

## Meta-Analysis of the Impact of Problem-Based Learning on High School Students' Critical Thinking Abilities in Biology Education

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**Abstract:** Every individual should possess the ability to think critically, making it imperative to foster this process starting from school. The purpose of this research is to analyze previously published studies to conclude on the success of the problem-based learning model in enhancing high school students' critical thinking skills in biology education. The research methodology employed is meta-analysis, where the researcher combines the outcomes of prior studies to obtain a comprehensive overview of the success of the problem-based learning model in enhancing critical thinking skills among high school students in biology education. The research findings indicate that the implementation of the problem-based learning model in biology education at the high school level can indeed enhance students' critical thinking abilities. This is evident from the comparison between pretest and posttest results, revealing an average increase of 0.17%. While this falls within the weak effect category, it still demonstrates a positive impact of Problem-Based Learning on students' critical thinking skills. The utilization of the Problem-Based Learning model contributes significantly to the cultivation of students' critical thinking skills in the context of biology education.

**Keywords:** Critical Thinking, Problem-Based Learning Model, Biology Education.

### INTRODUCTION

Civilization continues to evolve and undergo renewal, presenting various challenges at different levels in society, ranging from the local to the global scale. Adapting to the changing times brings forth a range of issues in human life, necessitating individuals to develop high-quality self and essential abilities such as analysis, assessment, and problem-solving (Temuningsih et al., 2017). In preparing to face these challenges of the era, education plays a crucial role in equipping the younger generation to conquer obstacles, compete in a competitive environment, and keep up with the rapid pace of modern developments. Therefore, both human resources and education need to possess high-quality competencies, requiring preparation to address these demands (Agnesa et al., 2022). One crucial competency that individuals must possess is critical thinking ability.

Critical thinking is a fundamental skill needed in the 21st century, a life skill that must be developed through the educational process (Zubaidah et al., 2018). It involves thinking effectively in all aspects of life, including identifying, analyzing, and solving problems (Sari et al., 2022). Critical thinking involves processing, manipulating, and transforming information. It's a skill that can be developed and allows students to evaluate others' opinions and express their own (Herzon et al., 2018).

Students with poor critical thinking abilities struggle to solve structured problems, face systematic challenges, and lack competitiveness (Kodariah et al., 2021). Hence, critical thinking is an essential skill for every individual, including students. In today's complex and ever-changing world, the ability to think critically enables individuals to better understand information, make

rational decisions, and solve complex problems. In the context of education, critical thinking is not only vital for academic success but also for equipping students to be active and engaged citizens in society.

Research by [Mardiyanti et al. \(2020\)](#) at SMA Negeri 1 Mataram identified that students' critical thinking skills are categorized as low. Nine students did not achieve the minimum criteria set, where the classical completeness standard is 75%, while the established standard is 85%. This was observed through daily assessments on environmental change topics. Similarly, [Susilawati et al. \(2020\)](#) found that about 15% of students at SMAN 1 Woha had very low critical thinking abilities, 64% had low abilities, and 21% had moderate abilities. Students faced challenges in handling questions that required critical thinking skills ([Riyanti et al., 2020](#)).

The low level of critical thinking skills is attributed to the lack of training during the learning process. Many teachers rely on lecture-based teaching methods, resulting in students lacking critical thinking skills ([Kurniahtunnisa et al., 2016](#)). Furthermore, in biology education, theoretical teaching approaches prevail, leading to passive listening, and diminished student curiosity. Implementing real-world problems in biology education is recommended ([Juanda et al., 2016](#)). Thus, designing a learning environment that engages students in the biology learning process is essential to develop critical thinking skills and conceptual understanding ([Kono et al., 2016](#)).

One effective approach to enhancing critical thinking skills is Problem-Based Learning (PBL) ([Fakhrizal & Hasanah, 2020](#)). PBL was first introduced by Howart Barrows in the 1970s for medical education at McMaster University ([Amir, 2016](#)). PBL is effective in improving critical thinking and problem-solving skills. It has been shown to be effective in various biology topics, including environmental pollution, excretion systems, and biodiversity ([Rahmi, 2014](#); [Kurniahtunnisa et al., 2016](#); [Wulandari et al., 2020](#)).

