



## The influence of problem-based learning on student's critical thinking skills in chemical equilibrium

Fatih Enzati Sayoga Wardana <sup>✉</sup> & Nurfinaz Aznam

Department of Chemistry Education, Universitas Negeri Yogyakarta, Indonesia

### Article Info

Received: Dec 1<sup>st</sup>, 2025

Revised: Dec 20<sup>th</sup>, 2025

Accepted: Dec 30<sup>th</sup>, 2025

*Keywords:*

*Problem-Based Learning,  
critical thinking skills,  
chemical equilibrium*

### Abstract

This study aims to analyze the influence of the PBL learning model on students' critical thinking skills, as well as to analyze changes in students' critical thinking skills before and after the implementation of PBL on reaction equilibrium material. The research method used was a quasi-experiment with a pretest-posttest control group design. The research sample consisted of an experimental class and a control class with a total of 72 students. The data were analyzed using an independent sample t-test to determine the effect of PBL learning on students' critical thinking skills, while a paired sample t-test was used to determine the changes before and after the treatment. The results showed that PBL learning significantly improved students' critical thinking skills. In addition, there was an increase in critical thinking skills in students before and after participating in PBL learning. Thus, the application of PBL learning significantly influenced and improved the critical thinking skills of high school students on the subject of chemical equilibrium.

© 2025 Universitas Negeri Yogyakarta

<sup>✉</sup> Corresponding Author:

Fatih Enzati Sayoga Wardana

[fatihenzati.2020@student.uny.ac.id](mailto:fatihenzati.2020@student.uny.ac.id)

e-ISSN 2581-2645

## INTRODUCTION

Education is a strategic process in shaping quality human resources, serving not only as a means of knowledge transfer, but also as a vehicle for fostering values, skills, and character in students so that they are ready to face global challenges (Susanto, 2019). In the 21st century, education is required to produce human resources with four basic skills, namely critical thinking, creative thinking, collaboration, and communication as preparation for adapting to the developments of the times (Hidayati & Sinaga, 2019). Critical thinking is one of the main skills that needs to be possessed because it enables a person to identify, analyze, and evaluate a problem based on logical and rational thinking (Thornhill-Miller et al, 2023). The urgency of this skill is also reflected in national policy, where the Merdeka Curriculum places the development of critical thinking skills as one of the profiles of Pancasila students, who are expected to be adaptive, creative, and globally competitive (Kemendikbudristek, 2022).

Based on the results of the 2022 Programme for International Student Assessment (PISA) survey released by the OECD, Indonesia still shows low achievements in reading literacy, mathematics, and science, which are closely related to critical thinking skills. Indonesia ranks 69th out of 81 countries with a reading score of 371, mathematics score of 366, and science score of 383, far below the OECD average of 480–490 (OECD, 2023). When compared to other ASEAN countries, Indonesia lags significantly behind. For example, Singapore ranks first in the world with an average score above 560, while Vietnam,

Malaysia, and Thailand also score higher than Indonesia (OECD, 2023). These low scores are consistent with various national studies indicating that Indonesian students' critical thinking skills remain weak. Research by Benyamin et al (2021) found that the majority of high school students in Indonesia have difficulty identifying arguments, constructing logical reasoning, and relating concepts to real contexts. Similarly, a study by Mayasari et al (2016) confirmed that the level of critical thinking skills among science students is in the low to moderate category, with the main obstacle being the dominance of teacher-centered learning.

Learning activities are unable to accommodate students' critical thinking skills. Teachers have not paid sufficient attention to broader areas, focusing instead solely on cognitive aspects, so that students do not have enough space to develop higher-level thinking skills (Tasrif, 2022). Teachers play a very significant role in determining success in the learning process (Silaloho et al, 2020). Learning activities that are not oriented towards improving student abilities can lead to weak student competencies (Saragih, 2020). Teachers act as facilitators during the learning process by guiding students' exploration, thereby stimulating their higher-order thinking skills (Andriani et al, 2019).

