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The Key to Success in Biology Learning: A Meta-Analysis of The Effectiveness Problem-Based Learning (PBL) Model on Cognitive Domain Learning Outcomes

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ABSTRAK

Pembelajaran merupakan bentuk komunikasi yang menjadi dasar pencapaian informasi oleh peserta didik. Pembelajaran yang tepat perlu penyesuaian dengan pemilihan model pembelajaran yang tepat pula. Model pembelajaran yang mampu memberikan peningkatan hasil belajar kognitif peserta didik ialah Problem-Based Learning (PBL). Relevansi yang ditemukan antara prinsip model PBL dan proses belajar Biologi membuat banyak penelitian yang mengaitkan antara penerapan PBL dengan pencapaian hasil belajar kognitif. Penelitian ini ditujukan untuk mengetahui efektivitas model Problem-Based Learning (PBL) terhadap hasil belajar kognitif mata pelajaran Biologi. Penelitian ini menggunakan metode kuantitatif dengan teknik meta analisis dengan mengkaji 15 artikel jurnal yang sesuai dengan kriteria penelitian serta perhitungan efektivitas model PBL terhadap hasil belajar kognitif dengan menggunakan rumus Effect Size (ES). Berdasarkan hasil yang didapatkan dari pengujian Effect Size diperoleh hasil dengan kriteria sedang berkisar antara 0,51 sampai 1,00 sehingga dapat diambil kesimpulan bahwa penerapan Problem-Based Learning (PBL) memberi efek positif berupa peningkatan hasil belajar kognitif mata pelajaran Biologi bagi peserta didik.

Keywords:
Biology
Learning Outcomes
PBL

ABSTRACT

The Key to Success in Biology Learning: A Meta-Analysis of The Effectiveness Problem-Based Learning (PBL) Model on Cognitive Domain Learning Outcomes. Learning is a form of communication that is the basis for achieving information by students. The learning model that can improve students' activeness and learning outcomes is Problem-Based Learning (PBL). The relevance found between the principles of the PBL model and the Biology learning process makes many studies link the application of PBL with the achievement of cognitive learning outcomes. This study aims to determine the effectiveness of the Problem-Based Learning (PBL) model on cognitive learning outcomes in biology using quantitative methods with meta-analysis techniques by reviewing 15 journal articles. The effectiveness of the PBL model on cognitive learning

outcomes used the Effect Size (ES) formula. Based on the results obtained from the Effect Size test, the results obtained with moderate criteria ranged from 0.51 to 1.00 so it means that the Problem-Based Learning (PBL) learning model has a positive effect on improving cognitive learning outcomes in Biology subjects for students.

INTRODUCTION

Learning is a form of communication that serves as the foundation for students to achieve information (Dewi, 2019; Masdul, 2021). The most effective method for students to achieve maximum information is through active, systematic, and enjoyable learning (Ridlo and Amaliyah, 2013; Wahyudi and Azizah, 2016). Student engagement in the learning process is expected to have a significant impact on student learning outcomes. Educators can facilitate the achievement of learning objectives by employing the most appropriate learning method or model.

The prevailing learning model in the classroom remains suboptimal, as evidenced by the prevalence of teacher-centered learning in many educational institutions. Furthermore, the 2019 IEA Evaluation of Educational Achievement indicates that Indonesia's cognitive abilities among students lag behind the international average, with a score of 386, below the 500 mark. This is due to the fact that a significant proportion of students lack the ability to think critically when assessing and responding to problems. Consequently, their problem-solving skills are limited to routine matters (Elyani, Izzati & Perdana, 2019).

The capacity to resolve problems effectively must be cultivated through active learning that is tailored to students' needs. This necessitates the development of a learning model that facilitates the acquisition of problem-solving skills during the learning process. Efforts to foster appropriate learning can be achieved by selecting an appropriate learning model and aligning it with the specific characteristics of the subject matter. Each subject possesses distinct communication nuances in the teaching and learning process. One of the subjects that requires active, systematic, and enjoyable learning is biology (Mokalu, et al., 2023).

