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The Effectiveness of Problem-Based Learning Model In Improving Critical Thinking Skills in Science Learning: a Meta-Analysis

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Abstract

The Effectiveness of Problem-Based Learning Model In Improving Critical Thinking Skills in Science Learning: a Meta-Analysis*. This study aims to determine the effectiveness of the problem-based learning (PBL) model in improving students' critical thinking skills in science learning. A meta-analysis study was carried out in this study by analyzing 30 scientific articles resulting from previous studies. The selected scientific articles have criteria namely; (1) articles that discuss the effect of applying the PBL model on critical thinking skills in learning science (physics and biology) (2) articles from national and international journals with research locations in Indonesia (3) journals published within the last five years. The data in this study were analyzed by calculating the average effect size from several previous studies and then categorized using the criteria set by Cohen's. The results of data analysis showed that the average effect size for physics subjects was 1.08 while for biology subjects it was 1.06. It can be concluded that the PBL model is effectively used to improve students' critical thinking skills in learning science (physics and biology) with a level of effectiveness in the high category.*

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Abstrak (10pt normal)

Pnelitian ini bertujuan untuk mengetahui efektifitas model problem based learning (PBL) dalam meningkatkan keterampilan berpikir kritis peserta didik dalam pembelajaran sains. Studi meta-anlisis dilakukan dalam penelitian ini dengan menganalisis 30 artikel ilmiah hasil dari penelitian sebelumnya. Artikel ilmiah yang dipilih memiliki kriteria yaitu; (1) artikel yang membahas tentang pengaruh penerapan model PBL terhadap keterampilan berpikir kritis dalam pembelajaran sains (fisika dan biologi) (2) artikel berasal dari jurnal nasional dan internasional dengan lokasi penelitian di Indonesia (3) jurnal dipublikasikan dalam rentang waktu lima tahun terakhir. Data dalam penelitian ini dianalisis dengan menghitung rata-rata effect size dari beberapa penelitian sebelumnya kemudian dikategorikan dengan menggunakan kriteria yang dibuat oleh Cohen's. Hasil analisis data menunjukkan bahwa rata-rata effect size untuk mata pelajaran biologi sebesar 1,06 sedangkan mata pelajaran fisika 1,08. Dapat disimpulkan bahwa model PBL efektif digunakan untuk meningkatkan keterampilan berpikir kritis peserta didik dalam pembelajaran sains (fisika dan biologi) dengan tingkat efektifitas berada pada kategori tinggi.

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INTRODUCTION

Currently, the world is in the 21st century. The 21st century is marked by the era of globalization which makes the world seem borderless (a borderless world). Various studies report that to face the challenges of the 21st century, various skills or competencies are needed. The Partnership for 21st Century Skills explains that one of the skills needed to face the challenges of the 21st century is critical thinking skills (Verawati et al, 2018). Critical thinking skills are the ability to interpret, evaluate, be able to give reasons effectively, be able to analyze, be able to solve problems, make conclusions, and be able to determine the credibility of existing evidence (Astika et al, 2013).

Critical thinking skills have now become a trend that is the main focus of learning in several developed countries in the world. Several developed countries such as the United States, Canada, Europe, Australia, and New Zealand place critical thinking skills into their educational curricula (Prayogi et al, 2018a; Howard, 2018). Likewise in Indonesia, since 2013 critical thinking skills have become one of the competencies that must be possessed by all students in Indonesia. Given the importance of critical thinking skills, several assessment programs at the international level include critical thinking skills as a domain in their assessment, including the PISA and TIMSS International Student Assessment Programs (Verawati et al, 2018; Mullis et al, 2015). Based on the data released by the two studies, it shows that the average score for the critical thinking domain of Indonesian students is always below the international average score (Simbolon, et.al., 2019). In addition, several research results also show that the critical thinking skills of Indonesian students are still low. The results of research by Kassiavera et al, (2019); Farcis, (2019); Makhrus et al, (2020); Safitri et al, (2021) show that students' critical thinking skills, especially in solving science problems, are still low. The results of this study indicate that learning activities in schools so far have not been able to improve students' critical thinking skills.