PBL emphasizes cooperative learning by fostering collaboration and inquiry-based learning to develop cognitive processes such as researching the environment, solving problems, analyzing data, and elaborating solutions. PBL starts with a problem related to real-world issues, allowing students to engage with targeted learning objectives. [Kusumaningtias et al. \(2013\)](#) states that PBL contextualizes learning through real-world issues. PBL encourages complex problem-solving and develops critical thinking skills, making students self-regulated learners. Group discussions within PBL provide opportunities for students to develop critical thinking indirectly ([Nuur et al., 2016](#)).

Implementing PBL requires teachers to play a significant role in guiding students' learning patterns. Providing diverse problems and questions stimulates students to seek answers and express opinions ([Rerung et al., 2017](#)). Educators need to understand how to present the material effectively to achieve the intended learning objectives ([Setiawan et al., 2017](#)).

Given the research findings of previous studies, the present study aims to delve deeper into the impact of Problem-Based Learning on high school students' critical thinking skills in biology education. Numerous studies suggest that PBL can enhance students' critical thinking abilities in biology education.

## METHOD

The method employed in composing this article follows a literature review approach. The research initiative began by systematically seeking out articles pertinent to the influence of the Problem-Based Learning (PBL) model on the development of critical thinking abilities among high school students within the domain of biology education. The criteria for the inclusion of scholarly articles encompassed publications from the years 2011 to 2022, ensuring the selection of relatively recent and contextually relevant studies. The information analyzed comprised a dataset of 25 national articles, sourced primarily from platforms such as Google, Google Scholar, and Google Scholarly.

The literature review methodology serves as a robust strategy for collecting, evaluating, and synthesizing pertinent existing research related to the focal subject. By narrowing the scope to articles published between 2011 and 2022, the review ensures alignment with contemporary educational circumstances. These gathered articles encapsulate a spectrum of insights,

methodologies, and contributions pertaining to the efficacy of the PBL teaching model in enhancing students' critical thinking capacities within the sphere of high school biology education.

During the article selection process, academic resources like Google Scholar provided access to a diverse array of reputable scholarly works and articles. A meticulously conducted literature review discerns patterns, contrasts, and common themes among prior investigations. This forms a sturdy groundwork for constructing arguments and drawing conclusions substantiated by the existing academic discourse.

Additionally, this research incorporates an analysis of the effect size associated with the Problem-Based Learning model's impact on students' critical thinking abilities. The effect size computation is executed using the following equations:

$$\text{Effect Size} = (\text{Posttest Average Score} - \text{Pretest Average Score}) / SD \quad \dots(1)$$

$$\text{Effect Size} = (\text{Experimental Group Average Score} - \text{Control Group Average Score}) / SD \quad \dots (2)$$

Where *Es* = Effect size; Posttest average score = Mean of posttest scores; Pretest average score = Mean of pretest scores; and *SD* = Standard deviation

Table 1. Effect Size Interpretation Standards

Effect Size	Interpretation
0 to -0.20	Weak Effect
0.21 to -0.50	Moderate Effect
0.51 to 1.00	Moderate Effect
> 1.00	Strong Effect

(Source: Cohen, 2007, as cited in Phasa, 2020)

Based on the interpretation standards presented in Table 1 above, the researcher concludes that effect sizes ranging from 0.20 to 1.00 fall within the standard range of the impact of the Problem-Based Learning instructional model on students' critical thinking abilities in biology education. Through the systematic analysis of these effect sizes, the study contributes to a more comprehensive understanding of the significance and scope of the PBL teaching approach in fostering critical thinking skills among high school biology students.

## RESULTS AND DISCUSSION

The use of the Problem-Based Learning (PBL) model in biology education has been investigated by several previous researchers. These studies elucidate that biology education employing the PBL model has the potential to enhance students' critical thinking abilities. By involving students in solving real-world problems, PBL can foster critical thinking skills that are crucial for students' future success.

Table 2. Studies Regarding the Impact Through the Implementation of Problem-Based Learning Model on The Critical Thinking Skills of High School Students

No	Title	Authors and Publication Year	Findings
1	The Influence of Reciprocal Teaching and Problem-Based Learning on the Critical Thinking Ability of High School Students in the Reproductive System Topic	Anggraeni et al. (2018)	There is an influence of Reciprocal Teaching (RT) and Problem-Based Learning (PBL) on the critical thinking ability of high school students in the reproductive system topic.

