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The Impact of Problem-Based Learning (PBL) Module on Critical Thinking Skills on Electrolyte and Nonelectrolyte Solutions

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Abstract
This research aims to determine the impact of using the Problem-Based Learning (PBL) module on students' critical thinking skills on the material of electrolyte and non-electrolyte solutions. This research uses a quasi-experimental method with a Nonequivalent Control Group Design. Sampling was carried out by using cluster purposive sampling. The data collection technique used was a critical thinking skills test instrument in the form of essay questions. Hypothesis testing was carried out by using the independent sample t-test. The result showed that using PBL module on the material of electrolyte and non-electrolyte solutions has a positive impact on the critical thinking skills of students at SMA N 1 Sijunjung and SMA N 7 Sijunjung. This is proven by the results of the t-test analysis using SPSS that the significance value is 0.000 less than 0.05 with a significance level ($\alpha = 0.05$) so that H0 is rejected and H1 is accepted. This means that the use of the PBL module has an impact on students' critical thinking skills regarding the material of electrolyte and non-electrolyte solutions. The critical thinking skills of students in the experimental class who learned using the PBL module were higher than those in the control class in both schools.

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INTRODUCTION

Science is the study of nature and its surroundings, namely how to study nature logically and systematically through the process of discovery or scientific methods. Most scientific concepts are abstract and highly theoretical (Sunyono, 2015). One of the things studied in the scope of science is chemistry. Chemical material consisting of many abstract concepts or theories which makes chemistry subjects is difficult for students to understand (Gurses et al., 2015). One of the chemistry materials taught at high school level is electrolyte and nonelectrolyte solutions that contains factual, conceptual and procedural knowledge.

Chemistry learning on high schools can be delivered through various learning models. One of those recommended in the independent curriculum *(Kurikulum Merdeka*) is the Problem Based Learning (PBL) model. The Problem Based Learning (PBL) model is a learning model with a student learning approach to authentic problems so that students can build their own knowledge, develop higher skills and inquiry, make students independent and increase self-confidence (Hosnan, 2014). PBL can be applied in teaching electrolyte and nonelectrolyte solution material because this material is closely related to real-world problems that occur in everyday life. For example, catching fish in a river using an electric tool, floods that cause people to die from electric shocks and people who are electrocuted when touching electrical contacts with wet hands. These problems can be given by the teacher at the stage of student orientation to the problem. Then students formulate hypotheses and seek solutions to the problems given according to the stages or syntax in the PBL model.

PBL is a teaching methodology that aims to improve students' understanding and knowledge of certain materials by solving some given problems. PBL stimulates the active role of students collaboratively to solve problems independently (Costa et al., 2023). The PBL model emphasizes problem-solving efforts through investigations that require skills in processing information from various sources (Meutia, 2021). By providing problems in learning, the students' critical thinking skills are trained to analyze and find out the solutions to these problems. Critical thinking skills are one of the 21st century skills that students must have in addition to communication, collaboration and creativity (Jufriadi et al., 2022).

PBL is an effective strategy or method because it helps students build basic skills in various domains or curricula. PBL is a teaching method that consists of utilizing real-world problems, so that students learn to think critically and improve problem-solving skills to assimilate important concepts of various disciplines (Gorghiu et al., 2015). In addition, research by (Drăghicescu et al., 2014) shows that Problem Based Learning (PBL) is a suitable strategy for science learning (Chemistry, Physics, Biology) because learning is centered on students that develop key skills by involving a proactive approach that facilitates student involvement in research, scientific investigation, problem analysis and problem solving. The PBL model provides students with the opportunity to learn solving the problems through group discussions. Furthermore, students' critical thinking skills can be measured and improved by the development of PBL-based formative assessments (Fahmi et al., 2023). PBL can improve critical thinking skills because students are asked to be able to work together to solve these problems so as to stimulate critical thinking abilities and skills (Masrinah et al., 2019).