Various efforts have been made by educators (teachers and lecturers) to improve students' critical thinking skills. One of the many efforts made by teachers and lecturers in improving students' critical thinking skills, especially in science learning, is to apply the Problem-Based Learning (PBL) model. PBL is a learning model that involves students solving contextual problems through scientific procedures so that students can learn knowledge related to these problems. Through problem-solving activities, students practice using critical thinking skills from analyzing problems to synthesizing various information needed in the problem-solving process given. This is in line with the opinion of Akhdinirwanto et al, (2020) which states that PBL is a learning model that uses real-world problems, as a context for students to practice how to think critically and gain skills to solve problems.

Empirically, the PBL model has proven to be effective in improving students' critical thinking skills in science learning. The results of research conducted by Ramadani & Murtiani, (2019); Ibrahim et al (2019); Selviani, (2019); Wulandari et al, (2020); Maulina et al, 2020); Astutia et al, (2021); Nasral & Meliandika, (2022) show that the PBL model is effective for improving students' critical thinking skills in science learning with an Effect size (ES) in the medium category. Likewise, Rahmawati's research results (2018); Aswan et al (2018); Parno et al, (2019); Cahyono & Dwikoranto, 2021; Nurhayati et al (2021); Triyanti, (2022); Fitriyyah, & Wulandari, (2022) show that the PBL model is effective for improving students' critical thinking skills in science learning with an Effect size (ES) in the high category. In fact, the results of research conducted by Laksono et al (2018); Yulianti & Gunawan (2019); Supriyanto and Mustika, (2019); Nasihah et al, (2019); Setyoko et al

(2019); Priyadi & Suyanto, (2019), Cristanti et al, (2021); Habibah et al, (2022); Fithriyana & Fikri, (2022); Fadhilah et al, (2022); Hestari et al, (2023) showed that the PBL model was very effective for improving students' critical thinking skills in science learning with an effect size (ES) in the very high category.

The results of the research above show that there are differences in the size of the impact of applying the PBL model in improving students' critical thinking skills even though these studies were carried out in the same context, namely in science learning. Therefore, it is necessary to carry out a meta-analysis study to determine the average effect size or level of effectiveness of the PBL model in improving students' critical thinking skills, especially in science learning. This is important to do as a consideration for educators in determining appropriate learning models in relation to the aim of improving students' critical thinking skills. In other words, the results of this meta-analysis study can be used as a basis for comparing the effectiveness of the PBL model with other learning models in relation to improving students' critical thinking skills.

METHOD

This research is a literature review research. This study seeks to analyze the effect size of the application of the PBL model in improving students' critical thinking skills. The subjects of this study were 30 science learning journals consisting of 15 physics journals and 15 biology journals. These journals consist of accredited national journals and international journals. The selected journals have criteria, namely (1) journals that discuss the application or implementation of problem-based learning models to students' critical thinking skills (2) journals originating from national and international journals with research locations in schools or educational institutions in Indonesia (3) journals that published within the last five years.

In this study, the determination of the size of the effect size is sought by the equation made by Cohen's as shown in Table 1 below (Putri et al, 2022)

Table 1. Equation to Determine the Effect Size

Statistics	Formula
Mean of one group (one group pretest-posttest design)	$ES = \frac{\bar{X}_{Post} - \bar{X}_{Pre}}{SD_{Pre}}$
Mean of two groups (two groups posttest only design)	$ES = \frac{\bar{X}_{Experiment} - \bar{X}_{Control}}{SD_{Experiment}}$
Mean in two groups (two groups pre-posttest design)	$ES = \frac{(\bar{X}_{Post} - \bar{X}_{Pre})_{Experiment} - (\bar{X}_{Post} - \bar{X}_{Pre})_{Control}}{\frac{(SD_{Pre} + SD_{Post})_{Control} + (SD_{Pre})_{Experiment}}{3}}$
t count	$ES = t \sqrt{\frac{1}{N_{Experiment}} + \frac{1}{N_{Control}}}$; $\sqrt{\frac{2t}{N}}$

The value of the effect size calculation results is then consulted with the criteria made by Cohen's (Putri et al, 2022) as shown in table 2 below.