Biology learning is related to the systematic acquisition of knowledge about nature. Therefore, it requires the implementation of an appropriate learning model to facilitate the mastery of a collection of knowledge in the form of facts, principles, concepts, and even discoveries (Ulfa, 2018). Biology learning is related to how to find out and understand nature systematically, so it requires the right learning model to form mastery of a collection of knowledge in the form of facts, principles, concepts, and even discoveries (Ulfa, 2018). In the end, choosing the right learning model can provide good cognitive learning outcomes for students. One of the learning models that can support problem solving and improve cognitive learning outcomes is the PBL (Problem Based Learning) model.

The PBL model is one of the systematic models that can facilitate active learning and create a positive learning environment. This model is a learning model that emphasizes problem-solving based on information owned by students, particularly in the context of natural sciences (Kembuan et al., 2020). The PBL learning model in science, which also includes biology, is carried out in four stages: presenting problems, asking questions, facilitating investigation, and opening dialog (Paat et al., 2021). This is supported by research by Fauzan et al. (2017), which states that the PBL learning model can improve student learning outcomes and enhance critical thinking, problem-solving communication, and collaboration skills. Jayadiningrat and Ati's research (2018) also indicates that the Problem-Based Learning learning model can enhance students' problem-solving abilities.

Problem-Based Learning (PBL) has been employed in a multitude of educational settings. The efficacy of PBL in the context of biology learning has been extensively investigated, particularly in relation to its capacity to enhance learning outcomes. Several studies have demonstrated the advantages of PBL in various domains. For instance, Bahri's research (2018)

revealed that students taught using PBL (Problem Based-Learning) exhibited superior biology problem-solving skills compared to those instructed using a teacher-centered approach. Priadi (2012) posits that the PBL model can enhance students' capacity to resolve biological issues.

One way to approach the various research results is through a meta-analysis study. This study refers to a meta-analysis study on the application of the PBL model to the cognitive aspects of students in the realm of biological problems (Astuti, 2019). A meta-analysis is a scientific methodology that aims to summarize the results of comparisons of various studies using statistical calculations (Bergstorm, J.C., & Taylor, L.O., 2006). The application of meta-analysis techniques in a scientific method can facilitate and provide high accuracy on the topic of research studies because it is done by combining many sources to find the same research objectives. The objective of this research is to examine the effectiveness of the PBL learning model in biology learning on cognitive learning outcomes, based on the findings of various studies. The results of this study can inform teachers about the most effective learning models for biology learning.

METHOD

This research using meta-analysis method which is reviewing a minimum of 15 research articles published in journal portals and then recalculating using certain formulas following the research objectives (Glass et. al., 1981). The recalculation was carried out to find out the amount of effectiveness of the application of the PBL learning model in Biology subjects on learning outcomes. The article search was conducted by searching e-journals through Google Scholar, DOAJ, and ResearchGate using the keywords "Problem-Based Learning", "Biology" and "Learning Outcomes" within the last 10 years (2013 - 2023). About 30 relevant articles were found and only 15 articles could be used as research material. The selection of the 15 articles was selected with indicators of coverage limitations, namely the research must be classified as experimental type and have complete control class and experimental class data in accordance with the data requirements.

Data analysis techniques to determine the effectiveness of the application of the PBL model in Biology subjects on learning outcomes were calculated through Microsoft Excel and using the size effect formula (Cohen, J., 2013).

Effect Size Formula (ES) for two sample groups (Experimental and Control), shown in Formula (1).

$$ES = \frac{\underline{X}E - \underline{X}C}{SDC} \ldots\ldots (1)$$

Information:
ES = Effect Size
$\underline{X}E$= Average experimental class score
$\underline{X}C$= Average control class score
SDC = Standard deviation of control class

Effects Size (ES) Formula with T-Count (If SD is unknown), shown in Formula (2).

$$ES = t\sqrt{\frac{1}{nE} + \frac{1}{nC}} \ldots\ldots (2)$$

Information:
t = t-count (T-value)
nE = Number of Experimental Samples
nC = Number of Control Samples

Effect size also has a range of criteria adapted from Cohen (2013), namely the effect size results in the range of 0 – 0.20 can be interpreted that the effectiveness is very low, the effect size results in the range 0.21 – 0.50 can be interpreted that the effectiveness is low, the effect size results

in the range 0.51 – 1.00 can be interpreted that the effectiveness is moderate, and the effect size results in the range > 1.00 can be interpreted that the effectiveness is high.

