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Problem-Based Learning Model on Students' Chemical Literacy and Critical Thinking on Reaction Rate Material

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ABSTRAK

Penelitian ini dilatarbelakangi oleh rendahnya keterampilan literasi kimia dan berpikir kritis siswa. Salah satu cara untuk mengatasi masalah tersebut adalah dengan menggunakan model pembelajaran yang dapat melibatkan siswa secara aktif seperti problem-based learning (PBL). Tujuan dari penelitian ini yaitu untuk menganalisis pengaruh dari PBL terhadap keterampilan literasi kimia dan berpikir kritis siswa. Penelitian ini menggunakan pendekatan kuantitatif dengan metode kuasi eksperimen. Desain penelitian yang digunakan adalah non-equivalent control group design. Teknik pemilihan sampel yang digunakan adalah cluster random sampling dengan memilih sampel sebanyak 70 siswa kelas dua SMA. Pengumpulan data menggunakan tes dengan instrumen berupa lembar tes esai mengenai posttest keterampilan literasi kimia sebanyak 7 soal dan posttest keterampilan berpikir kritis sebanyak 5 soal. Teknik analisis data menggunakan uji statistik non parametrik. Uji hipotesis menggunakan uji Kruskal-Wallis. Hasil penelitian menunjukkan adanya perbedaan yang signifikan antara siswa yang diajarkan dengan model PBL dan siswa yang tidak diajarkan dengan model tersebut. Penerapan model PBL terbukti berpengaruh terhadap keterampilan literasi kimia dan berpikir kritis siswa. Dengan demikian, dapat disimpulkan bahwa penerapan PBL secara nyata dapat meningkatkan literasi kimia dan keterampilan berpikir kritis siswa dibandingkan dengan metode pembelajaran yang tidak menggunakan model tersebut. Penelitian ini memiliki implikasi bahwa model pembelajaran berbasis masalah dapat mempengaruhi literasi kimia dan keterampilan berpikir kritis siswa dengan implementasi yang disesuaikan dengan konteks dan materi dalam penelitian ini yaitu laju reaksi.

ABSTRACT

This study was motivated by students'students' low chemical literacy skills and critical thinking skills. One way to overcome this problem is to actively use a learning model involving students, such as problem-based learning (PBL). This research aims to analyze the effect of PBL on students' chemical literacy and critical thinking skills. This study used a quantitative approach with a quasi-experimental method. The research design used was a non-equivalent control group design. The sample selection technique used was cluster random sampling, which was done by selecting 70 second-grade high school students. Data collection using tests with instruments in the form of essay test sheets regarding posttest chemical literacy skills with as many as seven questions and posttest critical thinking skills with as many as five questions. Data analysis techniques using non-parametric statistical tests. Hypothesis testing using the Kruskal-Wallis test. The results showed a significant difference between students taught with the PBL model and students who were not trained with the model. Applying the PBL model is proven to affect students' chemical literacy and critical thinking skills. Thus, it can be concluded that the application of PBL can significantly improve students' chemical literacy and essential thinking skills compared to learning methods that do not use the model. This study implies that problem-based learning models can influence students' chemical literacy and critical thinking skills with implementation tailored to the context and material in this study, namely reaction rates.