Chemistry is often considered a difficult subject for students to understand because it requires understanding at three different levels of representation, namely macroscopic, microscopic, and symbolic, which must be linked together in the learning process (Ye et al, 2018). This difficulty arises because students must be able to understand abstract concepts, such as the dynamic nature of equilibrium, Le Chatelier's principle, and their relationship to real-life phenomena, which cannot be observed directly (Kaya & Kaya, 2025). Research shows that learning chemical equilibrium requires students to analyze the relationship between factors of system change and their consequences on equilibrium shifts, thereby stimulating higher-order thinking skills such as analysis, evaluation, and logical reasoning (Simorangkir & Raidil, 2025). Another study conducted by Pratama et al (2025) confirms that critical thinking skills are essential in learning chemical equilibrium material to optimize students' chemistry literacy achievements.

Various challenges in the world of education require a learning model that not only focuses on mastering material, but also encourages students to develop critical thinking skills in depth. One solution offered is the application of Problem Based Learning (PBL), because this model places students at the center of learning through contextual problem solving that is close to real life. Thus, students are encouraged to analyze, evaluate, and construct arguments based on the information obtained.

PBL can significantly improve critical thinking skills because it requires students to actively ask questions, collaborate, and seek alternative solutions to a problem (Barakah & Kurniawati, 2025). In addition, PBL fosters independent learning and integrates interdisciplinary knowledge, so that students not only understand concepts theoretically but can also apply them in real life. This is in line with findings that the application of PBL at various levels of education has a significant positive impact on students' critical thinking skills (Junaidi, 2020). With these advantages, PBL can be a logical and rational learning strategy in facing the demands of 21st-century education, which emphasizes higher-order thinking skills.

## **METHOD**

This study is a quantitative study with a quasi-experimental design using a pretest-posttest control group design. This research was conducted in the odd semester of the 2025/2026 academic year at a high school in Sleman Regency. The population of this study was all 12th grade MIPA (Phase F) students at the high school who took chemistry, totaling 144 students, and 72 students from two classes were selected as samples using cluster random sampling. There were 36 students in the experimental class and 36 students in the control class. There were two classes in this study, namely the experimental class learning chemical equilibrium through the PBL learning model and the control class learning equilibrium through the direct instruction learning model. The collection technique used in this study was a test technique to measure critical thinking skills.

The test instrument for measuring students' critical thinking skills adapts several critical thinking indicators according to experts who have researched aspects and indicators that can be formulated as

critical thinking parameters. In this test instrument, there are five opinions from research by several experts that are used and formulated into five main indicators for measuring students' critical thinking skills. The formulation of critical thinking skill indicators used in this test instrument is presented in Table 1.

**Table 1.** Basis for adaptation of critical thinking ability indicators

<b>Expert</b>	<b>Expert Opinions</b>
Faccione, P. A (2015)	Critical thinking is the ability to interpret, <b>analyze, evaluate, draw conclusions</b> , provide explanations, and regulate oneself.
Halpern (2014)	Critical thinking is not only about <b>understanding arguments</b> but also <b>involves analysis, evaluation</b> , and the application of logical thinking in real-life situations.
Robert H Ennis (2018)	Critical thinking skills include accurately <b>identifying problems</b> or questions, <b>analyzing arguments, evaluating sources of information, drawing logical conclusions</b> , and evaluating and considering issues.
Watson & Glaser (2008)	Critical thinking is the <b>ability to identify problems</b> , determine the truth by <b>evaluating arguments</b> , and <b>draw conclusions</b> based on formulated solutions.
Dwyer, Hogan, Stewart (2014)	Critical thinking is the <b>ability to make assumptions, evaluate arguments, and draw conclusions</b> .

Based on Table 1, the researchers formulated the indicators in the critical thinking ability test instrument into five main indicators, namely (1) identifying problems, (2) analyzing problems, (3) reconstructing problems, (4) evaluating problems, and (5) drawing conclusions.

The research instrument used was a critical thinking test consisting of 10 essay questions. The learning tools used were Teaching Modules and Student Worksheets that were adapted to the learning model syntax and had been validated theoretically through expert judgement. The critical thinking test instrument was validated theoretically and empirically using the Pearson Correlation Product Moment test, and its reliability was tested using the Cronbach's Alpha test method, with the test results showing a Cronbach's Alpha value of 0.702 with a high reliability category. The data collected through the test instruments were pretest and posttest scores. The data were analyzed using the Independent sample t-test and paired sample t-test to determine the effect of PBL implementation and the improvement before and after PBL implementation on students' critical thinking skills.