RESULTS AND DISCUSSION

The meta-analysis research used aims to review various journals related to the application of PBL and cognitive learning outcomes in Biology subjects. From the results of the selection of articles various topics related to PBL and cognitive learning outcomes, including discussions of influence, effectiveness, and proof to comparison. From the results of the selection of articles obtained various topics related to PBL and cognitive learning outcomes. Here are 15 topics of PBL research on learning outcomes.

Table 1. Articles obtained various topics related to PBL and cognitive learning outcomes

Code	Authors	Years	Tittle
A1	Hartati, M. & Billa, K.	2023	The Effectiveness of PBL Implementation in Biology Subject on Learning Outcomes
A2	Juliyanti, K & Noproyeni	2023	Effect of Biology Learning Outcomes After PBL Implementation
A3	Natsir, M., Hasan, E., Wajdi, M., & Bahruddin	2022	The Effect After the Application of PBL on class X Virus Material on Learning Outcomes
A4	Asiyah, Topano, A., & Walid, A.	2021	The Effect of PBL Implementation on Problem-Solving Skills and Learning Outcomes
A5	Wabula, M., Papilaya, P.M., & Rumahlatu, D.	2020	The Effect of Video-Assisted Discovery Learning Model and PBL on Students' Motivation and Learning Outcomes
A6	Sukmawati, F., Setyosari, P., Sulton & Purnomo	2019	Effectiveness between PBL-Collaborative and PBL-Social Skill on Biology Learning Outcomes
A7	Pradasti, et.al.	2019	Effectiveness of application PBL model (Virus content) for Students Science Process Skills and Students Learning Outcomes
A8	Qomariyah, S.N	2018	The Impact of Implementing PBL to Improve Student Learning Outcomes
A9	Pratama, A.T.	2018	Evidence that PBL can Improve Learning Outcomes in Biology
A10	Wulansari, N.T., Sutrisna, I & Kesari, N.W	2018	Application of PBL to STIKES Bali Students on Learning Outcomes of Biology Courses
A11	Yusuf, M., Pujiastutik, H.	2017	Improved Biology Learning Outcomes Using PBL with Environmental Media
A12	Hartati., Ismail, I., & Afif A.	2016	Comparison of PBL with Mind Mapping Method and Relationship with Learning Outcomes
A13	Lelamula, M., Sasinggala, M., & Paat, M.	2016	The Effect of PBL with Power Point Media on Biology Learning Outcomes
A14	Aisyah, S., & Ridio, S.	2015	Effect of Puzzle Model on Cognitive Skills
A15	Asfadi., Yeliati., Budiarti.	2014	Effect of PBL Model on Biology Learning Outcomes

Based on the articles that have been selected in general, all of them discuss the correlation among the application of PBL and Biology cognitive learning outcomes. Through the selection of articles above, it is seen that PBL is one of the learning models that can influence and have a positive impact on cognitive learning outcomes. This is due to the PBL learning pattern which can influence the work of students' cognitive aspects, because students' cognitive aspects need to be developed and directed following structural learning (Aisyah, 2015). In addition, the PBL learning model is known for its characteristic of providing a problem around and allowing students to explore the problem until finally finding a solution that can be constructed into a cognitive knowledge (Hartati, 2023). Students' cognitive processes can also be formed through interactions and experiences gained by students and this is part of one of the processes in the stages of PBL implementation (Yusuf, 2017).

The statement is linear with various articles that have been selected for further analysis. The articles that have been selected are then analyzed to see each method and research results. The requirements needed in each article are that there is a control class and an experimental class. In addition, the quantitative data needed is the average score of the class of experimental and class of control, the total of students in the class used, standard deviation, and t-count. The following are data analysis results from various studies totaling 15 different article titles (Table 2).