No	Title	Authors and Publication Year	Findings
2	Efforts to Improve Students' Critical Thinking Skills in Biology through the Application of the Problem-Based Learning Model in Class X of SMA Negeri 1 Kluet Tengah	<a href="#">Fakhrizal &amp; Hasanah (2020)</a>	The Problem-Based Learning model has a positive impact on improving students' critical thinking skills in biology education.
3	The Influence of Problem-Based Learning Model on Students' Critical Thinking Skills in Biodiversity Topic	<a href="#">Wulandari et al. (2020)</a>	Implementing the Problem-Based Learning (PBL) model in the excretion system subject at SMA Negeri 1 Singorojo positively influences students' critical thinking skills.
4	Development of Song-Based Learning Media Using the PBL Model for the Classification of Living Organisms in SMA Negeri 1 Motoling	<a href="#">Paat et al. (2022)</a>	Song-based learning media using the PBL model for the classification of living organisms in SMA Negeri 1 Motoling is considered suitable as a learning medium by both media experts and subject matter experts.
5	The Influence of Problem-Based Learning Model Combined with Student Facilitator and Explaining on the Critical Thinking Skills of Class X Students at SMAN 6 Kediri in the Fungi Topic	<a href="#">Setiawan et al. (2017)</a>	The combination of Problem-Based Learning and Student Facilitator and Explaining has an influence on the critical thinking skills of Class X students at SMAN 6 Kediri in the Kingdom Fungi topic.
6	The Influence of Problem-Based Learning Model on Students' Critical Thinking in Excretory System	<a href="#">Kurniahtunnisa et al. (2016)</a>	The implementation of the Problem-Based Learning (PBL) model in the excretory system topic at State Senior High School 1 Singorojo has a positive impact on enhancing students' critical thinking abilities.
7	Impact of PBL Teaching Model on Students' Critical Thinking Skills in Biology	<a href="#">Putri &amp; Fitri (2022)</a>	The Problem-Based Learning (PBL) model has a positive influence on enhancing students' critical thinking skills in the context of Biology education.
8	Analysis of Critical Thinking Skills among 11th-grade Biology Students	<a href="#">Riyanti (2020)</a>	The implementation of the Model Problem Based Learning contributes to improving students' critical thinking skills in Biology.
9	Impact of PBL Implementation on Students' Analytical Abilities	<a href="#">Kodariah et al. (2021)</a>	The Problem-Based Learning model used in teaching the subject of Bryophytes in 10th-grade Science program at SMA YRM Cihawar has a significant and positive impact on students' analytical abilities, with a level of influence categorized as high.
10	Implementation of PBL for Enhancing Critical Thinking Skills in Environmental Changes	<a href="#">Mardiyanti (2020)</a>	The application of the Problem-Based Learning (PBL) teaching model can enhance critical thinking skills of 10th-grade students in Science Program-2 regarding Environmental Changes, conducted at SMA Negeri 1 Mataram during the academic year 2017/2018.

