JIPI (Jurnal IPA dan Pembelajaran IPA) 9(2), p.573-585 (2025)
p_ISSN: 2614-0500-e_ISSN: 2620-553X
https://jurnal.usk.ac.id/JIPI/index https://doi.org/**10.4815/jipi.v9i2.45875**

The Effect of Open-Ended Problem Based Learning Model on Energy Sources Material on Critical Thinking Skills and Pro-Environmental Attitudes of Elementary School Teacher Education Students

Ika Damayanti[1]*, Siwi Purwanti[2], Woro Sri Hastuti[1], Ikhlasul Ardi Nugroho[1], Supartinah[1], Ruqoyyah Amilia Andania[3], Ayu Luhanarky[4]

[1]Master's Program in Elementary Education, Faculty of Education and Psychology, Yogyakarta State University, Indonesia
[2]Elementary School Teacher Education Program, Faculty of Education and Psychology, Ahmad Dahlan University, Indonesia
[3]Education and Human Potentials Development, Hua Shih Collage of Education, National Dong Hwa University, Taiwan
[4]Master of Education in Early Childhood Education, Faculty of Education, Monash University, Australia

*Corresponding author's email: ikadamayanti.2024@student.uny.ac.id

Article History:
Received date: May 2 2025
Received in revised from: June 10 2025
Accepted date: June 17 2025
Available online: June 24 2025

Citation:
Damayanti, I., Purwanti, S., Hastuti, W.S., Nugroho, I.A., Dupartinah, Andania, R.A., & Luhanarky, A. 2025. The effect of open-ended problem based learning model on energy sources material on critical thinking skills and pro-environmental attitudes of Elementary School teacher education students. *JIPI (Jurnal IPA dan Pembelajaran IPA)*, 9(2):573-585.

Abstract. Critical thinking is one of the skills that need to be mastered in the 21st century. CTS especially in prospective elementary school teacher students, need to be developed because as an educator, teachers must face all the problems encountered in the learning process. This study aims (1) to determine whether there is a difference in CTS among students before and after receiving treatment (2) to identify the categories of differences in CTS among students after receiving treatment and its impact on their pro-environmental attitudes. This study is a pre-experimental research using a one group pretest posttest design. Students of the Elementary Education Study Program at Ahmad Dahlan University were given treatment through PBL by conducting an experiment on the use of banana peel waste as a substitute for carbon powder in batteries. A pretest was given before the students received treatment and the lecturer conducted the learning by presenting environmental problems, followed by a posttest. Data were analyzed using SPSS version 24 software to determine differences based on the Hake factor or N-gain. Additionally, the researcher analyzed the data using a paired t-test to assess the effectiveness of the PBL model. Based on the results of the study conducted using the N-Gain test, the average value obtained was 0.7239. This indicates that students experienced a significant improvement in learning outcomes, categorized as high ($g \geq 0.7$). Furthermore, based on the results of observations and interviews, there was a significant impact after students participated in learning with treatment on the material of energy sources affecting the environment. Students demonstrated a positive attitude toward the environment, as evidenced by their sensitivity and openness to contributing to environmental conservation. Based on the gain values obtained, it can be concluded that the PBL model influences students' CTS and supports a positive attitude toward the environment.
Keywords: Critical thinking skills; students; problem-based learning; pro-environmental attitudes

Introduction

The 21st century is a century in which all sectors are developing rapidly. The field of education is a field that is progressively developing by implementing learning models

that facilitate 21st century skills (Muslimin, 2024). 21st century learning requires students to have the ability to integrate literacy, knowledge skills, skills and character and be able to master technology (Hasmiza, 2025).

Educators as the spearhead of education are expected to be able to keep up with the changes and developments of the times. According to (Rakhmawati, 2024) in 21st century learning there is the concept of 4C. These four elements are instruments that can make students adapt and develop in the 21st century. Students will face various opportunities and challenges in the era of technological and information advances. These various skills can be integrated in independent activities such as learning activities, students are given a lighter problem, then the lecturer as a guide (Gea, 2025).

Active student participation is one of the indicators of effective learning (Kasmadi, 2025). Seven competencies that must be developed are the ability to think critically, work together and lead, adaptive, the ability to obtain information, high curiosity, high entrepreneurial spirit, and moral communication skills (Syafar, 2024).