Table 2. Effect Size Categories

Effect Size	Category
ES < 1.10	very high
0.75 < ES ≤ 1.10	high
0.40 < ES ≤ 0.75	medium
0.15 < ES ≤ 0.40	low
ES ≤ 0.15	Very low

RESULT AND DISCUSSION

Based on the results of the analysis that has been carried out, the effect size recapitulation of 30 samples of research articles in national and international journals is obtained as follows.

Table 3. effect size of the PBL model in improving students' critical thinking skills

Physics			Biology		
Article Code	**Effect Size**	**Category**	**Article Code**	**Effect Size**	**Category**
Phy 1	0.78	high	Bio 1	0.75	medium
Phy 2	0.60	medium	Bio 2	1.05	high
Phy 3	1.12	very high	Bio 3	2.06	very high
Phy 4	1.63	very high	Bio 4	0.73	medium
Phy 5	0.80	high	Bio 5	1.65	very high
Phy 6	2.81	very high	Bio 6	1.10	high
Phy 7	0.70	medium	Bio 7	0.50	medium
Phy 8	0.82	high	Bio 8	0.44	medium
Phy 9	1.20	very high	Bio 9	0.69	medium
Phy 10	1.65	very high	Bio 10	1.17	very high
Phy 11	0.80	high	Bio 11	1.80	very high
Phy 12	1.13	very high	Bio 12	0.69	medium
Phy 13	0.42	medium	Bio 13	1.95	very high
Phy 14	0.85	high	Bio 14	0.59	medium
Phy 15	0.82	high	Bio 15	0.73	medium
Average	**1.08**	**High**	**Average**	**1.06**	**High**

The effect size data as shown in Table 3 above shows that the average effect size value for physics subjects is 1.08. This effect size value indicates that the level of effectiveness of the PBL model in improving students' critical thinking skills is in the high category. That is, the relevant PBL model is applied to learning physics in schools about improving students' critical thinking skills. For biology subjects, the average effect size score is almost the same as for physics subjects, which is 1.06. This effect size value indicates that the level of effectiveness of the PBL model in improving students' critical thinking skills in learning biology is also in the high category. This means that the PBL model is very suitable to be applied to learning biology in schools in relation to improving students' critical thinking skills. In other words, in general, the PBL model is suitable to be applied to improve student's critical thinking skills in learning science (biology and physics).

Critical thinking skills are the ability to interpret, evaluate, give reasons effectively, analyze, solve problems, draw conclusions, and determine the credibility of existing evidence (Astika et al., 2013). Most of the articles analyzed in this study used indicators of critical thinking skills made by Ennis, (2011). The critical thinking skills indicators made by Ennis are substantially the same as the indicators made by other experts. Critical thinking skills indicators according to Ennis (Supriyati et al., 2018), namely; (1) provide simple explanations, (2) build basic skills, (3) draw conclusions, (4) provide further explanations, (5) set strategies and tactics. Furthermore, if we refer to the indicators of critical thinking skills and relate them to student activities in learning with the PBL model, it appears that PBL is relevant to be used to improve student's critical thinking skills.

In PBL, students learn to solve a problem by applying the knowledge they have or trying to find out or build the necessary knowledge. Furthermore, students integrate knowledge and skills simultaneously and apply them in the context of problem-solving. Broadly speaking, the steps of the PBL model consist of five steps, namely (1) Orientation of students to problems, (2) organizing learning activities, (3) guiding individual and group investigations, (4) developing and presenting work, (5) analyze and evaluate the problem-solving process (Astutia et al., 2021; Habibah et al., 2022; Fithriyana & Fikri, 2022; Tabroni et al., 2022; Triyanti, 2022; Fitriyyah, & Wulandari, 2022). Each stage in PBL always involves critical thinking activities in it.