No	Title	Authors and Publication Year	Findings
11	Difference in Critical Thinking Abilities of Students Using Guided Inquiry Model and Problem-Based Learning (PBL) in Biology Education for 10th-Grade Students at SMAN 2 Gerung, Academic Year 2016/2017	<a href="#">Puspita et al. (2018)</a>	There is a difference in critical thinking abilities between students using the guided inquiry model and the PBL model in the context of Biology education for 10th-grade students at SMAN 2 Gerung during the academic year 2016/2017. PBL was found to enhance students' critical thinking abilities more compared to the guided inquiry model.
12	The Impact of Problem-Based Learning (PBL) Model on Understanding Biological Concepts and Critical Thinking Skills of Students Regarding Ecosystem and Environment in 10th-Grade Class at SMA Negeri 1 Sigi	<a href="#">Kono (2016)</a>	The implementation of the Problem-Based Learning (PBL) model has an impact on enhancing students' understanding of biological concepts related to ecosystem and environment, as well as improving their critical thinking skills in a 10th-grade class at SMA Negeri 1 Sigi during the academic year 2014/2015.
13	Application of PBL Model in Biology Education to Enhance Competence and Critical Thinking Skills of 10th-Grade Students	<a href="#">Juanda &amp; Bandung (2016)</a>	The application of the problem-based learning (PBL) model in biology education contributes to enhancing the competence and critical thinking skills of 10th-grade students at SMA.
14	Impact of Problem-Based Learning (PBL) on Critical Thinking Skills	<a href="#">Herzon et al. (2018)</a>	PBL has a significant impact on improving the critical thinking skills of learners. The syntactical structure of PBL can train students to engage in higher-order thinking, including critical thinking. Proper implementation of PBL steps leads to effective and efficient geography education.
15	Impact of Problem-Based Learning (PBL) Model on Critical Thinking Skills	<a href="#">Triyuningsih (2011)</a>	The use of the problem-based learning (PBL) model has an impact on enhancing critical thinking skills in students, particularly in the context of the concept of pests in plants.
6	The Impact of Problem-Based Learning (PBL) Instruction on Critical Thinking Skills and Biological Concept Understanding of High School Students in Malang City	<a href="#">Hadi (2013)</a>	The improvement in students' critical thinking skills and understanding of biological concepts has been achieved through the use of problem-based learning (PBL) instructional model in high schools in Malang city.
17	Impact of Problem Learning Model on Critical Thinking Skills of High School Students in the Topic of Protists	<a href="#">Ayuningrum &amp; Susilowati (2015)</a>	The model of problem-based learning (PBL) has a positive impact on enhancing the critical thinking skills of high school students in the context of the topic of protists.
18	Application of PBL Model to Enhance Critical Thinking Skills Based on Students' Academic Abilities in Biology Topics	<a href="#">Apriyani et al. (2017)</a>	There is an improvement in students' critical thinking skills through the implementation of the problem-based learning (PBL) model, considering the

No	Title	Authors and Publication Year	Findings
			students' academic abilities in the field of biology.
19	Impact of Problem-Based Learning (PBL) Model on Critical Thinking Skills of Students in the Concept of Human Circulatory System	Wajdi (2022)	There is a positive impact of the problem-based learning (PBL) model on enhancing students' critical thinking skills in the context of the concept of human circulatory system.
20	The Impact of Model Problem-Based Learning (PBL) on Critical Thinking Skills (KBKr) in Sub-Topic of Sensory Organs (Quasi-Experimental Study in 11th-Grade Students at SMA Negeri 9 Garut)	Handayani (2015)	The model of problem-based learning (PBL) is capable of enhancing students' critical thinking skills in understanding the concept of sensory organs in biology, as demonstrated in a quasi-experimental study with 11th-grade students at SMA Negeri 9 Garut.
21	The Impact of Problem-Based Learning Model on Critical Thinking Skills and Biology Learning Outcomes of Students in SMA Negeri 06 Kota Bengkulu in the Context of Local Wisdom Ecosystems	Hasan & Syatriandi (2018)	There is an enhancement in critical thinking skills in biology education through the use of problem-based learning (PBL) method among students of SMA Negeri 06 Kota Bengkulu in relation to the local wisdom ecosystems.
22	Impact of Problem-Based Learning on Critical Thinking Skills of Students in the Topic of Local Wisdom Ecosystems	Manzil et al. (2019)	The model of problem-based learning (PBL) has a positive impact on enhancing the critical thinking skills of students in the context of the topic of local wisdom ecosystems in biology education.
23	Application of Problem-Based Learning Model (PBL) to Enhance Critical Thinking Skills of 10th-Grade MIPA Students in Biology Education	Zainal et al. (2021)	The use of problem-based learning (PBL) instructional model can enhance the critical thinking skills of 10th-grade MIPA students in understanding biological concepts, as demonstrated in a seminar on teacher professional education at FKIP UAD.
24	The Role of PBL in Enhancing Problem-Solving Skills in Biology	Bahri et al. (2018)	The role of problem-based learning (PBL) instructional model has a significantly positive impact on improving students' problem-solving skills in biology education.
25	The Application of the Problem-Based Learning Model on Critical Thinking Skills of Class XI Biology Students in the Human Locomotion System	Sari & Anwar (2022)	The Problem-Based Learning model can enhance critical thinking in biology education.