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1. INTRODUCTION

The principle of 21st-century learning is to combine science, thinking skills (critical, innovation, problem-solving), technology, and research. Correspondingly, critical thinking is important because it enables students to solve problems effectively and directly contribute to society (Dewanti & Santoso, 2020; Sadhu et al., 2019). Critical thinking is reflective and rational thinking to make an action on what to do. Knowledge and the ability to solve real-world problems is called science literacy (Ennis, 2011; Sadhu et al., 2019). One aspect of science literacy assessment is chemical literacy. Both chemical literacy and chemistry learning have a direct relationship and application in everyday life. Chemistry is one of the subjects that studies natural phenomena, structure, arrangement, properties, and changes in matter, as well as the energy that accompanies changes in matter. Chemistry learning provides students with hands-on experience and that requires conceptual involvement in everyday life. One of the topics related to everyday life in chemistry lessons is reaction rates. This material requires conceptual understanding and can be applied in real life so as to train students' problem-solving skills. But in fact, currently some students tend to prefer memorizing rather than understanding concepts, so they are not used to developing chemical literacy skills and critical thinking in solving problems and applying the concepts they have learned. In addition, students rarely find solutions to challenging real-world problems (Prihono & Khasanah, 2020; Sadhu et al., 2019). Chemical literacy and critical thinking are needed by teachers and students to understand broad and abstract concepts. Teachers must make students think and have the ability to predict a chemical concept in real life. According to other researchers, chemical literacy indicators include four main aspects, namely knowledge of chemical materials and scientific ideas, chemistry in context, higher-level learning skills, and effective aspects. Meanwhile, critical thinking indicators, according to R. Ennis (2011), are (1) providing basic explanations, (2) building basic skills, (3) making conclusions, (4) making further explanations, and (5) organizing strategies and tactics (Ennis, 2011; Fahmina et al., 2019). One way that can be done to train students' chemical literacy and critical thinking skills is to apply appropriate learning models. Chemical literacy and critical thinking skills can be trained through learning that involves students actively developing their ideas, requiring students to explore, question, find and solve problems (Anggreani et al., 2023; Siburian et al., 2019).

Literature studies conducted reveal that the learning model that is often used to train and improve chemical literacy and critical thinking skills is problem-based learning. Students actively construct their knowledge from the beginning to the end of the learning process. By providing problems in the real world, problem-based learning makes the learning process more meaningful. In problem-based learning, students are required to search, analyze, and evaluate information, make decisions, and solve problems. High critical thinking skills are acquired because students are more active during classroom learning. The problem-based learning model provides convenience in solving problems because it presents problems that are contextual to real life (Amin et al., 2020b, 2020a; Anggraeni et al., 2023; Helmon, 2018; Heong et al., 2020; Sanova et al., 2021). In order for learning activities to run optimally, the application of the right learning model must be accompanied by the use of appropriate learning media. Currently, there are many digital learning media to facilitate its use such as PhET virtual laboratories. Previous research states that PhET can improve students' critical thinking skills (Aminah et al., 2020; Hasyim et al., 2020; Salame & Makki, 2021). Then another study found the use of PhET as a learning medium with a problem-based learning model can improve learning outcomes. In addition, the success of the learning process must also be associated with the teacher's ability to develop a learning model that is oriented toward increasing student involvement in the learning process (Apriwahyuni et al., 2021; Widiastuti et al., 2023). Teachers must have sufficient knowledge and understand the concept of the learning model to be carried out in order to develop an effective learning model. Teachers' lack of understanding of these conditions causes the developed model to be less able to train the skills possessed by students and ultimately unable to make a significant contribution to the achievement of student learning outcomes (Handayani et al., 2023; Sutarto et al., 2020). Several previous studies have examined the role of PBL in improving student competence, including improving students' chemical literacy and critical thinking skills. In addition, research on the intermediate level has proven to be effective in improving High Other Thinking Skills (HOTS) by increasing HOTS skill scores in pretest and post-test. Multiple-choice test instrument to check chemical literacy skills in chemistry students (Arviani et al., 2023; Muntholib et al., 2020). This test was developed based on the chemical literacy component according to Shwartz and the OECD. 30 chemical literacy test questions based on PISA and Shwart to test the chemistry literacy competency of high school class X on carbon chemistry. A test and observation instrument to check the critical thinking skills of elementary school students (Djaen et al., 2021; Helmon, 2018).

Based on observations and interviews with teachers in the school where the research was conducted, teachers have carried out student-centered learning but have not explored various methods that can train chemical literacy skills and critical thinking. So far, teachers still use the lecture method. This results in students getting used to receiving information from the teacher and not studying it more deeply. These habits can make students less developed skills and skills they have. When teachers ask questions, students tend to be silent or not answer questions. This shows that the skill of describing a material in an explanation to be understood by students is still low. Students also have difficulty relating the material learned with science concepts in everyday life. Therefore, an innovation is needed that can train chemical literacy skills and critical thinking with various alternative learning models. The difference between this study and previous study is that this study focuses on investigating the role of PBL on chemical literacy and critical thinking skills of high school students. Syntax problem-based learning has been adjusted to chemical literacy indicators according to Shwartz and critical thinking according to Ennis. In addition, PhET virtual laboratory is used on the topic of collision theory and factors that can affect reaction rates in order for students to understand reaction rate material in terms of microscopy and sub-microscopic. So, the purpose of this study is to. analyze the effect of problem-based learning (PBL) on students' chemical literacy and critical thinking skills.