In the learning process, one of the important components to support student success in learning is the use of properly selected teaching materials. Appropriate teaching materials can support the achievement of learning objectives or certain competencies by attracting, stimulating and motivating students to be more active in learning. One example of teaching materials is a module. The purpose of using modules is to achieve learning objectives effectively and efficiently since students can learn in their own way (Nasution, 2008). The learning outcomes of students who studied using modules on atomic structure, reaction rates and thermochemistry were better than those of students who studied without modules. By learning using colorful and illustrated modules, students can be more interested in the teaching material thereby increasing motivation in learning (Ellizar et al., 2013).

Electrolyte and non-electrolyte solution material can be delivered properly by using a module that applies the Problem Based Learning (PBL) learning model. This Problem Based Learning (PBL) model is suitable for studying electrolyte and non-electrolyte solution material because the application of this material is very closely related to everyday life problems. The module which includes the discovery of concepts by giving students everyday life problems as well as practical activities that refer to the steps of the scientific method can be used to train and improve students' critical thinking skills.

PBL-based modules are arranged according to the stages of PBL and provide information on critical thinking skills that can be developed at each stage of PBL. The stage of student orientation to the problem trains students' ability to analyze problems. The stage of organizing students to learn trains students to formulate hypotheses. The stage of guiding individual and group investigations trains students to collect various information, provide simple explanations, arguments, create definitions, prove hypotheses. The stage of developing and presenting the results of the work trains students' ability to provide further explanations and the stage of analyzing and evaluating the problem-solving process trains students to make conclusions based on facts or investigation results.

Based on the results of observations and interviews with several chemistry teachers and students of SMA N 1 Sijunjung and SMA N 7 Sijunjung, it was obtained information that some students still have difficulty in understanding the material on electrolyte and nonelectrolyte solutions. Generally, the material on electrolyte and nonelectrolyte solutions is delivered through experimental methods and group discussions according to teaching materials in the form of textbooks provided by the school and student worksheets. However, some students and teachers complained that the explanation of the material and discussion of sample questions presented in the textbook were too long so that students found it difficult to take the essence of the material. Some concepts were stated directly in the textbook, so that the process of independent concept discovery by students had not been fully implemented. In addition, the student worksheets used was not colorful so that it was less interesting for students to learn. Based on the critical thinking skills test conducted during preliminary research, the following data was obtained.

Table 1. Results of Critical Thinking Skills Test in Preliminary Research

No.	Aspects of Critical Thinking Skills according to Ennis	% Student Skills
1	Providing a simple explanation	55.56%
2	Building basic skills	55.56%
3	Concluding	86.67%
4	Making further explanation	57.78%
5	Setting strategy and tactics	60%

Based on the table 1 data, it can be concluded that of the five aspects of critical thinking according to Ennis, only the aspect of concluding (86.67%) has developed well, while the other four aspects are still below the good criteria. The percentage of students' ability in the aspect of providing a simple explanation and building basic skills is still 55.56%. This can be caused by students not being used to finding concepts independently and creating their own knowledge. Hence, they have difficulty defining a concept and determining the right and valid procedures and sources. This also has an impact on students' ability to make further explanations which is still 57.78% and setting strategy and tactics (60%) in solving a problem in learning. Thus, overall, students' critical thinking skills still need to be trained and improved. PBL steps provide opportunities for students to practice critical thinking skills. By using a Problem Based Learning (PBL) based module, it is expected that students will be able to learn independently and discover for themselves the concept of the subject matter of electrolyte and non-electrolyte solutions. Through problem analysis given at the beginning of the learning process, the students' critical thinking skills can be trained and improved.

Many previous studies have proven that the implementation of the PBL model can improve students' learning outcomes and critical thinking skills. The results of (Arni et al., 2024) study showed that the PBL model significantly improved students' learning outcomes. The active inquiry-based learning strategy contained in PBL effectively engages students and provides a deeper understanding and retention of concepts. This occurs in various student learning styles, namely visual, auditory and kinesthetic. It can be concluded that the implementation of the PBL approach encourages academic success across various learning styles.