Based on the study of 25 papers discussing the impact conveyed through the implementation of the Problem-Based Learning instructional model on the level of critical thinking skills of high school students related to the subject of biology, it can be observed that the PBL instructional model has a positive influence on the level of students' critical thinking skills. Furthermore, the PBL model can also be combined with instructional media such as worksheets,

audiovisual aids, and animated media. It also plays a role in enhancing other aspects including student engagement in the learning process, learning outcomes, and problem-solving abilities.

Table 3. Meta-Analysis Based on Effect Size

Article No.	Analysis results	Category	Article No.	Analysis results	Category
1	75,67% - 73,36 % 100 = 0,01	Weak Effect	14	17,5 % - 4,14 % 100 = 0,13 %	Weak Effect
2	76,90% - 51,80 % 100 = 0,25	Moderate Effect	15	62,25% - 54,417 % 100 = 0,07 %	Weak Effect
3	75,80 - 70 100 = 0,05	Week Effect	16	85,2 - 63,2 100 = 0,22 %	Moderate effect
4	85,82 % - 83,56% 100 = 0,02 %	Week Effect	17	88,00 % - 55,00 % 100 = 0,33 %	Moderate Effect
5	80,89 % - 73,05% 100 = 0,07 %	Weak Effect	18	70,87 % - 60,80 100 = 0,100 %	Moderate effect
6	76,93% - 65,67% 100 = 0,11%	Weak Effect	19	51,35% - 45,94 % 100 = 0,05 %	Weak Effect
7	80,28 % - 58,92 % 100 = 0,21 %	Moderate effect	20	88,51 % - 62,93 % 100 = 0,25 %	Moderate Effect
8	91,7% - 77,7% 100 = 0,14 %	Weak Effect	21	69,58 % - 63,4 % 100 = 0,06 %	Weak Effect
9	3,2% - 2,33% 100 = 0,0087	Moderate Effect	22	86,95 % - 67,45 % 100 = 0,19 %	Weak Effect
10	88,89% - 77,78% 100 = 0,1	Weak Effect	23	88,23 % - 70,58 % 100 = 0,17 %	Weak E ffect
11	78,5% - 67 % 100 = 0,11	Weak Effect	24	91 % - 87 % 100 = 0,04 %	Weak Effect
12	98,06 % - 58,62 % 100 = 0,39	Moderate Effect	25	91 % - 86 % 100 = 0,05 %	Weak Effect
13	98,64 % - 91,64 % 100 = 0,07 %	Weak Effect			

Based on [Table 3](#), the analysis results are obtained using the effect size formula. Effect size is a measure of the difference or relationship between two variable effects or groups, one with another variable, in a study. Effect size portrays how much influence or difference exists between these two variables, which is usually quantified in standard units. It encompasses information from previous analyses conducted. The Effect Size formula can be derived by calculating the difference between posttest and pretest based on student learning outcomes, then dividing by the maximum achievement.

The analysis of the first article article "The Influence of Reciprocal Teaching and Problem Based Learning on Critical Thinking Abilities of High School Students in the Subject of Reproductive

System" resulted in a posttest of 76.90% and a pretest of 51.80%, yielding an effect size of 0.01, categorized as weak effect.

The analysis of the second article "Efforts to Improve Critical Thinking Skills of Students in Biology Subjects through the Application of Problem Based Learning Model in Class X of Public Senior High School 1 Kluet Tengah" resulted in a posttest of 76.90% and a pretest of 51.80%, resulting in an effect size of 0.25, categorized as moderate effect. The analysis of the third article "The Effect of Problem Based Learning Model on Critical Thinking Skills in Biodiversity Material" resulted in a posttest of 76.61% and a pretest of 66.83%, yielding an effect size of 0.09, categorized as weak effect.