## FINDINGS AND DISCUSSION

### Findings

The results of the pretest, posttest, and descriptive statistical measurements in the experimental and control classes in this study are presented in Table 2.

**Table 2.** Descriptive Statistics Research Results

<b>Descriptive</b>	<b>Pretest Score</b>		<b>Posttest Score</b>	
	<b>Experimental</b>	<b>Control</b>	<b>Experimental</b>	<b>Control</b>
Sample size	32	30	32	30
Highest Score	42,31	60,26	82,69	64,74
Lowest Score	16,03	16,03	41,03	35,26
Average Score	31,11	36,44	58,71	48,06
Standard Deviation	7,15	10,84	9,41	6,73

Based on Table 2, it can be analyzed that before the implementation of the learning model, the average critical thinking ability score of the experimental class was 31.11 and that of the control class was 36.44. Meanwhile, after learning with the PBL learning model in the experimental class and direct

instruction in the control class, there was an increase in the average critical thinking ability score of the students. The average score after implementing the learning model in the experimental class was 58.71 and in the control class was 48.06. In addition to being determined from the pretest-posttest scores, the increase in students' critical thinking skills can be analyzed using the n-gain calculation presented in Table 3.

**Table 3.** Avarage N-gain score

Parameter	Experimental Class		Control Class	
	n-gain	Category	n-gain	Category
Critical Thinking Skill Score	0,40	Moderate	0,17	Low

Based on Table 3, the average n-gain value in the experimental class was greater than that in the control class, namely 0.40 in the moderate n-gain category, while the average n-gain value in the control class was 0.17 in the low category. This indicates a significant difference based on the pretest and posttest scores of the two classes calculated using n-gain.

Hypothesis testing begins with prerequisite tests consisting of normality and homogeneity tests. Prerequisite tests are data analysis tests to determine the type of test to be performed, which are divided into two criteria: parametric statistics and non-parametric statistics. The normality test is conducted to determine the distribution of pretest, posttest, and n-gain values in the experimental and control classes compared to the normal curve. The normality test in this study uses the Shapiro-Wilk statistical analysis technique because the number of samples in the test group is  $\leq 50$  samples. Table 4 presents the results of the normality test.

**Table 4.** The Result of Normality Test

Data	Class	Shapiro-Wilk		Conclusion
		df	Significance	
Pretest	Experimental	32	0,217	The data are normally distributed
	Control	30	0,553	
Posttest	Experimental	32	0,579	
	Control	30	0,653	
N-gain	Experimental	32	0,446	
	Control	30	0,078	

In Table 4, the results of the normality test of the overall research data obtained a significance value greater than the significance level (0.05), so it can be concluded that the research data is normally distributed. Furthermore, a homogeneity test was conducted to determine whether there were differences in the variance of the data to be used in the hypothesis test. The homogeneity test was performed using the Levene Statistic Test of Homogeneity Variance. The results of the data homogeneity test are presented in Table 5.

**Table 5.** The Result of Homogeneity Test

Parameter	Data	Levene Test		Conclusion
		df	Significance	
Based on Mean	N-gain	60	0,163	The data is homogeneous
	Pretest-Posttest Score of Experimental Class	62	0,349	

Based on Table 5, the test results show that the significance value for the homogeneity test is greater than the significance level of 0.05. Thus, it can be concluded that the research data is homogeneous, meaning that there is no difference in data variance between the n-gain and pretest-posttest data of the experimental class. Both prerequisite tests have been statistically fulfilled, so that hypothesis testing can be continued using parametric statistical tests. The hypothesis tests used are the independent sample t-test and paired sample t-test.

The first research hypothesis test, namely the independent sample t-test, aims to analyze the significant difference in critical thinking skills between students in the experimental class and the control class. This test uses n-gain score data from the experimental class and the control class. The results of the independent sample t-test can be seen in Table 6.

**Table 6.** The Result of Independent Sample T-test

Parameter	Data	Sig. (2-tailed)	Conclusion
Equal variances assumed	N-gain	0,000	There is a significant difference

The independent sample t-test yielded a significance value of 0.000 ( $\leq 0.05$ ), leading to the conclusion that there was a significant difference in the critical thinking skills of students who applied the PBL learning model and those who applied the direct instruction learning model. The parameters in this test assume that there is no difference in variance in the test group data or that the data must be homogeneous.