Natural sciences (IPA) can be an effective means of exploring students' scientific attitudes, analytical abilities, critical thinking, objective, systematic and so on (Tukan, 2025). The success of science learning is measured by the ability of students to understand scientific concepts and process skills such as observing, asking questions, planning, carrying out and evaluating scientific actions (Aisah, 2025). In addition, students are also expected to have attitudes and behaviors that support positive contributions to the development and preservation of the environment (Syafitri, 2024).

Critical thinking ability (CTA) is the capacity to deal with complex situations or theories, then decipher and analyze in depth to gain scientific understanding (Novita, 2024). Students are said to have CTS if they are able to recognize problems, make decisions based on certain contexts, evaluate information and form assumptions that help in formulating problem-solving strategies (Solihin, 2024). However, low CTS in students are caused by strategies that lead to the ability to analyze (Humam, 2025). This occurs due to educators, where learning tends to be led by lectures from lecturers and assignments are given at the end of the learning session only with group presentations (Sugiartini, 2024).

Based on initial observations, the data showed that students were still passive in attending lectures. Students tend to be afraid to express their opinions in the discussion forum. Students are also fixated on the answers on the internet and do not develop their arguments in their own language. Based on tests conducted by lecturers in the Advanced Science course, there are 50% of students who have not met the grade standards, even though the questions given are description questions which should allow students to be more free to be creative and write their arguments. Students seem less enthusiastic during learning, this can be seen by some students chatting alone or playing on their cell phones. In addition, based on observations, some students still tend to bring bottled water into the lecture room and bring fast food wrapped in sterofoam. Some students are less sensitive to the dirty state of the classroom after learning. During the lecture process, lecturers are more active and cause students to present monotonously. As a result, there is no bridging facility for lecturers who can stimulate students' critical thinking by preparing careful planning so that the problems faced can be handled better (Hardianty, 2024).

The PBL model is considered a strategy to attract student attention (Aprina, 2024). This model facilitates learning to trigger students' analytical skills. According to (Hotimah, 2020), this model also emphasizes the ability to interpret a phenomenon or problem and come to a conclusion. According to (Dwijayanti, 2024) in PBL, students are given a stimulus to bring out the thinking skills of students in finding problem-solving steps that are relevant to the learning context. Students are encouraged to be active in solving problems and the information needed, all of which require CTS (Sholeh, 2024).

CTS an also affect a person's pro-environmental attitude. When students have been able to analyze an environmental problem and can provide the right arguments, students can choose and take actions that lead to a pro-environmental attitude. Pro-environmental attitudes have many terms such as environmentally friendly behavior. Behavior that is carried out with full awareness with the aim of minimizing the harm of actions to the surrounding nature is the definition of pro-environmental behavior. A person can be suspected of having a pro-environmental attitude with an awareness of environmental norms, protecting the environment and personal responsibility (Rahman, 2020). This awareness certainly comes from critical thinking about the consequences that will arise when taking an action. The ability to think critically will encourage the creation of a pro-environmental attitude which is very important for students to have. Based on the background above, the researcher wants to know (1) whether there is a difference in students' CTS before and after being treated (2) how the level of difference in CTS and pro-environmental attitudes after the application of PBL with open ended questions in elementary school teacher education students.

Methods

This type of research is pre-experimental with a one-group pretest posttest design, which means only using one class. Researchers give a pretest before treatment and measure the impact of treatment with a posttest. This research is considered sharper because it measures the difference by comparing the situation before and after (Sugiyono, 2019).

There are three flows and activities in this study, namely (1) preparation (2) treatment (3) results. In the first stage, researchers prepared research instruments that were validated by expert lecturers. In addition, researchers also analyzed the initial conditions of the class under study and collected data with literature studies. The second stage is the implementation of treatment. Researchers applied the PBL model with experiments in accordance with the PBL syntax. Then the last is to calculate the results by processing the final data obtained and then comparing with the initial data through the analysis process (Creswell, 2018).

Table 1. One-group prestest-postest research design

Pretest	Treatment	Posttest
O_1	X	O_2

Description:
O1 : Pretest
X : Treatment
O2 : Posttest

The research subjects consisted of 41 PGSD students. The instruments are critical thinking ability tests with open ended description types representing CTA indicators and interview sheets to find out students' pro-environmental attitudes. The instrument designed has gone through a validation process by three expert lecturers, namely a science expert lecturer and two lecturers in the field of basic education. The application used to analyze data is with SPSS software qualitative data is processed with descriptive.