First, at the orientation stage of students on the problem. At this stage, the teacher gives problems to students, and students are invited to identify information, analyze problems, provide simple explanations, analyze relationships between variables as a first step in making problem formulations, identify or formulate criteria to determine possible answers from the problem formulations that have been made and other critical thinking activities. Of course, these activities can support the improvement of students' critical thinking skills. This statement is in line with the statement of Leicester & Taylor, (2010), namely, students learn to think critically gradually through habits that are trained in the form of activities to identify problems, formulate problems, and answer questions that require explanation.

The second step of the PBL model is organizing learning activities. At this stage, the teacher organizes students to make plans related to the steps that must be taken. At this stage, there are several critical thinking activities that can encourage the improvement of students' critical thinking skills including; Selecting criteria for making solutions, formulating alternative solutions, determining what to do temporarily, reviewing the problems given, obtaining a number of solutions, and compiling a rubric for monitoring the progress of activities that have been planned. These activities can certainly train students' critical thinking skills, especially in the aspect of the ability to determine strategies and tactics.

The third step of the PBL model is to investigate to find a solution to the given problem. This process is very much dominated by critical thinking activities. At this stage, students observe phenomena and analyze and identify data, information, or concepts that are relevant to the given problem. these activities are very closely related to the process of critical thinking, especially for the Induce indicator and considering the results of induction and deduction. Likewise with the last stage of the PBL model. The last stage of PBL is to analyze and evaluate the problem-solving process. Analyzing and evaluating activities are identical to critical thinking activities.

However, if we refer to the data in Table 3 above, it can be seen that there are differences in the level of effectiveness of the PBL model in improving students' critical thinking skills from the 30 research articles analyzed. Based on the results of further analysis of the 30 articles analyzed, this difference in the level of effectiveness can be caused by

several factors, namely; (1) differences in the percentage of the implementation of the PBL model in classroom learning, (2) differences in the personal abilities of teachers in organizing students at each learning stage, (3) differences in the characteristics of students, and (4) the suitability of the learning model with the lesson content presented. These four factors influence each other. The percentage of implementation of this learning determines the quality of learning in the classroom. When a teacher is not optimal in the apperception and delivery of learning objectives at the beginning of learning, this will affect students' readiness to participate in the problem-solving process in the PBL model (Novelni & Sukma, 2021). The difference in the percentage of implementation of each learning stage is most commonly caused by the teacher's ability to manage time, the problems presented being too complicated or complex for students, and the characteristics of students who are not used to applying the PBL model in the learning process. These four factors are indicated as the main factors causing the difference in the size of the impact from several previous studies.

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CONCLUSION

It can be concluded that the PBL model is effectively used to improve students' critical thinking skills, especially in learning science (physics and biology) in schools with the impact size being in the high category. It is hoped that the results of this study can become a reference for educators in implementing PBL, especially in learning physics and biology or in learning science in general. In addition, the results of this study are expected to be used as a reference for further research.

SUGGESTION

Suggestions for further research are to be able to conduct a more in-depth analysis of the effectiveness of the PBL model in improving students' critical thinking skills in terms of differences in student characteristics and/or characteristics of the content (material) being taught. In addition, it is hoped that future researchers will be able to complete this research by including a review of chemistry subjects.