The implementation of PBL not only supports the constructivist approach by allowing students to actively build knowledge but also encourages a collaborative learning environment that facilitates peer learning and improves problem-solving skills. In chemistry, the implementation of the PBL model can improve student learning outcomes in hydrocarbon compound materials (Karepesina & Manuhutu, 2023) and electrochemistry (Choiriyah et al., 2022). The results of (Astuti et al., 2018) research show that the use of PBL-based LKPD received a positive response from students and was effective in improving students' critical thinking skills in chemical equilibrium material. Based on this, research on the impact of Problem Based Learning (PBL) based modules on students' critical thinking skills on electrolyte and non-electrolyte solution materials needs to be conducted.

METHOD

This study uses a quasi-experimental method with a Nonequivalent Control Group Design research design. This design involves a control class and an experimental class. A quasi-experiment is research that approaches a real experiment (Sugiyono, 2015). Nonequivalent Control Group Design is a research design where the research subjects are not selected randomly to determine the experimental group and the control group (Abraham & Supriyati, 2022). This research design was chosen by considering the suggestion that the classes used as research subjects are classes taught by the same teacher and the same chemistry lesson boundaries. The population in this study were class X (ten) students of SMAN 1 Sijunjung and SMAN 7 Sijunjung which chosen samples were class X MIPA 1 and MIPA 2 students in both schools. Sampling was carried out by using cluster purposive sampling. Determination of the sample is through normality test and homogeneity test. Class X MIPA 1 is the control class and X MIPA 2 is the experimental class in both schools. In the experimental class, treatment was given in the form of learning electrolyte and nonelectrolyte solution materials using a Problem Based Learning (PBL) module, while in the control class conventional learning was carried out. After the treatment, a post-test was conducted to determine students' critical thinking skills.

The data obtained in this study is quantitative data which is the results of the critical thinking skills test of students in the experimental class and control class at SMA N 1 Sijunjung and SMA N 7 Sijunjung. The data collection technique used was a critical thinking skills test in the form of 10 essay questions containing indicators of critical thinking skills according to Ennis. The test questions were given to students after being tested for validity, reliability, difficulty index and discrimination power. The validity test of critical thinking questions was conducted using the product moment correlation formula. From the results of the question validity test data, 10 valid questions were obtained from 15 questions that were tested. Meanwhile, the reliability of the questions was analyzed using the Kuder Richedson 21 (KR - 21) formula (Sudijono, 2009). From the data processing, $r11$ = 0.79 was obtained with the criteria for the level of question reliability being high. The data analysis techniques used were normality test, homogeneity test, and hypothesis test using *independent sample t-test*. The hypothesis in this study is as follows:

H_0 : $\mu_1 = \mu_2$ (There is no impact of module use on students' critical thinking skills in the experimental and control classes)

H_1 : $\mu_1 > \mu_2$ (There is an impact of the use of modules on the critical thinking skills of students in the experimental class and control class).

Information :

μ_1 = Average score of experimental class

μ_2= Average score of control class

Decision making criteria are based on significance values. If the significance value > 0.05, then H_0 is accepted and vice versa if the significance value < 0.05, then H_0 is rejected and H_1 is accepted. The criteria for student proficiency are listed in the table 2.

Table 2. Criteria for student Critical Thinking Skills proficiency (Arikunto, 2009).

Score (%)	Criteria	Code
81 – 100	Very Good	SB
61 – 80	Good	B
41 – 60	Enough	C
21 – 40	Low	K
0 - 20	Very Low	SK

RESULTS AND DISCUSSION

To see whether the use of the module can improve students' critical thinking skills, a critical thinking skills test was conducted on students in the control class and the experimental class as the learning of the electrolyte and non-electrolyte solution material ended. The distribution of students' critical thinking skills scores are summarized in Table 3.