This research also goes through classical parametric tests with normality and homogeneity tests. The normality test is carried out when the researcher wants to know whether the data is normally distributed or not, while homogeneity is used to determine whether the data has the same or different variants. The requirement for normally distributed data is probability or (Sig.) >0.05. The homogeneity test aims to determine whether the sample comes from a homogeneous population or not by comparing the two

variant (Isnaini, 2025). The condition that the data comes from a homogeneous population is the probability (Sig.) > 0.05 and if the probability (Sig.) < 0.05 then the data is not homogeneous (Nasution, 2019; Mulyati, 2024).

After the data is declared normal and homogeneous, the next hypothesis test is paired sample t-test. This test was chosen on the grounds that the data came from only one class and aimed to see the effect of the learning carried out (Hasnunidah, 2017). Based on the paired sample t-test results if sig.2-tailed <0.05 then H0 is rejected and Ha is accepted. Furthermore, the n-gain test was conducted to see the difference. N-Gain criteria for the effect of applying PBL models in improving CTS can be seen in table 2.

Table 2. N-gain criteria

N-gain value	Criteria
0.7≤g≤1.0	high
0.3≤g≤0.7	medium
0≤g≤0.3	low

Results and Discussion

Normality Test

This test is classified as a classic test with the intention of analyzing whether the data is normally distributed or not. The consequence of the normality test results is that if the data passes the normality test, the prerequisites are met and can perform parametric tests. But on the contrary, when it does not pass, it must be calculated with non-parametric. Normality test using pretest and posttest data shown in Table 3.

Table 3. Normality test of pre-test and data

Tests of Normality	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	.126	40	.108	.967	40	.282
Posttest	.135	40	.063	.952	40	.086

Based on Table 3, both the Kolmogorov-Smoirnov and Shapiro Wilk tests have good significance. The significance obtained for the pretest is 0.282 (0.282> 0.05), so Ho is accepted and Ha is rejected. The pretest obtained a significance value of more than 0.05 and concluded that it was normally distributed. The posttest obtained a significance of 0.086 (0.086 > 0.05), so Ho is accepted and Ha is rejected. Thus the posttest value is also normally distributed.

Homogeneity Test

Table 4. Homogeneity test of pre-test and post-test data

		Levene Statistic	df1	df2	Sig.
Value	Based on Mean	3.830	1	78	.054
	Based on Median	2.755	1	78	.101
	Based on Median and with adjusted df	2.755	1	67.976	.102
	Based on trimmed mean	3.488	1	78	.066

Based on the output above, it is known that the sig value≥ 0.05 is 0.054 and the data has the same variance with the criteria if the sig value> 0.05, it is said that the variance of the pretest and postest is homogeneous.

Paired Sample T-test

The test chosen to calculate the difference in average ability is the Paired sample T-test. The purpose of the test is to determine whether there is an average difference in CTS before and after treatment. This test processes pretest and posttest data from 41 students with the hypothesis:

Ho: There is no difference in the average CTS of students before and after the application of the PBL learning model.

Ha: There is a difference in the average CTS of students before and after the application of the PBL learning model.

The results of the paired sample t-test are shown in Table 5.

Table 5. Paired t-test results for CTA

		Mean	N	Std.Deviation	Std. Error Mean
Pair 1	Pretest	38.00	40	6.210	.982
	Posttest	82.70	40	8.564	1.354

The pretest mean value was found to be 38.00 and the posttest value was 82.70 which interpreted that there was a difference in the average before and after treatment.

Table 6. Significance results of 2 tailed paired t-tests

Paired Differences					T	Df	Significance	
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference					
			Lower	Upper			One-Sided p	Two-Sided p
Pre Test-Post Test	44.700	8.247	1.304	47.337	42.063	-34.281	39	<.001	<.001

Sig value. (2-tailed) 0.001 < 0.05 with a reference if sig. p < 0.05 then Ha is accepted and Ho is rejected. This means that there is a significant difference between the pretest and posttest scores after students take part in learning with treatment practicum.

N-Gain Test

After it is stated that there is a difference in the pretest and posttest scores, the next test is the N-Gain test which aims to calculate the difference category. The N-Gain value is calculated by finding the difference between posttest and pretest. The N-gain index states the high and low CTS presented in table 7. The hypothesis is written as follows:

Ho: There is no improvement in students' CTS after PBL learning.

Ha: There is an increase in students' CTS after participating in PBL learning.

Table 7. N-gain test calculation results of prestest and postest results

	N	Minimum	Maximum	Mean	Std. Deviation
N-Gain	40	40	.93	.7239	12906
valid N (listwise)	40				

Table 7 presents a summary of the N-gain results of 0.7239≥ 0.7 with high criteria. The table shows that the minimum value is 40% and the maximum is 93%. It can be inferred that the use of PBL models can improve the CTS of PGSD students.

