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The Effect of Problem-Based Learning (PBL) on Learning Outcomes: Meta-Analysis

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ABSTRACT

This study aims to analyze the effect of problem-based learning on learning outcomes. The research method carried out was a meta-analysis with a sample of 12 articles from qualified international journals (Q1, Q2 & Q3) and 2 articles from national journals. The instruments used in this study are coding sheets and research data will be analyzed using effect size calculations. The calculation of the average effect size was 1.83 with high effect size criteria in the 12 articles analyzed. The results of this study show that problem-based learning has a positive influence on learning outcomes. By analyzing 12 scientific articles, the study showed that PBL is effective in improving learners' learning outcomes. In addition, PBL has also been shown to correct misconceptions, develop critical thinking skills, and improve problem-solving skills. The results of this study provide strong support for the effectiveness of PBL in the context of chemistry education and the development of higher-order thinking skills. The study also highlights the importance of PBL in the context of modern education. Based on this meta-analysis, it is concluded that learning with problem-based learning has an influence on learning outcomes so that it is effectively used in learning to improve student learning outcomes.

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1. INTRODUCTION

Education is one of the fields of knowledge that is influenced by the development of the industrial revolution 4.0 (Belinski et al., 2020). Indonesia's readiness to support the development of the industrial revolution 4.0 by immediately improving the ability and skills of human resources through education. Improving the quality of human resources (HR) through primary, secondary to tertiary education is the key to being able to follow the development of the industrial revolution 4.0 (Lase, 2019; Maryanti et al., 2020; Yusuf et al., 2020). The success of a country in facing the industrial revolution 4.0 is also determined by the quality of educators, namely teachers (Alakrash& Razak, 2022; Ismail, et al., 2020; Tangahu et al., 2021). Efforts made in facing the era of the industrial revolution 4.0, education is needed that can form a creative, innovative, and competitive generation.

Chemistry as one of the studies of science that studies the structure of matter, properties, changes and energy that accompany these changes (Azizi, 2022; Dewi, 2022). The study of chemistry generally discusses concepts that are abstract, but have concrete examples encountered in life. Therefore, various learning facilities are needed that can support the effectiveness of the chemistry learning process (Huang, 2020; Dietrich et al., 2020). An educator uses a variety of approaches, models, strategies and learning media that can support the characteristics of chemical materials.

Problem-based learning (PBL) is one of the learning models developed based on constructivism learning theory (Srikan, 2021., Kassymova et al., 2020; Korkmaz, & Kalayci, 2021). Constructivist learning theory explains that the learning process can be interpreted if students can compile knowledge through activities to find problems, investigate problems, collect information and compile arguments for problem solving through group work (Korkmaz, & Kalayci, 2021; Rusman, 2017). The PBL model centers on subjective and contextual protégé participants (Bestetti et al., 2014; Matsuyama et al., 2019; Santyasa et al., 2020), thus PBL focuses more on identifying contextual learning problems, then finding alternatives to solving problems through learning activities.

Problem-based learning (PBL) is implemented through 5 steps of learning activities (Arends, 2014) namely orienting students to problems, organizing learning activities, guiding independent and group investigations, developing and presenting work, analysis and evaluation of problem-solving processes. The stages of the problem-based learning model according to Arends quoted from (Kemendikbud, 2017) includes five phases, as follows :

1. Orienting students to problems
   This stage focuses students to observe and analyze the problems displayed during the learning process. Problems can be displayed in contextual discourses and images in life. This is so that students can understand real problems in life that are connected with learning material.
2. Organizing learning activities
   This stage requires students to submit questions about the problems that have been submitted. The questions raised are used as a reference in learning activities. The final activity of learning is expected to find answers to the questions that have been presented.
3. Guding self research and clusters
   This stage learners collect information through experimental activities to solve problems independently or in groups. Learning activities are displayed through discourse in the form of explanations related to learning materials. The delivery of material is equipped with pictures, tables, and practice questions that help in conveying material and forming new concepts.

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4. Developing and presenting works
   This stage students associate and connect data found during learning activities through reading sources. Learning activities displayed in the form of practice questions and discussions related to the subject matter to find solutions to the questions asked. Students conduct discussions and presentations of the results of discussions in groups or in class.
5. Analysis and evaluation of the problem solving process
   This stage students assess whether the solution found during the learning process is correct. This activity is carried out by discussion with teachers and friends in groups. This is so that students get solutions to existing problems and find answers to questions that have been conveyed at the beginning of learning activities.