The analysis of the fourth article "Development of Learning Media in the Form of Songs Using the PBL Model in the Classification of Living Things in SMA Negeri 1 Motoling" yielded a posttest of 85.82% and a pretest of 83.56%, resulting in an effect size of 0.02, categorized as weak effect. The analysis of the fifth article titled "The Effect of Problem Based Learning Model Combined with Student Facilitator and Explaining on Critical Thinking Skills of Grade X Students of SMAN 6 Kediri on the Subject of Fungi" resulted in a posttest of 80.89% and a pretest of 73.05%, yielding an effect size of 0.07, identified as weak effect.

The analysis of the sixth article "The Effect of Problem Based Learning Model on Critical Thinking Skills in the Excretion System Material" resulted in a posttest of 76.93% and a pretest of 65.67%, yielding an effect size of 0.11, categorized as weak effect. The analysis of the seventh article "The Effect of Problem Based Learning Model on Critical Thinking Skills in the Excretion System Material" resulted in a posttest of 75.80% and a pretest of 70.00%, yielding an effect size of 0.05, identified as weak effect.

The analysis of the eighth article "Analysis of Critical Thinking Skills of Grade XI in Biology Subjects in State High Schools in Cilacap City" resulted in a posttest of 91.70% and a pretest of 77.70%, yielding an effect size of 0.14, categorized as weak effect. The analysis of the ninth article "The Effect of Problem Based Learning Model on Students' Analytical Abilities (Research on Grade X Students at SMA YRM Cihawar)" resulted in a posttest of 3.25 and a pretest of 2.33%, yielding an effect size of 0.0087, identified as weak effect.

The analysis of the tenth article "Application of the Problem Based Learning Model to Improve Critical Thinking Skills of Grade X MIPA-2 Students" resulted in a posttest of 88.95 and a pretest of 77.87%, yielding an effect size of 0.1, categorized as weak effect. The analysis of the eleventh article "Difference in Critical Thinking Abilities of Students Using Guided Inquiry Model and Problem Based Learning (PBL) in Biology Learning for Grade X Students of SMAN 2 Gerung" resulted in a posttest of 78.50% and a pretest of 67.00%, yielding an effect size of 0.11, identified as weak effect.

The analysis of the twelfth article "The Effect of Problem Based Learning Model on Understanding of Biology Concepts and Critical Thinking Skills of Students on Ecosystems and Environments in Grade X of SMA Negeri 1 Sigi" resulted in a posttest of 78.50% and a pretest of 67.00%, yielding an effect size of 0.11, identified as weak effect. The analysis of the thirteenth article "Application of the PBL Model in Biology Lessons to Improve Competence and Student Thinking Skills in Grade X" resulted in a posttest of 98.64% and a pretest of 91.64%, resulting in an effect size of 0.07, categorized as weak effect.

The analysis of the fourteenth article "The Effect of Problem Based Learning on Critical Thinking Skills" resulted in a posttest of 17.50% and a pretest of 4.14%, yielding an effect size of 0.13, identified as weak effect. The analysis of the fifteenth article "The Effect of Problem Based Learning Model on Critical Thinking Skills" resulted in a posttest of 62.25% and a pretest of 54.42%, yielding an effect size of 0.078, identified as weak effect. The analysis of the sixteenth article "The Effect of Problem Based Learning on Critical Thinking and Conceptual Understanding in High School Biology Students in Malang City" resulted in a posttest of 85.20% and a pretest of 63.20%, yielding an effect size of 0.22, identified as moderate effect.

The analysis of the seventeenth article "The Effect of Problem Based Learning Model on Critical Thinking Skills of High School Students in the Protista Material" resulted in a posttest of

88.00% and a pretest of 55.00%, yielding an effect size of 0.33, identified as moderate effect. The analysis of the eighteenth article "Application of the PBL Model to Improve Critical Thinking Skills Based on Student Academic Abilities in Biology Material" resulted in a posttest of 70.87% and a pretest of 60.80%, yielding an effect size of 0.100, identified as moderate effect.

The analysis of the nineteenth article "The Effect of Problem Based Learning Model on Critical Thinking Skills of Students in the Concept of Human Circulatory System" resulted in a posttest of 51.35% and a pretest of 45.94%, yielding an effect size of 0.05, identified as weak effect. The analysis of the twentieth article "The Effect of Problem Based Learning Model on Critical Thinking Skills of Students (KBKr) in the Sub-Material of Human Sense Organs (Quasi-Experimental Research on Grade XI Students of Public Senior High School 9 Garut)" resulted in a posttest of 88.51% and a pretest of 62.93%, yielding an effect size of 0.25, identified as moderate effect.