Table 8. N-Gain value of student CTA indicators

N-Gain indicator	Value				N-Gain	N-Gain (%)
	Pretest	Posttest	Post-pre	100-pre		
Interpretation	38.5366	85.85366	47.31706	52.68294	0.898148	89.81476736
Analysis	39.0244	80.4878	41.4634	58.5366	0.708333	70.83329063
Evaluation	34.6341	75.12195	40.48785	59.51215	0.680329	68.03291429
Conclusion	36.6341	80	43.3659	56.6341	0.765721	76.57206524
Explanation	37.0732	81.95122	44.87802	55.12198	0.814158	81.41583448

Table 8 on the indicators there is an escalation of students' CTS with the PBL learning model. The -1 indicator is interpretation. The pretest value reveals the number 38.5366 and on the posttest is 85.85366 with n-gain 0.898148 on high improvement criteria. Analysis is the 2nd indicator with a pretest of 39.0244 and a posttest of 80.4878 followed by an n-gain of 0.708333 on a medium improvement measure. Evaluation indicator with an average score of pretest 34.6341, posttest 75.12195, N-Gain 0.680329 on medium criteria. The 4th indicator is Inference, the average pretest 36.6341, posttest 80 and N-Gain value 0.765721 on high criteria. The 5th indicator, namely explanation, gets a mean pretest value of 37.0732 and a posttest of 81.95122 with an n-gain of 0.814158 in the high improvement category.

Differences in Student Ability Before and After Implementing

It is known that the paired t-test obtained a Sig value. = 0,001 < 0,05. The data interpretation reference used if Sig. p < 0.05 then Ha is accepted and Ho is rejected. There is a significant difference in pretest-posttest with PBL on CTS of elementary school teacher education students. The increase can occur because this model uses syntax by making students free to argue and think more critically. In the first syntax is interpretation, then the lecturer gives a lighter question that focuses on environmental issues such as the use of batteries that are not environmentally friendly and their impact on the environment. Students were seen thinking and contemplating for a moment that a small object like a battery turns out to bring enormous danger to the earth where we live. Students began to think that there is content in the battery stone that cannot be decomposed by the soil. Students can even relate to the great risk if the battery stone catches fire and explodes. Students are given the opportunity to think and innovate in making environmentally friendly battery stones by utilizing ambon banana peel waste. The practicum process is shown in Figure 1.

Figure 1. The process of students doing practicum

The application of the PBL learning model makes students more active and interested in the learning process (Gomez, 2024). Students are trained to contribute to thinking about real steps in reducing environmental pollution. Many students expressed their ideas and opinions in the discussion forum opened by the lecturer. Students become more confident in expressing their opinions because students feel that the questions asked are problems that are close to student life. This is in accordance with the results of interviews conducted with students that students claimed to be more motivated in learning with experiments.

"The questions are very close to environmental issues. After participating in the lesson, I became thinking about environmental issues where in our daily lives we often unknowingly become agents that have a very bad impact on the environment around us."

Before being given the treatment, many students were less sensitive to the surrounding environment, especially on energy use. Students often leave the classroom without turning off the air conditioner or lights in the classroom. In addition, some students bring food into the classroom. There are also students who charge their cell phones while learning is taking place.

Based on the results of interviews on indicators of pro-environmental attitudes towards students, the results show that after students get treatment, they have a sensitive attitude towards environmental problems. Referring to the research of (Bürgener, 2018) who combined ideas and projects in the form of scaffolding, making the classroom more active and increasing students' critical thinking. According to students, there are actually many potential natural materials that can replace non-renewable energy sources. Students also become more open to innovation and creative ideas to reduce environmental pollution.

"After participating in the lesson, I became more aware that there are many potential natural materials that can be used to replace materials that are not environmentally friendly, even those natural materials have been categorized as waste. I became more curious and want to find out more about what natural materials have the potential to be recycled."

Of course, innovative thinking must be supported by real action to contribute to caring for the surrounding environment (Honebein, 1996). In the second indicator of pro-environmental attitudes is the aspect of *environmentally responsible consumption,* the results show that students become wiser in buying food wrapped in styrofoam. According to students, it would be better to eat on the spot with the container provided without having to bring it to class and increase waste. The third indicator is energy conservation. After participating in PBL related to environmental pollution and energy waste, students become more sensitive to the surrounding environment by turning off the air conditioner and lights when finished learning. Students who are accustomed to charging cell phones on campus, become wiser in the use of energy. In the fourth indicator, students claimed to be greatly

helped by the existence of drinking water refill stations so that it would reduce plastic bottle waste. Students also feel that the presence of UAD buses is very helpful in reducing environmental pollution.