Table 3. Percentage of Students' Critical Thinking Skills on Electrolyte and Non-Electrolyte Solution Material

School	Class	% Critical Thinking Skills per Question									
		1	2	3	4	5	6	7	8	9	10
SMA N 1 Sijunjung	X MIPA 1 (Control)	82.58 SB	85.16 SB	73.55 B	81.29 SB	69.03 B	78.06 B	66.45 B	59.35 C	72.90 B	73.55 B
	X MIPA 2 (Experiment)	94.55 SB	85.45 SB	75.15 B	93.33 SB	90.91 SB	92.73 SB	75.15 B	68.48 B	75.15 B	75.15 B
SMA N 7 Sijunjung	X MIPA 1 (Control)	78.00 B	74.00 B	70.67 B	67.33 B	74.67 B	74.67 B	55.33 C	68.67 B	74.67 B	66.00 B
	X MIPA 2 (Experiment)	88.00 SB	86.00 SB	73.33 B	79.33 B	82.00 SB	86.67 SB	65.33 B	70.67 B	75.33 B	69.33 B

Based on Table 3, it can be seen that the critical thinking skills of students in the experimental class are higher than those in the control class in both schools. In the control class at SMA N 1 Sijunjung, the sub-indicator defining terms and considering a definition (acting by providing further explanation) is not yet included in the good category (59.35 %), but in the experimental class the sub-indicator is already included in the good category (68.48%). At SMA N 1 Sijunjung there was a significant increase in question number 5 (aspect of building basic skills) which was 69.03% in the control class and 90.91% in the experimental class. This is because the PBL steps guide students to think critically starting from the stage of student orientation to the problem to the stage of analysis and evaluation of the problem-solving process. Students are trained to learn to analyze real-world problems, formulate hypotheses, collect data and information, prove hypotheses in finding solutions to solving the problem.

Likewise in SMA N 7 Sijunjung, in the control class, there are still critical thinking sub-indicators that are not included in the good category, namely the sub-indicator of making and determining consideration results (making and determining consideration results based on background facts) with a percentage of 55.33% but in the experimental class this sub-indicator is already included in the good category (65.33%). Overall, in the experimental class in both schools, many indicators of critical thinking skills are already included in very good category while in the control class in SMA N 1 Sijunjung only 3 indicators are included in the very good category and the control class in SMA N 7 Sijunjung does not yet have any critical thinking skills indicators that are included in the very good category.

Hypothesis testing on the impact of module use on students' critical thinking skills was conducted using a t-test with the help of SPSS software. The summary of the hypothesis test results are presented in Table 4.

Table 4. Results of Hypothesis Testing of Critical Thinking Skills of Sample Class Students

School	Class	N	Mean	S	Sig.	Caption
SMA N 1 Sijunjung	Experiment	33	82.61	5,534	0.000	Reject H_0
	Control	31	74.19	8,006		
SMA N 7 Sijunjung	Experiment	30	77.60	6,044	0.000	Reject H_0
	Control	30	70.40	7,762		

Table 4 shows that in SMA N 1 Sijunjung and SMA N 7 Sijunjung, the significance value obtained is the same, namely 0.000 at a 95% confidence level with a significance level (α = 0.05). This significance value is smaller than 0.05 so that H_0 is rejected and H_1 is accepted. This means that there is an influence of the use of modules on the critical thinking skills of students in the experimental and control classes in both schools. Based on the results, the use of Problem Based Learning (PBL) based modules in chemistry learning, especially in the material on electrolyte and non-electrolyte solutions, can improve students' critical thinking skills. So it can be said that this Problem Based Learning (PBL) based module is effective for use in learning. A product is said to be effective if the results obtained from using the product are as expected (Plomp & Nieveen, 2013).

This finding is supported by some previous research. Based on Table 3, in general, the critical thinking skills of students in the experimental class in both schools were higher than those in the control class. When compared to the four sample classes, data showed that the average critical thinking skills of students in the experimental class at SMA N 7 Sijunjung were higher than the average critical thinking skills of students in the control class at SMA N 1 Sijunjung. This can be influenced by the use of Problem Based Learning (PBL) modules used in the experimental class because learning using Problem Based Learning (PBL) modules trains students to improve their critical thinking skills through the stages in the PBL model. The stages in the PBL model are able to train students' critical thinking skills (Istiani & Azizah, 2015). The use of the PBL model encourages student activity and critical thinking skills in 21st century chemistry learning activities (Imanah et al., 2023).