The analysis of the twenty-first article "The Effect of Problem Based Learning Based on Problem (PBM) on Critical Thinking Ability and Learning Outcomes of High School Students in Bengkulu City 06" resulted in a posttest of 69.58% and a pretest of 63.4%, yielding an effect size of 0.05, identified as weak effect. The analysis of the twenty-second article "The Effect of Problem Based Learning on Critical Thinking Skills of Students on the Ecosystem Material of Local Wisdom" resulted in a posttest of 86.95% and a pretest of 67.45%, yielding an effect size of 0.19, identified as weak effect.

The analysis of the twenty-third article "Application of the Problem Based Learning (PBL) Model to Improve Critical Thinking Skills of Grade X MIPA Students in Biology Learning" resulted in a posttest of 88.23% and a pretest of 70.58%, yielding an effect size of 0.17, identified as weak effect. The analysis of the twenty-fourth article "The Role of PBL in Enhancing Biological Problem-Solving Skills" resulted in a posttest of 91% and a pretest of 87%, yielding an effect size of 0.04, identified as weak effect. The analysis of the twenty-fifth article "Application of the Problem Based Learning Model to Improve Critical Thinking Skills of Grade XI Biology Students on the Human Locomotion System" resulted in a posttest of 91% and a pretest of 86%, yielding an effect size of 0.05, identified as weak effect.

In the analysis of the published articles, the effect size assessment criteria adapted from Cohen were used. There are four categories used to classify the impact of the PBL model on critical thinking ability, with the following categories: weak effect (size 0 to 0.20), indicating a very low impact caused by the Problem Based Learning model on critical thinking ability. This means that the use of this method has minimal influence on improving critical thinking ability. For effect size 0.20 to 0.50, this category indicates a low impact resulting from the Problem Based Learning model on critical thinking ability. Although an impact is observed, the increase in critical thinking ability is not yet significant. In the moderate effect category (size 0.51 to 1.00), the impact resulting from the Problem Based Learning model on critical thinking ability is classified as moderate. This suggests that this method has a fairly significant influence in improving critical thinking ability. In the strong effect category (size greater than 1.00), this category indicates a high impact resulting from the Problem Based Learning model on critical thinking ability. This implies that the use of this method has a very significant impact in enhancing critical thinking ability. By using these effect size assessment criteria, the research can classify the impact of the Problem Based Learning model on critical thinking ability according to its level, ranging from very low to high.

Identifying whether there is a difference in impact generated for the subjects, the published analysis results show that an influence has been obtained from the Problem Based Learning model on students' critical thinking ability. This can be seen from a total of 25 articles, with 2 articles categorized as moderate effect, 6 articles as moderate effect, and 17 articles as weak effect. Based on these analysis results, it is evident that the Problem Based Learning teaching model has a positive impact on critical thinking ability. Although most articles demonstrate weak and moderate effects, this indicates that the Problem Based Learning model strengthens students' critical thinking abilities.

## CONCLUSION

The analysis conducted using the meta-analysis technique titled "The Impact of the Problem Based Learning Model on Critical Thinking Abilities" yields the conclusion that Problem Based Learning brings about significant benefits to students' critical thinking abilities. This can be observed from the difference between the pretest and posttest results, with an average of 0.17%, falling within the weak effect category. The utilization of the Problem Based Learning model in the context of education has proven to have a positive impact on students' critical thinking abilities. This method encourages students to actively think, analyze problems, seek creative solutions, and develop their critical thinking skills. With an improvement of 0.17% between the pretest and posttest results, it can be generally concluded that the consistent use of the Problem Based Learning model helps students strengthen their critical thinking abilities.

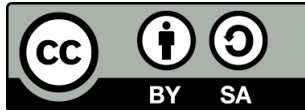
It is recommended that teachers be more creative in selecting and determining learning models that align with the intended goals, subject matter, and student conditions. Matching the learning model to these factors can further enhance the effectiveness of teaching and promote a more comprehensive development of students' critical thinking skills.

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