The application of the PBL learning model can improve reasoning skills better known as higher order thinking skills (HOTS). Higher order thinking skills (HOTS) are complex thinking processes in deciphering material, making inferences, building representations, analyzing and building relationships by involving the most basic mental activities. Teacher activities and student activities that apply problem-based learning models can be seen in **Table 1**.

Table 1. Teacher and Student Activities

Learning Syntax	Teacher Activities	Student Activities
Orient learners to problems	Problems are posed contextually and learners find them through reading materials or activity sheets.	Observe and understand the problems raised from the suggested reading material.
Organizing learners to learn	Ensure learners understand learning objectives.	Stating questions related to the problems raised.
Guide individual/group research	Observe learners in collecting information during the learning process.	Conduct information gathering and discussion processes.
Presenting and developing works	Observe and guide discussions.	Conduct discussions to find solutions to problems and present them.
Analyze and evaluate the problem-solving process	Guiding presentations and giving awards and together with students making material conclusions.	Presenting the results found and making conclusions.

(Ariyana et al., 2018)

According to Bloom's Taxonomy, revision of higher-order thinking skills is in the cognitive realms of analyzing (C4), evaluating (C5) and creating (C6). Higher order thinking skills are divided into 3 namely: transfer of knowledge, critical and creative thinking, problem solving. Critical thinking skills are very important to be trained and improved in the learning process at the middle school or college level. Given the increasingly complex and diverse problems that occur in real life.

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Based on the explanation above, the purpose of this study is to statistically analyze the effect of problem-based learning on learning outcomes through meta-analysis in reputable international articles.

2. METHODOLOGY

Literature review research is a systematic activity that collects, processes and analyzes research information derived from research documents related to the research theme to find a conclusion (Sari & Asmendri, 2020). Meta-analysis is a systematic methodology for finding empirical studies reported from research results by combining quantitative results from different studies on related topics and providing effect measures that represent each study in the form of average standard differences (Becker & Park, 2011). This meta-analysis aims to combine research results in the form of statistical data from research findings and similar studies whose results are consistent and coherent.

The research carried out is literature review research with the type of meta-analysis. This meta-analysis aims to combine research results in the form of statistical data from research findings and similar studies whose results are consistent and coherent. This meta-analysis research was carried out with the following steps (Demirel & Dagyar, 2016).

2.1. Determining Research Questions

Penelitian meta-analisis ini dilakukan untuk mengetahui bagaimana pengaruh pembelajaran problem-based learning terhadap hasil belajar. Kata kunci yang digunakan dalam proses pencarian artikel dalam penelitian ini yaitu: problem based learning, model problem based learning in chemistry, effect problem based learning, influence problem based learning (PBL), effect problem based learning ini chemistry, effect problem based learning in HOTS, problem based learning in chemistry education.

2.2. Search for Articles Related to Keywords

Article search is done through www.googlescholar.com. Furthermore, researchers will identify the quality of journals in articles found through www.schimago.com links in the scientific journal rankings (SJR) section to determine the quality of scientific articles to be analyzed. The articles analyzed include articles with SJR Q3, Q2 and Q1 to produce credible analysis results.

2.3. Defining Article Criteria

Some of the criteria used in this study are: (a) the article has SJR Q3, Q2 and Q1, (b) the research methodology carried out is experimental methodology or quasi-experiment, (c) using a problem-based learning (PBL) learning model or strategy, (d) has statistical data in the form of mean, standard deviation (standard deviation) from the research results, (e) related articles discuss the influence of problem-based learning on student learning outcomes.

2.4. Analyzing Articles with the Help of Encoding Tables

Articles that fall into predefined categories are further analyzed through coding tables. The components in the coding table are article title, journal name, scientific journal rankings (SJR), author, volume / issue, page, year, research objectives, research methods, research findings, review results. This information can be obtained through the abstract of each article.