Furthermore, PBL is a powerful pedagogical approach, a teaching and learning system aligned to explicitly and directly teach critical thinking skills (Kek & Huijser, 2011). Problem-based learning approaches can be integrated into instructional strategy settings to encourage students' critical thinking skills (Birgili, 2015). In PBL, students are asked to find solutions to the problems they face. From the process of students finding solutions to these problems, students will be trained to think critically (Sadia, 2008). The PBL model provides opportunities for students to play an active role, build new knowledge and work together in the learning process so as to train students' critical thinking skills (Zahro & Lutfianasari, 2024). Students' critical thinking skills can be increased through the PBL models in constructivism theory approaches because raises curiosity and increases motivation so that it can develop critical thinking skills (Kusumawati et al., 2022).

Table 4 shows the results of the t-test using SPSS software which was conducted to see the effect of using the PBL module on the critical thinking skills of students in the experimental and control classes. The significance value obtained for both schools is less than 0.05 so that H_0 is rejected. These results indicate that there is an influence of the use of PBL modules on students' critical thinking skills. The critical thinking skills of students who learn using PBL modules are higher than students who learn without using modules significantly. It is because the steps of the PBL model contained in the module train students' critical thinking skills.

Some previous research are in line to this finding. Problem-based learning models can train students' critical thinking skills on electrolyte and non-electrolyte solution materials (Puspitasari & Muchlis, 2016)(Istiani & Azizah, 2015). The application of the PBL model also has a significant positive effect on critical thinking skills on the topic of buffer solutions (Marhamah et al., 2020), colloids (Agustina & Mutmainah, 2024) and improves students' critical thinking skills on compound nomenclature materials (Meutia, 2021). Learning with the PBL model is an effective way to teach chemistry so that it can improve students' critical thinking skills (Aidoo et al., 2016). Not only in Chemistry subjects, the implementation of the PBL model also improves learning outcomes and students' critical thinking skills in Physics learning for the sub-topic of static fluids (Prayogi & Asy'ari, 2013), temperature and heat matter (Yulianti & Gunawan, 2019).

CONCLUSION

Based on the results of the research and discussion, it can be concluded that learning using a *Problem Based Learning* (PBL) module on the material of electrolyte and nonelectrolyte solutions has a positive influence on the critical thinking skills of students at SMA N 1 Sijunjung and SMA N 7 Sijunjung. This is evidenced by the results of the t-test analysis using SPSS that the significance value is 0.000 less than 0.05 with a significance level (α = 0.05) so that H_0 is rejected and H_1 is accepted. This means that there is an influence of the use of the PBL module on the critical thinking skills of students on the material of electrolyte and nonelectrolyte solutions in both schools.

BIBLIOGRAPHY

Abraham, I., & Supriyati, Y. (2022). Desain Kuasi Eksperimen Dalam Pendidikan: Literatur Review. *Jurnal Ilmiah Mandala Education*, *8*(3), 2476–2482. https://doi.org/10.58258/jime.v8i3.3800

Agustina, S., & Mutmainah, P. A. (2024). Implementasi Model Problem Based Learning (Pbl) Berbasis Kearifan Lokal untuk Meningkatkan Keterampilan Berpikir Kritis pada Materi Koloid Kelas XI SMAN 3 Kota Bima. *Jurnal Redoks: Jurnal Pendidikan Kimia Dan Ilmu Kimia*, *7*(2), 58–64.

Aidoo, B., Boateng, S. K., Kissi, P. S., & Ofori, I. (2016). Effect of Problem-Based Learning on Students' Achievement in Chemistry. *Journal of Education and Practice*, *7*(33), 103–108.

Arikunto, S. (2009). *Manajemen Penelitian*. Rineka Cipta.

Arni, K. J., Kosim, & Verawati, N. N. S. P. (2024). The Effect of Problem-Based Learning Model on Students' Learning Outcomes Viewed from Learning Styles. *Hydrogen : Jurnal Kependidikan Kimia*, *12*(2), 402–412. https://doi.org/https://doi.org/10.33394/hjkk. v12i2.11788

Astuti, S., Danial, M., & Anwar, M. (2018). Pengembangan LKPD Berbasis PBL (Problem Based Learning) untuk Meningkatkan Keterampilan Berpikir Kritis Peserta Didik pada Materi Kesetimbangan Kimia. *Chemistry Education Review (CER)*, *1*(2), 90–114.