2. METHOD

The method used in this study is quantitative which is quasi-experimental (Bunselmeyer & Schulz, 2020; Maciejewski, 2020). The research design used was a posttest-only control group design. The sample selection technique is the cluster random sampling technique. The sample used in this study was 70 second-year high school students divided into two groups, namely the experimental and control groups. The experimental group will be given a PBL model with PhET media, and the control group will be given a discovery learning model. Both classes were chosen because they have almost the same level of understanding of the material compared to other classes. PhET learning media is used on the topic of collision theory and factors that affect reaction rate. With the use of PhET, students not only learn concepts through their macroscopic aspects but students are invited to study a chemical reaction from their sub-microscopic and microscopic aspects. The problem-based learning syntax used in this study has been adjusted to chemical literacy indicators according to Shwartz and critical thinking indicators according to Ennis, as can be seen in Table 1.

Table 1. Syntax of Problem-Based Learning on Indicators of Chemical Literacy and Critical Thinking

Syntax of Problem-Based Learning	Chemical Literacy Indicators	Critical Thinking Indicators
Student orientation on the problem	Chemistry in context	Provide basic explanations
Organize students to learn	Knowledge of chemical matter	Strategize and tactics
Guiding individual or group	Chemical material knowledge, high-level learning skills	Give a simple explanation, give further explanation
Develop and present the group	High-level learning skills	Building basic skills, making conclusions
Analyze and evaluate the problem-solving process	Knowledge of chemical matter	Gives simple explanations, organizes strategies and tactics, makes conclusions

Data collection techniques were in the form of written tests twice, namely the posttest of chemical literacy skills and the posttest of critical thinking skills, while the instrument used is a description test. The posttest of chemical literacy skills used is an essay question consisting of 7 questions arranged based on chemical literacy indicators according to Shwartz as shown in Tabel 2. According to Ennis, the posttest of critical thinking skills used is an essay question consisting of 5 questions arranged based on critical thinking indicators as shown in Tabel 3. Before being used in research, the test instrument was validated by two expert validators, then analyzed using the Gregory formula, and valid results were obtained.

Tabel 2. Indicator Chemical Literacy Skills According to Shwartz

Indicator	Sub Indicator	Number of Question
Knowledge of chemical matter	Explain the dynamics of chemical processes and reactions	1
	Using chemical understanding	2
Chemistry in context	Explain everyday situation	2
High-level learning skills	Explain phenomena using chemical concepts	2

Tabel 3. Indicator critical Thinking Skills According to Ennis

Indicator	Sub Indicator	Number of Question
Basic clarification	Provide a simple explanation	1
Building basic skills	Develop basic skills	1
Inference	Make conclution	1
Advance clarification	Provide further explanation	1
Strategy and tactic	Develop strategic and tactics	1

Data analysis techniques use prerequisite tests and hypothesis tests. The prerequisite test is a normality and homogeneity test. The normality test is said to be normally distributed if it has a significance value of > 0.05. The homogeneity test is considered homogeneous if it has a significance of > 0.05. The hypothesis test is carried out by looking at the normality and homogeneity test. A parametric hypothesis test will be carried out if normal and homogeneous data are obtained, but if abnormal data is obtained, a non-parametric hypothesis test will be carried out. The hypothesis test in this study was carried out with the Kruskal-Wallis test because the data was not normally distributed. The result of hypothesis test, if the sig value is obtain (2-tailed) < 0,05 then H_0 rejected.