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2.5. Calculating the Effect Size of Each Research Result

The effect size used in the meta-analysis was Cohen's (1969) introduced by Glass (1976). The determination of the effect size of each article aims to measure the difference in the average standard between treatment and comparison in research (Fritz et al., 2012; Kraft, 2020). The calculation of effect size can be done if a research result provides average information and standard deviation The formula used to calculate effect size can be seen in Table 2 below:

Table 2. Effect Size Conversion Statistics Formula

Data Statistics	Rumus
Mean and Standard Deviation of 1 group	$\frac{\bar{x}\ postes - \bar{x}\ pretes}{SD\ pretes}$
Mean and Standard Deviation 2 postest groups	$\frac{\bar{x}\ eksperimen - \bar{x}\ kontrol}{SD\ kontrol}$
Mean and Standard Deviation 2 groups of pretest-postes	$\frac{\left(\overline{x_{postes}} - \overline{x_{pretes}}\right)_{kontrol} - \left(\overline{x_{postes}} - \overline{x_{pretes}}\right)_{eksperimen}}{\frac{SD_{pretes\ kontrol} + SD_{pretes\ eksperimen} + SD_{postes\ kontrol}}{3}}$
Mean and Standard Deviation 2 groups of pretest-postes	$\frac{\left(\overline{x_{postes}} - \overline{x_{pretes}}\right)_{kontrol} - \left(\overline{x_{postes}} - \overline{x_{pretes}}\right)_{eksperimen}}{\frac{SD_{pretes\ kontrol} + SD_{pretes\ eksperimen} + SD_{postes\ kontrol}}{3}}$

(Becker & Park, 2011)

2.6. Reporting the Final Results of Meta-Analysis Activities

Meta-analysis is carried out by reviewing the research results of articles related to the research theme. Furthermore, the calculation of the effect size value was carried out and reported the results of this analysis to the meta-analysis research question.

There are 10 articles that will be meta-analyzed by calculating the effect size of articles. Effect size is the difference in effect size between research and comparison of article research results (Ben-Shachar et al., 2020; Kraft, 2020;). The interpretation of the calculated effect size is considered according to Cohen (1988) as Table 3 below:

Table 3. Interpretation of Effect Size Value

Effect Size	Interpretasi
< 0,20	Low-level influence
0,20 - 0,80	Mid-level influence
> 0,80	High degree of influence

(Demirel & Dagyar, 2016)

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3. RESULT AND DISCUSSION

3.1. Result

The research carried out is a meta-analysis research by selecting scientific articles in international journals and national journals. The search process is carried out using keywords related to learning outcomes using problem-based learning models and cognitive conflict learning strategies. Based on the results of this search, 10 reputable international articles and 2 national articles were obtained. Analysis of articles was conducted to explain the effect of problem-based learning and cognitive conflict strategies on learning outcomes. The international and national articles analyzed can be seen in Table 4.

Table 4. International and National Articles

Article Description	*Scientific Journal Rangkings* (SJR)	Metodologi Penelitian
(Barth et al., 2019)	Q1	Control experimental group
(Ayyildiz & Tarhan, 2017)	Q1	Quasi-experimental postest-pretest
(Baran & Sozbilir, 2017)	Q1	Mixed method: quantitative and qualitative
(Tosun & Taskesenligil, 2013)	Q1	Control experimental group
(Yoon et al., 2012)	Q1	Quasi-experiment noequivalent control group pretes-postes
(Tarhan & Acar, 2007)	Q1	Experimental and control groups
(Ismail et al., 2018)	Q2	Experiment with pretest-posttest control groups
(Kuvac & Koc, 2019)	Q2	Nonequivalent pretest-postes control grup
(Saputro et al., 2020)	Q3	Quasi-experiment noequivalent control group pretes-postes
(Valdez & Bungihan, 2019)	Q3	Descriptive-comparative and pretest-posttest experiments

The selected articles have an experimental research methodology. This aims to calculate the effect size of each research result and obtain a general conclusion. The value of effect size in each article can be seen in Table 5.