Improvement of Student CTA Pretest and Posttest Results

The N-Gain test suggests that there is an increase with a high category for the CTS of PGSD students with the mean pretest posttest value obtained 0.7239≥0.7. The minimum value is 40% and the maximum is 93%, which means that students' CTS between before and after the application of the PBL model jumped. Students become more challenged in learning, especially when understanding solutions and are required to solve problems. Research by Uliyanti (2024) that the PBL allows students to gain insight into solving problems related to contextual problems. In addition, other research conducted by mathematical problem solving skills can increase by applying PBL (Ramadhani, 2024).

Giving problems related to the problem to be solved. This research is supported by (Pertiwi, 2023) which states that the PBL model is very suitable to be applied to determine the initial understanding of students and the extent of their analytical abilities. This research is not only by implementing the model, but students are also invited to make environmentally friendly energy sources by making battery stones from banana peels. Practicum can make students feel more deeply in concept mastery. In line with (Andarias, 2025) that through practicum activities that have structured activities, students will be encouraged to understand concepts. In addition, through practicum students will feel more direct learning and gain real experience.

Interpretation **indicators** with an average pretest of 38.5366, posttest 85.85366 and N-Gain 0.89 high category. Before students were given material and understanding related to environmental problems, students could not comprehensively explain the reasons for the impact of using battery stones on the environment. Students are less able to write their answers comprehensively. Some students answered with the environment becoming dirty, becoming polluted, a lot of garbage. But students have not been able to write down the substances contained in batteries that can harm the soil and the difficulty of batteries decomposing in the soil. After being given the treatment of learning models and practicum together, students became more able to answer interpretation questions in more depth. Such as the presence of carbon-colored black powder in the battery stone to the battery cover made of zinc which is difficult to decompose. In agreement with (Facione, 2011) that interpretation is defined as the competence of realizing an intention in the form of events, conditions or objects.

The second indicator is analysis. The average pretest indicator is 39.0244, the posttest is 80.4878 with an N-Gain value of 0.7083 with high improvement criteria. Students answered pretest questions that analyzed why battery stones from natural materials are more environmentally friendly. Before being treated, many students answered the question briefly without thinking deeply. Most students answered that battery stones from natural materials are more environmentally friendly because they are made from natural materials. After being given treatment and students were directly involved in the practicum. Students became more critical and answered questions with more depth. Their analytical skills also increased, marked by each writing an answer accompanied by supporting arguments. Analytical ability is the ability to know the meaning and relationship between statements, questions, opinions and experiences (Facione, 2011).

The third indicator is evaluation. The N-Gain value is 0.68 with a mean pretest of 34.63 and posttest of 75.12 which is also categorized as high. This third indicator is the indicator with the lowest pretest score. When before being treated, students were so confused with the question of why electricity can occur in natural materials and not chemicals. Students whose backgrounds are not too deep into electrical material seem confused. Students also hesitated and did not believe that natural materials could replace

carbon in batteries. Many students also assume that the source of electricity comes from the fibers of banana peels, even though the electricity comes from water from the content of banana peels that have been pounded. After being given the treatment, students became more critical and convinced that the source of electric current comes from banana peel water and students understood that banana peels must be pounded as softly as possible until they release the water. This agrees with (Dewanda, 2020) that evaluation is related to logical reasoning skills to achieve CTS.

The 4th indicator of Inference also occupies a high improvement category with an N-Gain value of 0.76. Previously, students found it difficult to draw conclusions with their own sentences. Students were fixated on the video given by the lecturer without developing their own sentences. This is also an impact of the students' low ability to interpret. When students were asked about the effectiveness of banana peel waste replacing carbon in batteries, many students could not conclude the answer effectively, quite effectively or ineffectively. Many students wrote answers in the form of reasons only without drawing conclusions. After being given treatment, students can draw conclusions in their own language. Students can also write strong arguments after they answer how effective. Some students answered that it is very effective because banana peel waste material is very easy to obtain in nature and does not damage the environment either in the short or long term. Some students wrote less effective, because the electric current produced is limited so it is difficult to apply to large electronic objects. This agrees with (Kurnianto, 2024) that to achieve inferential skills, students must be able to master various aspects. Research according to (Cai, 2021) states that inferential ability is obtained when a person can master various aspects including environmental aspects.