The second research hypothesis test, namely the paired sample t-test, aimed to determine whether there was a significant increase in students' critical thinking skills before and after participating in learning by applying the PBL learning model. This test used pretest and posttest data from the experimental class. The results of the paired sample t-test can be seen in Table 7.

**Table 7.** The Result of Paired Sample T-test

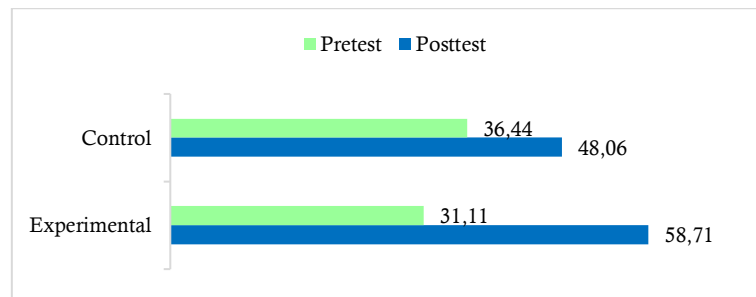
Data	Sig. (2-tailed)	Conclusion
Pretest-Posttest Score of Experimental Class	0,000	There is a significant difference

In Table 7, the significance value for the paired sample t-test result was 0.000 ( $\leq 0.05$ ), so it can be concluded that there was a significant difference in the pretest and posttest scores for critical thinking skills among students in the experimental class. Thus, there was a significant increase in students' critical thinking skills after participating in learning using the PBL learning model.

## Discussion

This study found that the critical thinking skills of students in the experimental class who used the PBL learning model were better than those of students in the control class who used the direct instruction learning model. The results of the independent sample t-test showed that there was a significant difference in critical thinking skills between the experimental and control classes, with a significance value of 0.000 ( $\leq 0.05$ ). This indicates that the two classes had statistically different mean n-gain scores. In addition to the n-gain scores, there were other statistical differences between the two classes based on their pretest and posttest scores.

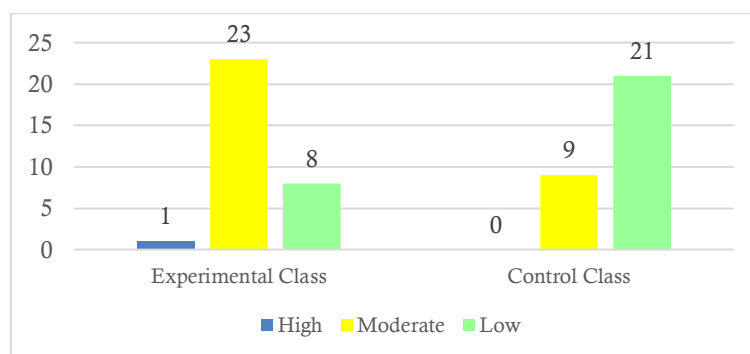
The increase in critical thinking skills can also be analyzed statistically using the average pretest and posttest scores in the experimental and control classes. A comparison of the two scores for both classes is presented in Figure 1.



**Figure 1.** Average of Pretest and Posttest Score

Based on Figure 1, there is a statistical difference between the pretest and posttest scores in both classes. However, both show an increase in critical thinking skills compared to before receiving treatment by applying the learning model. The critical thinking ability scores in the experimental class increased by 27.6, while those in the control class increased by 11.62. The difference in the average increase in critical thinking ability scores in both classes was influenced by the difference in the learning models applied. The increase in the average critical thinking ability score was higher in the experimental class with the application of the PBL learning model. This indicates that the PBL learning model is suitable for stimulating the development of students' critical thinking skills. In the PBL learning model, the syntax or activities carried out by students emphasize the problem-solving process. The problem-solving process that occurs must go through several stages, including identification, analysis, reconstruction, evaluation, and drawing conclusions from the problem. These activities have a direct contribution to the thinking skills of students. Meanwhile, in the control class, there was still an increase in the average critical thinking skills score. However, the increase that occurred was not significant compared to the increase that occurred in the experimental class.