Table 5. Calculation of Effect Size of Scientific Articles

Article Description	Experimental Group		*Effect Size*	Kriteria *Effect Size*
	$\bar{X}$ Pretes (SD)	$\bar{X}$ Postes (SD)		
(Barth et al., 2019)	48,21 (16,42)	64,25 (14,80)	2,75	High
(Ayyildiz & Tarhan, 2017)	60,76 (20,14)	87,23 (12,75)	1,87	High
(Baran & Sozbilir, 2017)	12,00 (2,52)	23,00 (1,96)	0,20	Medium

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Article Description	Experimental Group		*Effect Size*	Kriteria *Effect Size*
	$\bar{X}$ Pretes (SD)	$\bar{X}$ Postes (SD)		
(Tosun & Taskesenligil, 2013)	86,3 (7,7)	98,7 (10,8)	0,82	High
(Yoon et al., 2012)	33,14 (7,798)	73,86 (10,232)	1,60	High
(Tarhan & Acar, 2007)	77,63 (11,10)	86,79 (7,57)	1,36	High
(Ismail et al., 2018)	3,94 (0,41)	4,10 (0,35)	0,41	Medium
(Kuvac & Koc, 2019)	10,23 (1,85)	14,05 (2,30)	6,00	High
(Saputro et al., 2020)	20,45 (1,405)	31,50 (1,711)	4,36	High
(Valdez & Bungihan, 2019)	0,32 (0,21)	0,79 (0,31)	1,18	High
(Heryandi, 2018)	-	76,88 (95,622)	0,73	Medium
(Galib et al., 2020)	41,92 (10,66)	78,25 (9,58)	0,68	Medium
Average			1,83	High

Table 5. provides information that the 12 articles analyzed have a high influence on learning with problem-based learning models and cognitive conflict strategies on learning outcomes. The average value of the effect size calculation is expressed by a value of 1.83 with high influence criteria.

3.2. Discussion

Based on the results of Table 5 above, the average effect size of 1.83 was obtained with high effect size criteria in the 12 articles analyzed. This shows that learning carried out with problem-based learning models is effective in improving learning outcomes. This is supported by the results of research that explains that problem-based learning is effectively used to improve student achievement through active learning. Learning is implemented through collaborative group work and effective communication and leadership skills (Ayyildiz & Tarhan, 2017).

PBL learning outcomes can improve academic achievement and skills related to cognitive and affective domains (Baran & Sozbilir, 2017). Problem-based learning can also improve access and use of knowledge, group work, self-study and problem-solving skills. Problem-based learning suggests that conceptual understanding is better than traditional learning. During problem-based learning, learners are asked to follow a series of procedures in solving problems in everyday life (Tosun & Taskesenligil, 2013).

Problem-based learning is also reported to be effective on learning achievement and correcting misconceptions. In addition, students are also trained to have good critical thinking skills (Tarhan & Acar, 2007). Problem-based learning outcomes can be used as effective learning to promote metacognitive awareness towards procedural knowledge, planning and debugging (Kuvac & Koc, 2018). In addition, students also allow to be able to evaluate themselves and discuss in groups to improve cooperation (Hidayatullah, et al., 2020; Nahar, 2022; Saldo & Walag, 2020).

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Problem-based learning has a positive influence on higher-order thinking skills in learning activities. This is evidenced in the effect size in articles 1, 4, 9 and 10 with high influence. PBL learning provides opportunities for learners to develop their understanding through problems in life and find solutions to problem solving (Faozi et al., 2020; Saputro et al., 2020; Sarwi et al., 2020). Problem-based learning provides problems in life as an introduction to learning activities so that students can connect with previous knowledge to find relationships between real-world problems and subject matter. Problem-based learning has a positive effect on improving problem-solving skills in chemical concepts (Valdez & Bungihan, 2019). This is because during learning learners are faced with real-world problems that help learners in improving thinking skills through the problem-solving process.

The results of the learning evaluation show that learners become more positive and confident in the problem-solving and work process. Problem-based learning has proven to be an effective learning strategy to improve creative thinking skills and independent learning and self-evaluation. This is because the learning process is carried out through real problems and independently in finding solutions to solve these problems so as to train an efficient and unique thinking process (Yoon et al., 2012). The results of research that have been conducted by (Luise et al., 2019) Explain that problem-based learning is effectively used in training programs adapted by pre-service teachers through teaching elements. Learning is implemented by expanding information for problem-solving activities by combining the problem-based learning cycle with a series of mictoteaching activities and videos in a learning environment.