Table 2. Data analysis from each article

Tittle Code	Years	Result							
		x experiments	x control	SD control	t-counts	nE	nC	SE	Interpretation
A1	2023	-	-	-	2,451	36	36	0,58	Moderate
A2	2023	73,70	57,58	11,439	-	-	-	1,40	High`
A3	2022	81,08	78,16	8,654	-	-	-	0,33	Moderate
A4	2021	-	-	-	3,035	26	26	0,84	Moderate
A5	2016	83,29	77,43	7,31	-	-	-	0,801	Moderate
A6	2019	81,973	77,720	7,898	-	-	-	0,538	Moderate
A7	2019	-	-	-	2,802	36	36	0.66	Moderate
A8	2018	52.00	48.55	7.548	-	-	-	0,45	Moderate
A9	2018	65,52	53,41	12,14	-	-	-	0.99	Moderate
A10	2018	-	-	-	2,048	81	81	0,321	Moderate
A11	2021	55,75	50,45	5,106	-	-	-	1,02	High
A12	2016	-	-	-	3,489	64	32	0,755	Moderate
A13	2016	-	-	-	5,422	25	24	1,54	High
A14	2015	-	-	-	3,02	40	38	0,68	Moderate
A15	2013	-	-	-	2,564	36	36	0,604	Moderate

Information:
t = t-count (T-value)
nE = Number of Experimental Samples
nC = Number of Control Samples

Based on the results obtained from the calculation of the effect size of 15 articles, there are 3 articles that have a large effect, and 12 articles that have a moderate effect. Table 2 shows that article A2 has an effect size of 1.40, A11 has an effect size of 1.02 and A13 has an effect size of

1.54, in accordance with Table 1 that the effect size of more than 1.00 is included in the high criteria. This shows that Problem-Based Learning (PBL) is effective in improving student cognitive learning outcomes in Biology subjects. PBL has proven effective in improving student learning outcomes because the process is related to honing students' ability to solve problems that will provide results at the end of the process (Malmia et al., 2019; Yani et al., 2021). The basic concept of the PBL model is to let students solve problems to carry out the process of learning. This is in line with Faradila & Kashardi's research (2022) that the PBL learning model is one of the models that leads to critical thinking skills and encourages students to solve problems following real life and can make students more active in learning.

The difference in effect size criteria as in Table 2 is because this PBL learning model has advantages, weaknesses, and factors that can affect learning outcomes of students in biology subjects. The PBL (Problem-Based Learning) learning model has the advantage that during the process of learning using problem-based learning so that students can do more experiments so that students are easier to remember lessons in the long term (Asiyah et al., 2020). The syntax applied in this model allows students to get better learning outcomes. According to Arends (2009), the Problem-Based Learning (PBL) model has five stages or five syntaxes, namely: 1. Orienting the problem to students, 2. Organizing the students for learning, 3. Guiding the students in groups to conduct investigations, 4. Developing and giving presentations from discussion results and 5. Analyzing and giving evaluate the problem-solving process. There are some of weaknesses of the PBL model such as the model require a long time in the learning process students who are not familiar with the PBL model and certain materials may experience difficulties, there is a possibility that students who do not understand the basic concepts will become passive and result in differences in student learning outcomes, and not all learning materials are suitable for PBL learning models (Warsono & Hariyanto, 2013).

Factors that affect student learning outcomes, namely: 1. Internal factors, 2. External factors, and 3. Learning approach factors. Internal factors are factors that arise from students in the form of conditions, intelligence, and physical and spiritual readiness. This is in line with Hamalik's research (2004) that a person's intelligence factor can affect success in learning so students who have higher intelligence tend to have high learning outcomes as well. This is reinforced by Lvie (1998) that students with high academic ability will achieve better thinking skills so that they are useful as capital in problem-solving and can affect the intellectual level of students. External factors arise from outside such as environmental conditions, one of which is the school environment. The school environment is one of the factors that influence the learning process because there are teaching and learning activities, various co-curricular activities, and others. According to Sudjana (2016), the school environment has a very important role in influencing student learning outcomes. In addition, the learning environment also affects students' learning motivation. This is confirmed by research by Martina (2019) that the school environment influences student learning outcomes. Learning approaches are students' learning efforts such as learning strategies used to carry out activities in learning material (Musriadi, 2014). Learning outcomes are indeed influenced by various factors that have been mentioned, but it is also related to how the process is passed during the learning period. These factors will later work together with all forms of learning processes, ranging from the use of models, and methods to techniques during the process of learning.

CONCLUSION

Based on the results of the meta-analysis that has been carried out regarding the effectiveness of the Problem-Based Learning (PBL) model on cognitive learning outcomes in high schools, the effect size value is 0.33 to 1.54. It can be concluded that the application of PBL in biology learning effectively has a positive effect on cognitive learning outcomes.

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