3. RESULT AND DISCUSSION

Result

Some results of data analysis are presented to answer the problem formulation of the effect of the problem-based learning model on chemical literacy and critical thinking skills. The data presented include normality tests, homogeneity tests and hypothesis tests. The normality test to see the distribution of students in each phase and group. The homogeneity test to determine whether or not the variation of a number of populations is the same. The results of the normality test and the homogeneity test of posttest data on chemical literacy and critical thinking skills can be seen in Table 2 and Tabel 3.

Table 2. Normality Test Result

Class	Variable	Significance	Results	Conclusion
Experimental	Chemical Literacy Skills	0.002	H_0 rejected	Not normal
Class	Critical Thinking Skills	0.029	H_0 rejected	Not normal
Control Class	Chemical Literacy Skills	0.015	H_0 rejected	Not normal
	Critical Thinking Skills	0.014	H_0 rejected	Not normal

Tabel 3. Homogeneity Test Result

Variable	Significance	Result	Conclusion
Chemical Literacy Skills	0.099	H_0 accepted	Homogenous
Critical Thinking Skills	0.948	H_0 accepted	Homogenous

Based on Table 2, the results of the posttest normality test of students' chemical literacy and critical thinking skills in the experimental class and control class had a Saphiro Wilk significance of < 0.05 which means that the data is abnormal. The results of the posttest homogeneity test of students' chemical literacy and critical thinking skills on Table 3 have a significance of > 0.05, meaning that the data is homogeneous. Hypothesis testing is carried out with non-parametric tests because the data obtained is abnormal. The results of the hypothesis test can be seen in Table 3.

Tabel 4. Kruskal-Wallis Test Result

Test Parameters	Sig. (2-tailed)	Results	Conclusion
Posttest Chemical Literacy and Critical Thinking Skills	0.000	H_0 rejected	There is a different

The hypothesis test was carried out with the Kruskal-Wallis test because the data was not normally distributed. Based on the results of the Kruskal-Wallis test in Table 4, obtained a significance result (2-tailed) of 0.000 < 0.05, which means that the problem-based learning model influences students' chemical literacy and critical thinking skills. The data analyzed were taken from post-test data on students' chemical literacy and critical thinking skills. Posttest data was used to determine the average difference in students' chemical literacy and critical thinking skills in experimental classes using problem-based learning and control classes using discovery learning. Posttest data is also used to determine the magnitude of the achievement of chemical literacy and critical thinking indicators.

Table 5. Statistical Results Posttest Chemical Literacy and Critical Thinking

Posttest	Group	N	N_{min}	N_{max}	Mean	Deviation Standards
Chemical Literacy Skills	Experimental Class	34	40	100	77.21	19.97
	Control Class	36	15	95	56.67	24.94
Critical Thinking Skills	Experimental Class	34	50	100	80.67	15.25
	Control Class	36	43	93	73.81	14.52

Table 5 shows the results of the posttest of chemical literacy skills; the average value of the experimental class chemical literacy skill posttest is 77.21, while the control class is 56.67. This showed that the average posttest score of the experimental class was significantly higher than that of the control class. The control class's posttest value's standard deviation is greater than the experimental class's. The experimental class had a standard definition of 19.97 and a control class 24.94. Statistical data on posttest scores of critical thinking skills of the experimental class and control class are presented in Table 5. The experimental class's average posttest score of critical thinking skills was 80.67, while the control class was 73.21. This showed that the average posttest score of the experimental class was significantly higher than that of the control class. The control class's posttest value's standard deviation is greater than the experimental class's. The experimental class had a standard deviation 15.25, while the control class had a standard deviation 14.52. The percentage of Achievement of Each Chemical Literacy Indicator is presented in Figure 1.