REFERENCES

Akhdinirwanto, R.W., Agustini, R., & Jatmiko, B. (2020). Problem-Based Learning With Argumentation as A Hypothetical Model To Increase The Critical Thinking Skills For Junior High School Students, *Jurnal Pendidikan IPA Indonesia*, 9 (3), 340-350. https://doi.org/10.15294/jpii.v9i3.19282

Astika, K. U., Suma, I. K., & Suastra, I. W. (2013). Pengaruh Model Pembelajaran Berbasis Masalah Terhadap Sikap Ilmiah Dan Keterampilan Berpikir Kritis, *e-Journal Program Pasca Sarjana Universitas Pendidikan Ganesha Program Studi IPA*, 5(2):1-10. Retrieved from: https://ejournal-pasca.undiksha.ac.id/index.php/jurnal_ipa/article/view/851

Astutia, N.S.D., Priyayib, D.F., & Sastrodiharjo, S. (2021). Perbandingan keterampilan berpikir kritis peserta didik melalui penerapan model problem based learning (PBL) dan discovery, *Edu Sains Jurnal Pendidikan Sains & Matematika*, 9 (1), 1-9. 10.23971/eds.v9i1.1912

Aswan, D.M, Lufri L. & Sumarmin, R. (2018). Influence of Problem Based Learning on Critical Thinking Skills and Competence Class VIII SMPN 1 Gunuang Omeh,

2016/2017, *IOP Conf. Series: Materials Science and Engineering*, 10.1088/1757-899X/335/1/012128

Cahyono, B.D.T., & Dwikoranto, (2021). Implementasi Model Pembelajaran Problem Based Learning untuk Meningkatkan Kemampuan Berfikir Kritis pada Siswa, *IPF: Inovasi Pendidikan Fisika*, 10 (1), 1–7. https://doi.org/10.26740/ipf.v10n1.p1-7

Cristanti, Murtono, & Kanzunnudin, M. (2021). Pengaruh Model Pembelajaran Guidedddinquirydan Problem Based Learningterhadap Efektivitas Berpikir Kritis Peserta Didik Pada Mata Pelajaran IPA Kelas V Di Sekolah Dasar, *Jurnal Prakarsa Paedagogi*, 4 (2), 158-165. 10.24176/jpp.v4i2.5959

Ennis, R.H. (2011). *The Nature of Critical Thinking: An Outline of Critikal Thinking Dispositions and Abilities*. Chicago: University of Illinois.

Fadhilah, N., Nurdiyanti, Anisa, & Wajdi, M. (2022). Integrasi STEM-Problem Based Learning melalui Daring Terhadap Keterampilan Berpikir Kritis Mahasiswa Pendidikan Biologi, *Jurnal IPA dan Pembelajaran IPA*, 6(1), 1-10. 10.24815/jipi.v6i1.22721.

Farcis, F. (2019). Profil Keterampilan Berpikir Kritis Mahasiswa Pendidikan Fisika Universitas Palangka Raya Dalam Proses Analisis Artikel Ilmiah, *Jurnal Jejaring Matematika dan Sains*, 1 (1), 52-58. https://doi.org/10.36873/jjms.v1i1.137

Fithriyana, E.F., & Fikri, A.A. (2022). Implementasi model PBL berbasis etnobiologi untuk meningkatkan kemampuan berpikir kritis materi sistem reproduksi manusia, *SEMINAR NASIONAL VII 2022 Prodi Pendidikan Biologi Fakultas Keguruan dan Ilmu Pendidika*, 24-42. Retrieved from: http://research-report.umm.ac.id/index.php/psnpb/article/view/5189

Fitriyyah, S.J. & Wulandari,T.S.H. (2019). Pengaruh Model Pembelajaran Problem Based Learning terhadap Berpikir Kritis Siswa SMP pada Pembelajaran Biologi Materi Pemanasan Global, *BIOEDUKASI: Jurnal Pendidikan Biologi*, 12(1), 1-7. https://doi.org/10.20961/bioedukasi-uns.v12i1.27354