Birgili, B. (2015). Creative and Critical Thinking Skills in Problem-based Learning Environments. *Journal of Gifted Education and Creativity*, *2*(2), 71–80.

Choiriyah, I. N., Masriani, Rasmawan, R., Erlina, & Sartika, R. P. (2022). Pengaruh Model Problem Based Learning (PBL) terhadap Hasil Belajar Siswa pada Materi Elektrokimia. *Hydrogen : Jurnal Kependidikan Kimia*, *10*(2), 162–173.

http://ojs.undikma.ac.id/index.php/hydrogen/index

Costa, A. M., Escaja, N., Fité, C., González, M., Madurga, S., & Fuguet, E. (2023). Problem-Based Learning in Graduate and Undergraduate Chemistry Courses: Face-to-Face and Online Experiences. *Journal of Chemical Education*, *100*(2), 597–606. https://doi.org/10.1021/ACS.JCHEMED.2C00741/ASSET/IMAGES/LARGE/ED2C00741_0003.JPEG

Drăghicescu, L. M., Petrescu, A.-M., Cristea, G. C., Gorghiu, L. M., & Gorghiu, G. (2014). Application of Problem-based Learning Strategy in Science Lessons – Examples of Good Practice. *Procedia - Social and Behavioral Sciences*, *149*, 297–301. https://doi.org/10.1016/J.SBSPRO.2014.08.245

Ellizar, Bayharti, & Andromeda. (2013). Pengaruh Motivasi dan Pembelajaran Kimia Menggunakan Modul dan Tanpa Modul Terhadap Hasil Belajar Kimia di RSMA-BI. *Prosiding Semirata FMIPA Universitas Lampung*, 117–124.

Fahmi, J., Nahadi, & Hernani. (2023). Pengembangan Asesmen Formatif Berbasis Problem Based Learning untuk Meningkatkan Keterampilan Berpikir Kritis: Need Assessment Study. *Orbital: Jurnal Pendidikan Kimia*, *7*(2), 237–249. https://doi.org/10.19109/OJPK.V7I2.19922

Gorghiu, G., Drăghicescu, L. M., Cristea, S., Petrescu, A.-M., & Gorghiu, L. M. (2015). Problem-based Learning - An Efficient Learning Strategy in the Science Lessons Context. *Procedia - Social and Behavioral Sciences*, *191*, 1865–1870. https://doi.org/10.1016/J.SBSPRO.2015.04.570

Gurses, A., Dogar, C., & Geyik, E. (2015). Teaching of the Concept of Enthalpy Using Problem Based Learning Approach. *Procedia - Social and Behavioral Sciences*, *197*, 2390–2394. https://doi.org/10.1016/J.SBSPRO.2015.07.298

Hosnan, M. (2014). *Pendekatan Saintifik dan Kontekstual dalam Pembelajaran Abad 21: Kunci Sukses Implementasi Kurikulum 2013*. Ghalia Indonesia.

Imanah, L. F., Yetmi, Y., & Handayani, D. (2023). Upaya Peningkatan Keterampilan Berpikir Kritis Dan Aktivitas Belajar Siswa Sma Pada Pembelajaran Abad-21 Dengan Menerapkan Model Problem Based Learning (PBL). *DIKSAINS : Jurnal Ilmiah Pendidikan Sains*, *4*(1), 66–74. https://doi.org/10.33369/DIKSAINS.4.1.66-74

Istiani, R., & Azizah, U. (2015). Penerapan Model Pembelajaran Berdasarkan Masalah untuk Melatih Keterampilan Berpikir Kritis Siswa pada Materi Pokok Larutan Elektrolit dan Nonelektrolit Kelas X SMA Negeri 1 Pasuruan. *UNESA Journal of Chemical Education*, *4*(2), 256–261.

