot

In this meta-analysis, the Trim and Fill method can detect publication bias. Based on a previous study, the Trim and Fill plan uses an iterative procedure to remove the most extreme small studies from the positive side of the funnel plot and then recalculate the adjusted effect size, reducing the effect variance, resulting in a narrower confidence interval. Thus, the researcher could see changes in the effect size when unpublished studies were included in the analysis (Retnawati et al., 2018). The results of Crop and Fill data with the help of JASP software are shown in Figure 2.

Figure 2 shows no open points in the funnel plot with the random effects model. The display shows no that no missing (unpublished) research was found. Therefore, the conclusion is that problem-based learning has a positive effect compared to conventional wisdom, which is free from potential bias. To strengthen this argument, the results of the initial prediction tile of Figure 1 will be compared with the prediction tile using the Cut and Fill Method.

The results of the prediction plot analysis using the trim and fill method show the same image as Figure 1. There is no difference in each selected sample data interval between the initial prediction of the plot image and the predicted plot image using the trim and fill method. The comparison thus reinforces the previous argument that there is no indication of bias in the meta-analysis. Therefore, the conclusion that PBL effectively improves higher-order thinking skills (HOTS) compared to conventional wisdom is valid.

Various studies have been carried out separately in space and time. So, it is not strong enough to justify their research results to be applicable in a wide scope. This study produces findings with a broad range because it concludes various studies. This meta-analysis concludes that the results have generality. In another sense, this is also a finding that PBL can improve the quality of problem-based learning processes that impact higher-order thinking skills (HOTS) under normal circumstances. This finding can be used to consider the urgency of implementing PBL in various parts of the world, of course, with normal circumstances and situations.

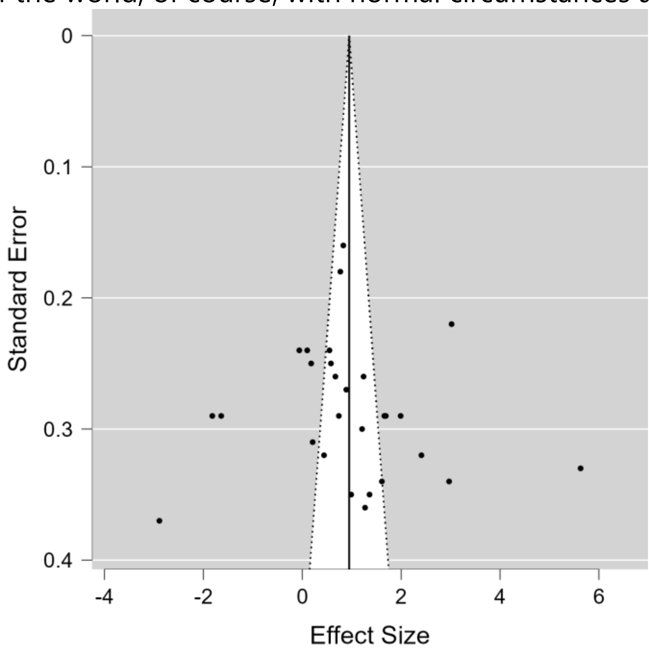

Figure 2. Trim and Fill method funnel plot

Discussion

Higher-order thinking skills include the ability to read with comprehension and identify required and unneeded materials. The ability to draw conclusions correctly from the given data and be able to determine inconsistencies and contradictions in a group of data is part of critical thinking skills. In other words, Hots is analytical and reflexive (Heong et al., 2012). Furthermore, argues that Higher Order Thinking Skills are essential to be applied in various aspects of knowledge. Because students are developed to learn higher-order thinking, teachers no longer tell students, but students must find out. Figuring out what this means requires an intelligent and analytical thought process. to think intelligently and analytically means higher-order thinking. Higher-order thinking skills introduced early in school will positively impact later. An educator must be able to read various phenomena and the latest developments to develop, plan, and carry out a series of learning optimally to create the quality of the educational process (Dinni, 2018). Students can read and independently identify various phenomena, challenges, problems, and developments to lead and direct students to higher-order thinking skills (Raiyn, 2016).

This proves that student learning outcomes using the PBL model are better than conventional learning. This result is obtained because PBL is a model based on many problems that require authentic inquiry, that is, investigations that need real solutions. PBL is an innovation in learning because, in PBL, students' thinking abilities are optimized through a systematic process of group or teamwork so that they can empower, sharpen, test, and develop their thinking skills on an ongoing basis (Syarifah & Ritonga, 2020).

The advantages of applying the PBL model are. First, students become accustomed to solving problems given by the teacher, thus making students more independent. The results obtained are in line with (Abanikannda, 2016) research. Second, applying the PBL Model makes students think critically, in line with research conducted by Tarigan (2017). Third, using the PBL model has been proven to increase student learning activities in line with the study of (Syarifah & Ritonga, 2020).

The weakness of the application of the PBL model in research is in the first stage, namely providing problem orientation to students; some students are less able to relate problems in everyday life, so they lack confidence in solving problems; in the third phase, which is helping independent and group investigations, there are still many students who are confused in carrying out the practicum because they are not used to using practicum tools and materials and do not understand the work procedures they will do, causing the class to be less conducive and controlled. In the fifth phase, which is presenting and evaluating the problem-solving process, the researcher lacks time, so each group offers the results of the discussion in front of the class because it takes much time in the third stage, namely in the process of investigating the problem.

CONCLUSION

The analysis results show a significant difference between the results of problem-based learning and HOTS skills using PBL and conventional in the learning process; the students who learn by utilizing PBL have better learning outcomes than those who do use conventional. Prediction plot data shows a summary effect of 1.00 so it can be interpreted that learning outcomes using PBL are 100% higher than students using conventional learning models. In addition, with 0.95% confidence, there is a summary effect interval ranging from 0.33 to 1.58 so it does not contain zero. This shows a significant difference between students who study with PBL and conventional. Testing for publication bias can be done using the Trim and Fill method, which indicates no publication bias in the meta-analysis. Thus, the conclusion that problem-based learning based on PBL is more effective than conventional education is free from discrimination. Based on the analysis results, the urgency of implementing PBLf in supporting the problem-based learning process with HOTS skills is apparent.

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