Habibah, F.N., Setiadi, D., Bahri, S., & Jamaluddin, (2022). Pengaruh Model *Problem Based Learning berbasis Blended Learning* terhadap Keterampilan Berpikir Kritis Peserta Didik Kelas XI di SMAN 2 Mataram, 7 (2b), 686 – 692. https://doi.org/10.29303/jipp.v7i2b.603

Hestari, s., Ibrohim, & Gofur, a. (2023). Pengembangan Perangkat Pembelajaran PBL *(Problem Based Learning)* Berbasis STEM (Science, Technology, Engineering, and Mathematics) Untuk Meningkatkan Keterampilan Berpikir Kritis dan Keterampilan Komunikasi Siswa Kelas X SMA, *Jurnal Ilmu Sosial dan Pendidikan (JISIP)*, 7 (2). 1358-1363. http://dx.doi.org/10.58258/jisip.v7i2.4911

Howard, P. G. (2018). Twenty-First Century Learning as a Radical Re-Thinking of Education in the Service of Life. *Education Sciences.* 8 (189), 1-13. https://doi.org/10.3390/educsci8040189

Ibrahim, Almukarramah, Gunawan, Marwa, & Don, Y. (2019). Implementation of problem-based learning to improve students' critical thinking skills, *Journal of Physics: Conf. Series 1460 (AICMSTE 2019)*, 10.1088/1742-6596/1460/1/012058.

Kassiavera, S., Suparmi, A., Cari, C., & Sukarmin, S. (2019). Survei Keterampilan Berpikir Kritis Mahasiswa pada Materi Usaha dan Energi, *Prosiding SNFA (Seminar Nasional Fisika dan Aplikasinya)*, Retrieved from: file:///C:/Users/USER/Downloads/35928-93377-3-PB.pdf

Laksono, E.W., Suyanta and Rizky, I. (2018). Problem-based learning implementation to develop critical thinking and science process skills of madrasah Aliyah students in yogyakarta, *Journal of Physics: Conf. Series 1097 (ICRIEMS 5).* 10.1088/1742-6596/1097/1/012059

Leicester, M., & Taylor, D. (2011). *Critical thinking across the curriculum.* New York: McGraw-Hil Open University Press.

Makhrus, M., Syahrial A.,Wahyudi, Verawati, S.N.P.S., & Busyairi, A. (2020). Kema puan Berpikir Kritis Mahasiswa pada Materi Optik Saat Proses Pembelajaran dengan CCM-CCA Berbantuan Eksperimen Virtual, *KAPPA Journal*, 4 (2), 143-148. *10.29408/kpj.v4i2.2632*

Maulina, D., Setiadi, D., Yamin, & Jamaluddin, M. (2020). Pengaruh Pembelajaran Problem Based LearningBerbasis Bauran terhadap Keterampilan Berpikir Kritis Siswa Kelas X SMAN1 Kuripan, Jurnal Ilmiah Profesi Pendidikan, 7 (2b), 554 –558. 10.29303/jipp.v7i2b.572

Mullis, I. V. S., Martin, M. O., Foy, P., & Hooper, M. (2015). *TIMSS 2015 International Results*. Boston: TIMSS & PIRLS International Study Center.

Nasihah, E.D., Supeno, & Lesmono,A.D. (2019). Pengaruh Tutor Sebaya Dalam Pembelajaran Problem Based Learning Terhadap Keterampilan Berpikir Kritis Fisika Siswa SMA, *Jurnal Pendidikan Fisika*, 1 (8), 44-57. http://dx.doi.org/10.24127/jpf.v8i1.1899

Nasral, & Meliandika, R., (2022). Pengaruh Model PBL (Problem Based Learning) dengan Media Animasi terhadap Kemampuan Berpikir Kritis dan Hasil Belajar Biologi Siswa di SMAN I Kota Bengkulu, *Jurnal Pendidikan Tambusai*, 6(1), 672-683. Retrieved from: https://jptam.org/index.php/jptam/article/view/2963