The 5th indicator is explanation. This indicator obtained an average pretest score of 37.07, the average posttest was 81.95 and the N-gain was 0.81. In this indicator, students are given the opportunity to be able to explain the flow of how a dead battery works and is filled with banana peel waste. Before being given the treatment, students looked very confused. Students answered the question briefly, even though the question had been given instructions to explain but students only wrote with short sentences, for example because there is electricity, banana peel waste has strong fibers and so on. Students were not able to explain the flow of electricity comprehensively. After being given the treatment, students became more detailed in providing answers. The explanation given was also very coherent and thorough. Many students connected practicum activities to answer this question. Therefore, the development of thinking skills is one of the most important aspects of learning as its quality affects further human activities (Djamas et al., 2021).

In conclusion, the problem-based learning model research with the practicum of energy sources from banana peel waste supports the improvement of students' CTS by 0.7239 with a high category. In addition, this model is suitable and has an impact on students' pro-environmental attitudes. Students become more sensitive and critical towards the threat of environmental pollution. Students become wiser in using energy sources. CTS can be developed with a PBL model that facilitates students with problems that are close to everyday life so that it will have an impact on pro-environmental attitudes and behaviors.

Conclusion

Based on the discussion above, (1) there are differences in students' CTS before and after being treated (2) the category of increasing students' CTS after being treated is in the high category and has a significant impact on students' pro-environmental attitudes. The PBL on electricity material has a learning stage that exposes the problem to students

with the impact of waste electricity sources that are harmful to the environment. Based on interviews, students become more open and sensitive to environmental conditions. PBL opens students' minds related to environmental problems and their impacts. Students claimed to be more challenged because they knew that natural materials have a lot of potential to replace chemicals. Students also claimed to be more aware and want to contribute positively to the environment. The average N-gain score shows 0.7239 for students' CTS which greatly facilitates students to think and carry out the role of analytical thinking, especially for environmental problems close to student life. Students contribute as agents of change with a pro-environmental attitude that arises from CTS. There is a difference in the CTS of Ahmad Dahlan University Elementary School Teacher Education students between before and after treatment indicated by the average pretest score of 38.00 while the average posttest is 87.20. The mean of the pretest-posttest difference is 44.70, which means that students' CTS between before and after the application of the PBL model have increased.

Acknowledgement

The author would like to express his gratitude to the head of the Elementary School Teacher Education Study Program at Ahmad Dahlan University, especially to the female tutor in carrying out teaching practice and research for elementary school teacher education students. Sincere thanks are also extended to all parties involved, who have provided support and assistance in this research, allowing it to be completed successfully.

References

Aisah, S., & Eka, I. 2025. Analisis keterampilan proses sains (KPS) pada mahasiswa calon guru MI/SD di Institut Ummul Quro Ai-Islami Bogor. *Pendas : Jurnal Ilmiah Pendidikan Dasar*, 10(1):341–357. https://doi.org/10.23969/jp.v10i01

Andarias, S.H., Fitriani, B., Mitrakasih, L.O., Ferriyanti., & Sapna, P. 2025. Pelatihan penggunaan peralatan laboratorium untuk meningkatkan pemahaman dan keterampilan mahasiswa pendidikan guru sekolah dasar. *Room of Civil Society Development*, 4(2):257–267. https://doi.org/10.59110/rcsd.472

Aprina, E.A., Erma, F., & Andi, S. 2024. Penerapan model problem based learning untuk mengembangkan keterampilan berpikir kritis pada muatan IPA sekolah dasar. *Didaktika: Jurnal Kependidikan*, 13(1):981–990. https://doi.org/10.58230/27454312.496

Bürgener, L., & Barth, M. 2018. Sustainability competencies in teacher education. Making teacher education count in everyday school practice. *Journal of Clean*, 174(821e826): 1-10. https://doi.org/10.1108/IJSHE-10-2018-0183

Cai, P. 2021. Thinking skills development in mobile learning: the case of elementary school students studying environmental studies. *Thinking Skills and Creativity*, 42(100922): 1-10. https://doi.org/10.1016/j.tsc.2021.100922

Creswell, J.W., & Creswell, J.D. 2018. Research and design qualitative, quantitative, and mixed methods approaches. In Thousand Oaks California.