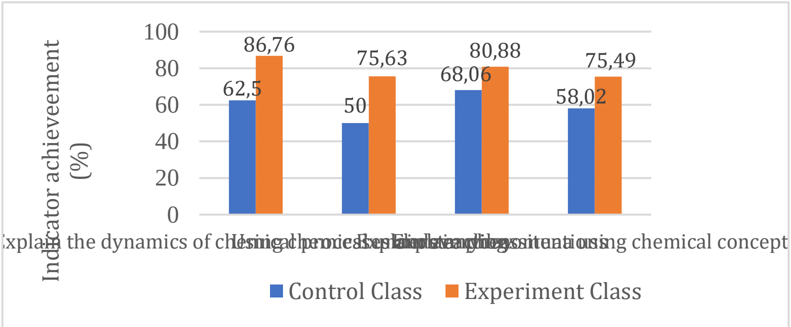

Figure 1. Percentage of Achievement of Each Chemical Literacy Indicator

Based on Figure 1, the order of achievement of chemical literacy indicators from the largest is the sub-indicator explaining the dynamics of chemical processes and reactions by 86.76%, explaining daily situations by 80.88%, using chemical understanding by 75.63%, and explaining phenomena using chemical concepts by 75.49%. The average achievement of chemical literacy indicators in the experimental class was 79.69%, and in the controls class was 59.69%. This has a positive influence because the averages in the experimental and control classes have significant differences. The percentage of Achievement of Each Critical Thinking Indicator is presented in Figure 2.

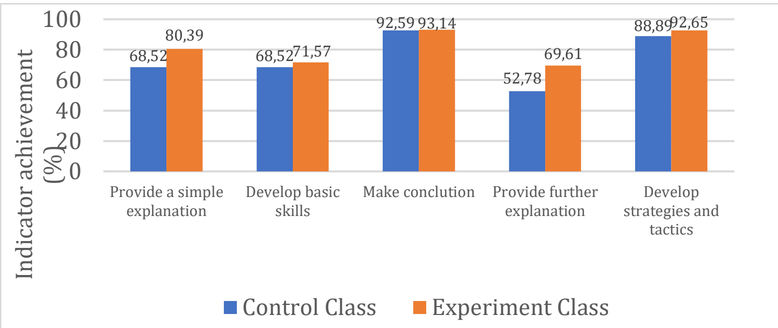

Figure 2. Percentage of Achievement of Each Critical Thinking Indicator

Based on Figure 2, the highest sequence of critical thinking indicators was obtained in the aspect of developing strategies and tactics by 92.65%, making conclusions by 93.14%, providing simple explanations by 80.93%, developing basic skills by 71.57%, and providing further explanations by 69.61%. The average achievement of critical thinking indicators in the experimental class was 81.47%, and in the control, class was 74.26%. This has a positive influence because the average in the experimental class is higher than the control class, although the difference is not too significant.

Discussion

Based on statistical data that has been explained in the previous section, the problem-based learning model affects students' chemical literacy and critical thinking skills. This is shown by a significance value of 0.000 which is smaller than the significance level of 5% (0.000 <0.05). Research shows that the PBL model has a positive influence on students' chemical literacy and critical thinking skills (Azizah et al., 2021; Iskandar et al., 2021). There was a difference in the results of the chemical iteration and critical thinking skills test in the control and experimental classes because the average score of the post-test of the experimental class was higher than that of the control class. The average value of the experimental class chemical literacy skill posttest is 77.21, while the control class is 56.67. And the experimental class's average posttest score of critical thinking skills was 80.67, while the control class was 73.21. Chemistry is one of the subjects that studies natural phenomena, structure, arrangement, properties, and changes in matter, as well as the energy that accompanies changes in matter. Chemistry learning provides students with hands-on experience and that requires conceptual involvement in everyday life. So that chemistry learning must be actualized in a fun way and involve students to think critically that will help them to solve everyday problems from a scientific perspective. This is supported by the selection of the right learning model and media. The advantages of the PBL model are (1) students are encouraged to have problem-solving skills in real situations, (2) students have the skills to build their own knowledge through learning activities, (3) learning focuses on problems so that unrelated materials do not need to be studied by students, (4) scientific activities occur through group work, and (5) students are accustomed to using knowledge sources, both from the library, internet, interviews, and observations.