The difference in critical thinking skills among students can also be analyzed through the n-gain scores obtained from the experimental class and the control class. Table 2 shows that the average n-gain score obtained by the experimental class was 0.40, while that of the control class was 0.17. The n-gain score of the experimental class was in the moderate category, while that of the control class was in the low category. In more detail, the average n-gain score for each class can be analyzed by categorizing the distribution of n-gain scores for each student. Figure 2 shows the distribution of n-gain score categories achieved by students in each class.

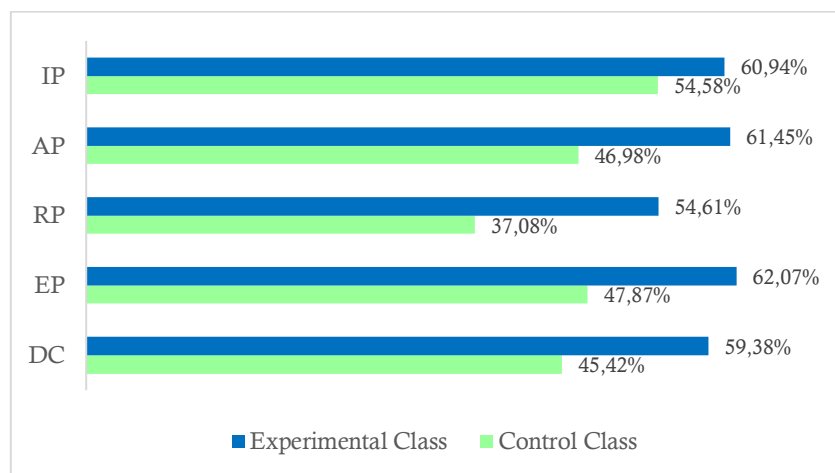


**Figure 2.** Distribution of N-gain Score Category

Based on Figure 2, the n-gain scores in the experimental class had a better distribution than those in the control class. There was one student in the experimental class who experienced a very significant increase in critical thinking skills with an n-gain score in the high category. This statistically contributed to the difference in the two average n-gain scores for the two classes. The distribution of n-gain in the experimental class was 1 student in the high category, 23 students in the medium category, and 8 students in the low category. Meanwhile, the distribution of n-gain scores in the control class was 9 students in

the medium category and 21 students in the low category. There was a significant difference between the distribution of n-gain scores in the experimental and control classes. This indicates that the application of the PBL learning model is more effective than the direct instruction learning model in improving students' critical thinking skills.

Critical thinking skills have five main indicators that have been synthesized through previous research by experts in the field of education. These indicators include the ability to identify problems (IP), analyze problems (AP), reconstruct problems (RP), evaluate problems (EP), and draw conclusions (DC). Interventions carried out in the learning process using the PBL and direct instruction learning models showed statistically significant differences in the achievement of each critical thinking indicator. The achievement of critical thinking indicators in the experimental and control classes can be observed in Figure 3.



**Figure 3.** Percentage of Achievement of Critical Thinking Ability Indicators

In Figure 3, this study shows that there are differences in achievement for each critical thinking ability indicator in the experimental and control classes. The achievement of critical thinking skills in the experimental class was as follows: problem identification (60.94%), problem analysis (61.45%), problem reconstruction (54.61%), problem evaluation (62.07%), and drawing conclusions (59.38%). The achievement of critical thinking ability indicators in the control class was problem identification (54.58%), problem analysis (46.98%), problem reconstruction (37.08%), problem evaluation (47.87%), and drawing conclusions (45.42%). The overall achievement of indicators in the experimental class was superior to that of the control class. However, there was a similar imbalance between the experimental class and the control class in that the problem reconstruction (RP) indicator had the lowest achievement percentage among the other indicators. The indicator with the highest achievement based on its percentage in the experimental class was the problem evaluation (EP) indicator, while in the control class it was the problem identification (IP) indicator. The difference in achievement between indicators in the experimental class compared to the control class was the smallest parameter in this study to reveal the difference in students' critical thinking abilities with the application of different learning models.