Novelni, D. & Sukma, E. (2021). Analisis Langkah-Langkah Model Problem Based Learning Dalam Pembelajaran Tematik Terpadu Di Sekolah Dasar Menurut Pandangan Para Ahli, *Journal of Basic Education Studies*, 4 (1). 3869-3888. Retrieved from: file:///C:/Users/USER/Downloads/4342-Research%20Results-15316-1-10-20211017%20(2).pdf

Nurhayati, Wahyudi, and Angraeni, (2021).The influence of problem based learning model and critical thinking ability on higher order thinking skills (HOTs) of physics prospective teachers students, *Journal of Physics: Conference Series, (SNPF 2021)*. 10.1088/1742-6596/2104/1/012007

Parno, Fathurrahman, Asim, Suwasono, P.,& Ali, M. (2019). The Influence of Problem Based Learning on Critical Thinking Ability for Students in Optical Instrument Topic, Jurnal Pendidikan Fisika Indonesia 15 (1), 39-45. 10.15294/jpfi.v15i1.19309

Prayogi, S., Yuanita, L. & Wasis, (2018a). Critical In- quiry Based Learning: A Model of Learning to Promote Critical Thinking among Prospective Teachers of Physics, Journal of Turkish Science Education, 15 (1), 43-56. Retrieved from: https://www.tused.org/index.php/tused/article/view/148

Priyadi, A. A. & Suyanto, S. (2019). The Effectiveness of Problem Based Learning in Biology with Fishbone Diagram on Critical Thinking Skill of Senior High School Students, *Journal of Physics: Conference Series, (ICRIEMS 6)*, 1-8. 10.1088/1742-6596/1397/1/012047

Putri , C.D., Pursitasari, I.D., & Rubini, B. (2020). Problem Based Learning Terintegrasi Stem di Era Pandemi Covid-19 Untuk Meningkatkan Keterampilan Berpikir Kritis Siswa, *JIPI (Jurnal IPA dan Pembelajaran IPA),* 4(2), 193-204. https://doi.org/10.24815/jipi.v4i2.17859

Putri, D.A.H., Fauziah, N., & Wati, W.W., (2022). Analisis Effect Size Pengaruh Model Problem Based Learning Terhadap Keterampilan Berpikir Kritis dan Pemecahan Masalah Dalam Pembelajaran Sains, *ORBITA. Jurnal Hasil Kajian, Inovasi, dan Aplikasi Pendidikan Fisika*, 8 (2), 205-211. https://doi.org/10.31764/orbita.v8i2.10295

Putri, R., Saminan Ismail, S., & hasan, M. (2016). Pengaruh Model Problem Based Learning Terhadap Berpikir Kritis dan Hasil Belajar Elastisitas Siswa Kelas XI SMA Negeri 7 Banda Aceh, *Jurnal Pendidikan Sains Indonesia*, 4 (1) 117-128. Retrieved from: https://www.neliti.com/id/publications/122494/pengaruh-model-problem-based-learning-terhadap-berpikir-kritis-dan-hasil-belajar

Rahmawati, R.I. (2018). Pengaruh Implementasi Model Problem Based Learning (PBL) terhadap Kemampuan Berfikir Kritis IPA Siswa SMPN 1 Pakusari, *Eduscience, 1* (1), 31-36. https://doi.org/10.19184/se.v1i1.9490

Ramadani, I. & ,Murtiani, (2019). Pengaruh Implementasi Problem Based Learning (PBL) Terhadap Keterampilan Berpikir Kritis Siswa Dalam Pembelajaran Fisika Kelas XI di SMA N 5 Padang, *Pillar of Physics Education*, 4, 49-56. http://dx.doi.org/10.24036/1890171074

Safitri, H., Hamidah, I., Setiawan, W., & Kaniawati, I. (2021). Profil Keterampilan Berpikir Kritis dan Perilaku Mahasiswa Pendidikan Fisika: Sebuah Peluang MenerapkanProblem Based Learningdalam Pembelajaran Online, *JIPFRI (Jurnal Inovasi Pendidikan Fisika dan Riset Ilmiah).* 5 (2), 87-94. https://doi.org/10.30599/jipfri.v5i2.1055