This meta-analysis research was conducted on the article of the effect of cognitive conflict strategies on learning outcomes. The results of learning using this cognitive conflict strategy turned out to have a significant effect seen from the average value of N-gain (Galib et al., 2020). The implementation of cognitive conflict strategies can help students' critical thinking skills during the learning process. The response of learners during the learning process by applying problem-based learning models and cognitive conflict strategies is very positive based on the results of research that has been conducted by other researchers (Heryandi, 2018).

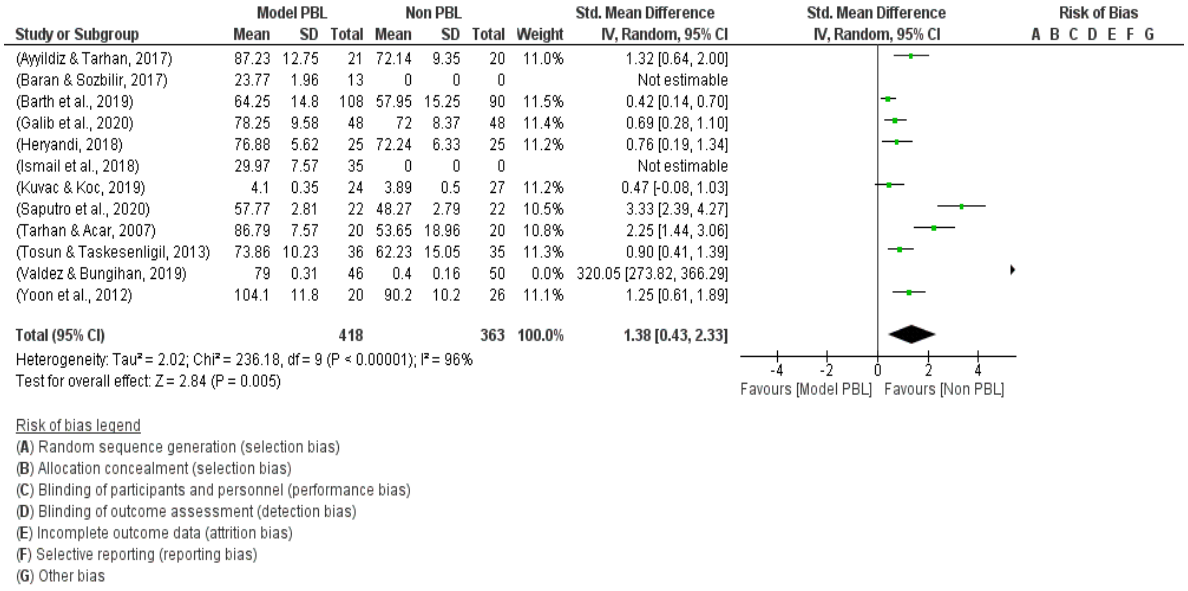

Figure 1. Forest Flot Meta-Analisis 12 Article

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The results of the meta-analysis in these 12 articles are displayed in a forest plot to summarize the results of the meta-analysis such as Figure 1. Based on Figure 1, it is known that the articles used in this study have a high heterogeneity of 96% with an overall effect value of Z = 2.84 (P < 0.005 or P < 0.05), then the research of *the problem-based learning model has* a significant effect on learning outcomes in the analysis of articles that have been carried out. However, there are 2 articles with *standard mean different* articles, which are *not estimable* because they do not have a comparison value for the control class in their research.

By analyzing 12 scientific articles, the study showed that PBL is effective in improving learners' learning outcomes. In addition, PBL has also been shown to correct misconceptions, develop critical thinking skills, and improve problem-solving skills. The results of this study provide strong support for the effectiveness of PBL in the context of chemistry education and the development of higher-order thinking skills. The study also highlights the importance of PBL in the context of modern education.

4. CONCLUSION

The calculation of the average effect size was 1.83 with high effect size criteria in the 12 articles analyzed. The results of this study show that problem-based learning has a positive influence on learning outcomes as evidenced by the overall effect Z = 2.84 (P = 0.005). Based on this meta-analysis, it is concluded that learning with problem-based learning is effectively used in learning to improve student learning outcomes. As for further research, an analysis should be carried out with many variables on the influence of problem-based learning, especially in chemistry learning.

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