In the PBL and direct instruction learning models, there are clear differences in terms of the placement of student learning activities during the learning process. The PBL model places students as discoverers, researchers, and problem solvers, not just recipients of knowledge (Utami et al, 2017). The achievement of critical thinking indicators with the PBL model is in line with the principles of constructivism, where students build knowledge based on experience, namely the problem-solving process (Maulana et al, 2021). In addition, there is a collaborative process carried out in the PBL model that trains students in the ability to reconstruct and analyze problems. Collaboration in the PBL model is carried out through group discussions. Group discussion activities strengthen student interaction in

comparing perspectives, constructing arguments, and evaluating the knowledge gained (Sulaiman & Azizah, 2020). In addition, the PBL model also emphasizes rationality or formal logic. This ability is related to skepticism, where there is consideration in accepting an argument based on logical and rational thinking (Atabaki et al, 2015).

## CONCLUSION

Based on the results of the research and discussion, it can be concluded that there is a significant effect of the application of the Problem-Based Learning model on the critical thinking skills of students compared to students who apply the direct instruction learning model in chemistry equilibrium material. In addition, there is a significant increase in the critical thinking skills of students after participating in learning that applies the Problem-Based Learning model. The influence of the PBL learning model needs to be comprehensively applied to other materials in chemistry learning so that students' higher-order thinking skills can be maximized. The application of the PBL learning model can be varied with other models or approaches to reveal students' potential and should be carried out in the long term and continuously.

## REFERENCES

- Andriani, M., Muhali & Dewi, C. A. (2019) Pengembangan Modul Kimia Berbasis Kontekstual Untuk Membangun Pemahaman Konsep Siswa Pada Materi Asam Basa. *Hydrogen: Jurnal Kependidikan Kimia*, 7(1), 25-35. <http://dx.doi.org/10.33394/hjkk.v7i1.1653>
- Atabaki, A. M. S., Keshtiaray, N & Yarmohammadian, M. H. (2015). Scrutiny of Critical Thinking Concept. *International Education Studies*, 8(3), 93-102. <http://dx.doi.org/10.5539/ies.v8n3p93>
- Barkah, F. A., & Kurniawati, D. (2025). Efektivitas Modul Berbasis PBL Terintegrasi Stem Materi Keseimbangan Kimia Terhadap Hasil Belajar Siswa. *Biocephy: Journal of Science Education*, 5(1), 188-194. <https://doi.org/10.52562/biocephy.v5i1.1597>
- Benyamin, B., Qohar, A., & Sulandra, I. M. (2021). Analisis Kemampuan Berpikir Kritis Siswa SMA Kelas X Dalam Memecahkan Masalah SPLTV. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, 5(2), 909-922. <https://doi.org/10.31004/cendekia.v5i2.574>
- Hidayati, Y. & Sinaga, P. (2019). The Profile of Critical Thinking Skills Students on Science Learning. *Journal of Physics: Conference Series*, 1402(4), 1-5. <https://dx.doi.org/10.1088/1742-6596/1402/4/044075>
- Junaidi, J. (2020), Implementasi Model Pembelajaran Problem-Based Learning Dalam Meningkatkan Sikap Berpikir Kritis. *Jurnal Pendidikan dan Pembelajaran Ilmu Sosial*, 9(1), 25-35. <https://dx.doi.org/10.20527/jurnalsocius.v9i1.7767>
- Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia. (2022). Kurikulum Merdeka: Profil Pelajar Pancasila. Jakarta: Kemendikbudristek. <https://kurikulum.kemdikbud.go.id/profil-pelajar-pancasila/>
- ECD. (2023). PISA 2022 results (volume III): The state of learning and equity in education. Paris: OECD Publishing.
- Thornhill-Miller, B., Camarda, A., Mercier, M., Burkhardt, J.-M., Morisseau, T., Bourgeois-Bougrine, S., Vinchon, F., El Hayek, S., Augereau-Landais, M., Mourey, F., Feybesse, C., Sundquist, D., & Lubart, T. (2023). Creativity, Critical Thinking, Communication, and Collaboration: Assessment, Certification, and Promotion of 21st Century Skills for the Future of Work and Education. *Journal of Intelligence*, 11(3), 54. <https://doi.org/10.3390/jintelligence11030054>
- Maulana, M. P., Sholikin, F., & Dewi, K. (2021). Penerapan Model Problem Based Learning (Pbl) Dalam Meningkatkan Aktivitas Dan Hasil Belajar Peserta Didik Pada Materi Keseimbangan Kimia Sman 3 Kota Bengkulu. *Jurnal Zarah*, 9(2), 75-82. <https://doi.org/10.31629/zarah.v9i2.3110>
- Mastul, A. R. H. (2024). The Crucial Role of Teachers in Fostering Creativity, Critical Thinking, and Motivation in Students. *Jurnal Praktik Baik Pembelajaran Sekolah Dan Pesantren*, 3(02), 54-59. <https://doi.org/10.56741/pbpsp.v3i02.563>
- Mayasari, T., Kadarohman, A., Rusdiana, D., & Kaniawati, I. (2016). Apakah model pembelajaran problem based learning dan project based learning mampu melatih keterampilan abad 21?