Dewanda, K.J., Ida, A.M.R.D., & Laila, H. 2020. Penerapan model pembelajaran PBL terintegrasi pendekatan TaRL dalam meningkatkan hasil belajar matematika. *Jurnal*

Pendidikan, Sains, Geologi, dan Geofisika, 7(1):831–837. https://doi.org/10.29303/goescienceed.v6i2.765

Dwijayanti, A.A., & Wayan, W. 2024. Problem based learning using open ended questions improves students' mathematical critical thinking ability in elementary schools. *Thinking Skills and Creativity Journal*, 7(1):167–174. https://doi.org/10.23887/tscj.v7i1.78033

Djamas, D., Tinedi, V., & Yohandri. 2021. Development of interactive multimedia learning materials for improving critical thinking skills. *Hershey: IGI Global*. https://doi.org/10.4018/978-1-7998-3022-1.ch026

Facione, P.A. 2011. Critical thinking : what it is and why it counts:*13*. Pearson Education.https://www.law.uh.edu/blakely/advocacysurvey/Critical%20Thinking%20Skills.pdf

Gea, N., Isihati, N., Lasmi, Z., Mentari, T., & Arozatulo, B. 2025. Dampak artificial intelligence (AI) dalam pendidikan: peluang dan tantangan di era digital. *Jurnal Education and Development Institut Pendidikan Tapanuli Selatan*, 13(1):637–644. https://doi.org/10.37081/ed.v13i1.6680

Gomez, C.V.G. 2024. Teaching entrepreneurship in higher education: The application active based learning activities to environmental protection. *Thinking Skills and Creativity*, 52(101502): 1-11. https://doi.org/10.1016/j.tsc.2024.101502

Hardianty, S., Purnama, S., Nursakiah, & Sulastri. 2024. Peningkatan keterampilan berpikir kritis peserta didik dengan menggunakan model pembelajaran inkuiri pada kelas IV SD Telkom Makassar. *CJPE: Cokroaminoto Journal of Primary Education*, 7(2):507–516. https://doi.org/10.30605/cjpe.722024.4716

Hasmiza. 2025. Model kurikulum pendidikan islam di era digital: mengoptimalkan teknologi untuk pembelajaran yang inovatif. *Research and Development Journal of Education*, 11(1):164-170. https://doi.org/http://dx.doi.org/10.30998/rdje.v11i1.28068

Hasnunidah, N. 2017. *Metodologi penelitian pendidikan*. Yogyakarta: Media academia

Honebein, P.C. 1996. Seven goals for the design of constructivist learning environments. Constructivist learning environments: case studies in instructional design. Retrieved 16 June 2024 from https://www.semanticscholar.org/paper/Seven-goals-for-the-design-of-constructivist-Honebein/ed9339452692b7ea41d184f007bfabc485474b7a

Hotimah, H. 2020. Penerapan metode pembelajaran problem based learning dalam meningkatkan kemampuan bercerita pada siswa Sekolah Dasar. *Jurnal Edukasi*, 7(3):5-11. https://doi.org/10.19184/jukasi.v7i3.21599

Humam, M.S., & Muhammad, H. 2025. Strategi pembelajaran aktif dalam meningkatkan keterampilan kritikal siswa di era modern. *Jurnal Bintang Pendidikan Indonesia*, 3(1):262–281. https://doi.org/10.55606/jubpi.v3i1.3592

Isnaini, M., Muhammad, W.A., Al, H., & Ilham, A. 2025. Teknik analisis data uji normalitas. *J-Ceki: Jurnal Cendekia Ilmiah*, 4(2):1377–1384. https://doi.org/10.56799/jceki.v4i2.7007

Kasmadi, F.S., & Uce, L. 2025. Pembelajaran berbasis proyek : solusi inovatif untuk pembelajaran efektif mata kuliah farmasetika. *Science : Jurnal Inovasi Pendidikan Matematika dan IPA*, 5(1):194–203. https://doi.org/10.51878/science.v5i1.4502

Kurniawan, I., Erik, A.I., & Ika, A.P. 2024. Pengaruh model problem based learning berbantuan media rimba terhadap kemampuan berpikir kritis siswa sekolah dasar. *Jurnal Basicedu,* 8(4):2647-2659. https://doi.org/10.31004/basicedu.v8i4.8178

Mulyati. 2024. Pengantar spss: teori, implementasi dan interpretasi. Padang: Cv. Gita Lentera.

Muslimin, T.P., & Andi, A.B.F. 2024. Kompetensi dan kesiapan guru sekolah dasar terhadap tantangan pendidikan di era society 5.0. *CJPE: Cokroaminoto Juornal of Primary Education*, 7(1):55-72. https://sinta.kemdikbud.go.id/journals/profile/7800#!