Selviani, I. (2019). Pengembangan Modul Biologi Problem Based Learning Untuk Meningkatkan Kemampuan Berpikir Kritis Peserta Didik SMA, *IJIS Edu: Indonesian J. Integr. Sci. Education,* 1 (2), 147-154. http://dx.doi.org/10.29300/ijisedu.v1i2.2032

Setyoko, Indriaty, Wibowo, T.H. (2019). Efektifitas Bahan Ajar Ekologi Hewan Berbasis Problem Based Learning Terhadap Kemampuan Berpikir Kritis dan Pemecahan Masalah Mahasiswa Pendidikan Biologi, *BIOEDUKASI Jurnal Pendidikan Biologi*, 133-139. http://dx.doi.org/10.24127/bioedukasi.v10i2.2493

Simbolon, H. Simbolon, M. R., & Harahap, F. (2019). An Analysis of Students' Scientific Literacy Skillsin State Senior High Schools throughout Central Tapanuli District.

Advances in Social Science, *Education and Humanities Research*, 384, 105-109. Retrieved from: https://www.atlantis-press.com/proceedings/aisteel-19/125928346

Sunarti, I. (2019). Penerapan Model Pembelajaran Problem Based Learning (PBL) Terhadap Kemampuan Berpikir Kritis Siswa, *Equilibrium: Jurnal Penelitian Pendidikan dan Ekonomi,* 16 (1), 15-25. 10.21831/jpv.v4i1.2540

Supriyanto, E. and Mustika, (2019). The Improvement of Critical Thinking Skills Through Problem Based Learning Models Assisted by Trackers Video on Parabolic Movements, *Journal of Physics: Conference Series* (SNF 2021), 10.1088/1742-6596/2019/1/012029

Supriyati, E., Setyawati, O.I., Purwanti, D.Y., Salsabila, L.S., & Prayitno, B.A. (2018). Profil Keterampilan Berpikir Kritis Siswa SMA Swasta di Sragen pada Materi Sistem Reproduksi, *BIOEDUKASI: Jurnal Pendidikan Biologi*, 11 (2), 74-80. http://dx.doi.org/10.20961/bioedukasi-uns.v11i2.21792

Triyanti, M. (2022). Pengaruh Problem Based Learning Berbasis Blended Learning Terhadap Kemampuan Berpikir Kritis Siswa di SMA Negeri 4 Rejang Lebong, *Linggau Journal Science Education*, 2(1), 67 – 76. https://jurnal.lp3mkil.or.id/index.php/ljse/article/view/237

Verawati, N. N. S. P., Ayub, S., &Prayogi, S. (2018). Development of Inquiry-Creative-Process Learning Model to Promote Critical Thinking Ability of Physics Prospective Teachers. *Journal of Physics: Conference Series 1108*, 1-6. 10.1088/1742-6596/1108/1/012005

Wulandari, T Kadir, A., Fua, J.L., & Zainuddin, (2020). Pengaruh Model Problem Based Learning Berbasis Multimedia Terhadap Kemampuan Berpikir Kritis dan Hasil Belajar IPA, Kulidawa, 1 (1), 29-34. http://dx.doi.org/10.31332/kd.v1i1.1806

Yulianti, E. & Gunawan, I., (2019). Model Pembelajaran Problem Based Learning (PBL) Efeknya Terhadap Pemahaman Konsep dan Berpikir Kritis, Indonesian Journal of Science and Mathematics Education 02 (3), 399-408. Doi: 10.24042/IJSME.V2I3.4366

Yuliatia, Fauziah, R. and Hidayat, (2018). Student's critical thinking skills in authentic problem based learning, Journal of Physics: Conf. Series 1013, 10.1088/1742-6596/1013/1/012025