- Jurnal Pendidikan Fisika Dan Keilmuan (JPFK), 2(1), 48-55.  
<http://dx.doi.org/10.25273/jpfk.v2i1.24>
- Pratama, F. I., Rohaeti, E., & Laksono, E. W. (2024). Students' Chemical Literacy Profile On Chemical Equilibrium Material: Case Of Coral Reefs Topic. *Jurnal Eduscience*, 11(3), 623-635.  
<https://doi.org/10.36987/jes.v11i3.6451>
- Qurniati, D., Lestari, A. F., & Ningrat, H. K. (2020). Pengembangan Modul Kimia Sma Berbasis Problem Based Learning (PBL) Pada Materi Kelarutan Dan Tetapan Hasil Kali Kelarutan. *Spin Jurnal Kimia & Pendidikan Kimia*, 2(1), 1-12. <https://doi.org/10.20414/spin.v2i1.2021>.
- Saragih, S. (2020). Problem-based learning as an effort to improve students' critical thinking ability. *International Journal of Instruction*, 13(2), 457-474. <https://doi.org/10.29333/iji.2020.13232a>
- Sihaloho, M., Hadis. S.S., Kilo, A.K., & Kilo A. L. (2021). Diagnosa miskonsepsi siswa SMA Negeri 1 Telaga Gorontalo pada materi termokimia. *Jambura Journal of Educational Chemistry*, 3(1), 7-13.
- Simorangkir, A., & Raidil, M. (2025). High School Chemistry Learning: The Correlation Between Student's Critical Thinking and Self-Efficacy. *Jurnal Pendidikan Matematika dan Sains*. 13(Special\_issues), 143-153. [https://doi.org/10.21831/jpms.v13iSpecial\\_issue.88280](https://doi.org/10.21831/jpms.v13iSpecial_issue.88280)
- Sulaiman, A. & Azizah, S. (2020). Problem-Based Learning Untuk Meningkatkan Kemampuan Berpikir Kritis di Indonesia: Sebuah Tinjauan Literatur Sistematis. *Jurnal Pedagogik*, 7(1), 107-152.  
<https://doi.org/10.33650/pjp.v7i1.792>
- Susanto, A. (2019). *Teori Belajar dan Pembelajaran di Sekolah Dasar (Edisi Kedua)*, Jakarta: Prenadamedia Group.
- Tasrif, T. (2022). Higher Order Thinking Skills (HOTS) dalam pembelajaran social studies di sekolah menengah atas. *Jurnal Pembangunan Pendidikan: Fondasi dan Aplikasi*, 10(1), 50-61.  
<https://doi.org/10.21831/jppfa.v10i1.29490>
- Windarti, C. O. & Yanti, F. A. (2021). Penerapan Model Problem Based Learning Untuk Meningkatkan Keterampilan Berpikir Kritis Peserta Didik. *Jurnal Pendidikan Sains dan Matematika*, 9(1), 61-70.  
<https://doi.org/10.23971/eds.v9i1.2716>
- Ye, J., Lu, S., & Bi, H. (2019). The Effects Of Microcomputer-Based Laboratories On Students Macro, Micro, And Symbolic Representations When Learning About Net Ionic Reactions. *Journal Chem. Educ. Res. Pract.*, 20(1), 288-301. <http://dx.doi.org/10.1039/C8RP00165K>