Nasution, L.M. 2019. Dasar statistika. *Al-Fikru: Jurnal Ilmiah*, 13(2):141–145. https://doi.org/10.51672/alfikru.v13i2.18

Novita, R., Cirtye, L., Andi, S.J., Atika, N., Efrina, J., & Heru, W**.** 2024. Implementasi metode pembelajaran berbasis proyek untuk meningkatkan kemampuan berpikir kritis mahasiswa. *Indonesian Research Journal on Education*, 4(4):3166–3172. https://doi.org/10.31004/irje.v4i4.1100

Pertiwi, F.A., Reza, H.L., & Mohammad, A. 2023. Problem based learning untuk meningkatkan keterampilan berpikir kritis: meta analisis. *JSE: Jurnal Sharia Economica*, 2(1):42–49. https://doi.org/10.46773/jse.v2i1.559

Rahman, A.A. 2020. Hubungan antara orientasi nilai (value orientation) dengan perilaku pro lingkungan (pro environmental behavior) siswa. *IJEEM -Indonesian Journal of Environmental Education and Management*, 5(2):152–164. https://doi.org/10.21009/ijeem.052.04

Rakhmawati, D., Reksa A.P., Nana, H., & Ana, N. 2024. Peran guru dalam mengoptimalkan model-model pembelajaran berorientasi pada keterampilan abad 21. *Jurnal Pendidikan Dasar Flobamorata*, 5(1):75–85. https://doi.org/10.51494/jpdf.v5i1.1352

Ramadhani, S.P., Firda, M.P., Zefi, H.F., & Bambang, E.S. 2024. Studi literatur: efektivitas model problem based learning (PBL) untuk meningkatkan kemampuan pemecahan masalah matematis terhadap pembelajaran matematika. *Prima*, 7:724–730. https://proceeding.unnes.ac.id/prisma/issue/view/58

Sholeh, A., Mochamad, N., & Andi, K. 2024. Analisis pembelajaran berbasis masalah dalam persepektif filsafat progresivisme. *Pendas : Jurnal Ilmiah Pendidikan Dasar*, 9(4):319–329. https://doi.org/10.23969/jp.v9i04.21881

Solihin, F.K & Mateh, I. 2024. Penerapan model pembelajaran problem based learning (Pbl) untuk meningkatkan minat dan berpikir kritis mahasiswa pada mata kuliah model pembelajaran ips semester Vi Program Studi PGSD. *Pedagogik*, XII(2):123–130. https://doi.org/10.33558/pedagogik.v12i2.9808

Sugiartini, N.N.A., Gunamantha, I.M., & Ardana, I.M. 2024. Model pembelajaran project based learning terhadap pemahaman konsep IPA dan sikap ilmiah siswa kelas IV SD. *Jurnal Ilmiah Pendidikan Profesi Guru*, 7(2):293–305. https://doi.org/10.23887/jippg.v7i2.73267

Sugiyono. 2019. Metode penelitian kuantitatif, kualitatif, dan R&D. Bandung: Alfabeta.

Syafar, D., Firman, S., & Muchamad, A.K. 2024. Menentukan dan mengukur standar mutu pendidikan (studi di Sekolah Dasar Negeri Kota Gorontalo). *Tadbir:Jurnal Manajemen Pendidikan Islam*, 12(1):106–119. https://doi.org/10.30603/tjmpi.v12i1.4693

Syafitri, R. & Kadarisman, Y. 2024. Hubungan pengetahuan dan etika lingkungan terhadap perilaku pro lingkungan pada mahasiswa anggota organisasi mahasiswa pecinta alam di Universitas Riau. *Jurnal Paradigma: Journal of Sociology Research and Education*, 5(1):318–335. https://doi.org/https://doi.org/10.53682/jpjsre.v5i1.8992

Tukan, M.B., Faderina, K., Maria, A.U.L., Monika, L., Maria, I.J., & Claudia, S. 2025. Pelatihan praktikum kimia berbasis kontekstual di SMAN 3 Kupang Timur. *JIPMAS: Jurnal Visi Pengabdian Kepada Masyarakat*, 6(1):95–104. https://doi.org/10.51622/pengabdian.v6i1.2595

Uliyanti, F., Sekar, D.A., & Fina, F. 2024. Peningkatan kemampuan berpikir kritis siswa melalui model problem based learning pada pembelajaran IPAS kelas V SD berbantuan media augmented reality. *Nusra: Jurnal Penelitian dan Ilmu Pendidikan*, 5(3):1468–1478. https://doi.org/10.55681/nusra.v5i3.3164