Jufriadi, A., Huda, C., Aji, S. D., Pratiwi, H. Y., & Ayu, H. D. (2022). Analisis Keterampilan Abad 21 Melalui Implementasi Kurikulum Merdeka Belajar Kampus Merdeka. *Jurnal Pendidikan Dan Kebudayaan*, *7*(1), 39–53. https://doi.org/10.24832/JPNK.V7I1.2482

Karepesina, N. G., & Manuhutu, J. B. (2023). Application of Problem-Based Learning (PBL) on Hydrocarbon Compound Lesson to Increase Student Learning Outcomes. *Hydrogen: Jurnal Kependidikan Kimia*, *11*(1), 51–59. https://doi.org/10.33394/hjkk.v11i1.6961

Kek, M. Y. C. A., & Huijser, H. (2011). The power of problem-based learning in developing critical thinking skills: preparing students for tomorrow's digital futures in today's classrooms. *Higher Education Research & Development*, *30*(3), 329–341. https://doi.org/10.1080/07294360.2010.501074

Kusumawati, I. T., Soebagyo, J., & Nuriadin, I. (2022). Studi Kepustakaan Kemampuan

Berpikir Kritis Dengan Penerapan Model PBL Pada Pendekatan Teori Konstruktivisme. *JURNAL MathEdu (Mathematic Education Journal)*, *5*(1), 13–18. https://doi.org/10.37081/MATHEDU.V5I1.3415

Marhamah, I., Yahdi, Y., & Hajaroh, S. (2020). Pengaruh model pembelajaran problem based learning terhadap keterampilan berpikir kritis. *Spin Jurnal Kimia & Pendidikan Kimia*, *2*(1), 68–82.

Masrinah, E. N., Aripin, I., & Gaffar, A. A. (2019). Problem Based Learning (PBL) untuk Meningkatkan Keterampilan Berpikir Kritis. *Prosiding Seminar Nasional Pendidikan*, *1*, 924–932.

Meutia, C. (2021). Peningkatan Hasil Belajar dan Kemampuan Berpikir Kritis Siswa dalam Materi Perhitungan Kimia Melalui Model Pembelajaran Problem Based Learning. *Jurnal Kinerja Kependidikan (JKK)*, *3*(1), 39–60.

Nasution, S. (2008). *Berbagai Pendekatan dalam Proses Belajar Mengajar*. Bumi Aksara.

Plomp, T., & Nieveen, N. (2013). *Part A: Educational Design Research: An Introduction*. SLO.

Prayogi, S., & Asy'ari, M. (2013). Implementasi Model PBL (Problem Based Learning) untuk Meningkatkan Hasil Belajar dan Kemampuan Berpikir Kritis Peserta didik. *Prisma Sains : Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan IPA IKIP Mataram*, *1*(1), 80–88. https://doi.org/10.33394/j-ps.v1i1.521

Puspitasari, Y., & Muchlis. (2016). Penerapan Model Pembelajaran Berbasis Masalah pada Materi Larutan Elektrolit dan Nonelektrolit untuk Melatihkan Keterampilan Berpikir Kritis Peserta didik Kelas X SMA. *UNESA Journal of Chemical Education*, *5*(2), 367–375.

Sadia, I. W. (2008). Model pembelajaran yang efektif untuk meningkatkan keterampilan berpikir kritis (suatu persepsi guru). *Jurnal Pendidikan Dan Pengajaran Undiksha*, *2*(2), 219–237.

Sudijono, A. (2009). *Pengantar Evaluasi Pendidikan*. Raja Grafindo Persada.

Sugiyono. (2015). *Metode Penelitian Pendidikan: Pendekatan Kuantitatif, Kualitatif dan R&D*. Alfabeta.

Sunyono. (2015). *Model Pembelajaran Multipel Representasi*. Media Akademi.

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*, *2*(3), 399–408. https://doi.org/10.24042/ijsme.v2i3.4366

Zahro, M., & Lutfianasari, U. (2024). Penerapan Model Pembelajaran Problem-Based Learning terhadap Kemampuan Berpikir Kritis dan Aktivitas Belajar Peserta Didik pada Materi Hidrolisis Garam. *Jurnal Inovasi Pendidikan Kimia*, *18*(1), 17–22. https://doi.org/10.15294/JIPK.V18I1.45567