In the experimental class group, students using the PBL model with PhET media tended to be more excited and interested. Students are also better at connecting everyday problems with the chemistry learning they are learning, namely reaction rates. Problem-based learning helps students better relate what they have learned to real-world problems (Hartmann et al., 2021; Heong et al., 2020). Students are more active in seeking information, discussing, and expressing their ideas so as to develop brain function and practice their critical thinking in solving given problems. Students are very interested when using PhET because they can see the picture of molecules that occur in chemical reactions. PhEt presents molecular shapes, molecular colors, and chemical symbols in terms of their microscopic aspects so that it makes it easier for students to organize and remember information. After the discussion, each group presented the results of their discussion in front of the class so that students were actively involved in learning.

Problem-based learning is active learning and encourages students to find answers to given problems involving real-world situations to help students retain information better. In addition, experimental classes use PhET media, which can involve students in learning activities that require high cognitive skills and the training of their critical thinking. This is in accordance with the results of research, which states that PhET can improve students' critical thinking skills (Aminah et al., 2020; Hasyim et al., 2020; Salame & Makki, 2021). PhET helps students more easily understand the concept of abstract material in concrete. In PhET there is a visual display and interaction between students and the concepts taught that help develop their understanding (Apriwahyuni et al., 2021; Salame & Makki, 2021) In learning the concept of reaction rate, students are involved in thinking about what is associated with real-life problems such as car crashes, fish deaths due to acid rain, and fruit rot in dragon fruit farming due to high rainfall. Students become more motivated and enthusiastic in following existing learning through this real concept. Based on the existing posttest results, the chemical literacy skills of the control class had a higher average than the experimental class. The highest chemical literacy indicator is achieved in the sub-indicator explaining the aspects and dynamics of chemical processes and reactions. Explain the dynamics of chemical processes and reactions where chemistry provides knowledge to explain phenomena in other fields.

The Effect of PBL on Chemical Literacy Skills

The first indicator of chemical literacy is knowledge of chemical matter. Knowledge of the chemical matter in question is explain the dynamics of chemical processes and reactions and using chemical understanding. This indicator is seen when students answer questions at the beginning of learning and when conveying ideas or ideas from their discoveries. The experimental class has a higher indicator of chemical knowledge than the control class in both the first and second sub-indicators. In the sub-indicator explain the dynamics of chemical processes and reactions, the percentage in the experimental class was 86.76% and in the sub-indicator using chemical understanding was 75.63%. This is because the experimental class uses a problem-based learning model and PhET learning media. Students will more easily understand the concept being learned if the learning carried out connects the concept with a context that can be applied to real life so that the memory of the concept is stronger and not easily forgotten (Masgumelar & Mustafa, 2021; Sanova et al., 2021). The use of PhET helps students understand the rate of reactions in terms of sub-microscopic and microscopic levels so that students know how a reaction takes place judging from the movement between its particles. The second indicator is chemistry in context. Chemical indicators in the context in question describe everyday situations. A chemically literate person is able to recognize the importance of chemistry in explaining everyday phenomena and use his understanding in everyday life. In this indicator 80,88% of students give the correct answer. In syntax of problem-based learning, this indicator is visible during the orientation stage of the problem. Students seem to show interest and enthusiasm in discussing chemistry issues that exist in everyday life. The experimental class obtains chemical indicators in a higher context because, in the *problem-based learning* model, students are given problems related to real life to train and develop thinking and literacy skills, especially chemical literacy (Djaen et al., 2021; Sanova et al., 2021).

The third indicator is high-level learning skills. The high-level learning skills indicator in question is to explain phenomena using chemical concepts. Explaining phenomena using chemical concepts recognizes the importance of chemical knowledge in explaining everyday phenomena that include broad and deep applications. This indicator looks at the stage of guiding individual and group experiences. Students construct their understanding through various available sources. Chemical literacy skills are built by familiarizing students with the ability to think independently and build their knowledge concepts (Anggraeni et al., 2023; Sanova et al., 2021). The experimental class obtained higher indicators (75,49%) because students conducted experiments through PhET and built their understanding based on what had been done. This indicator gets the lowest percentage, which can be caused by students not understanding the questions at hand, so it is difficult to connect chemical concepts to everyday life.

In critical thinking skills, the first indicator is achieved by providing a simple explanation *(basic clarification).* Providing simple explanations includes focusing on questions, analyzing arguments, and asking and answering questions that require answers or challenges. The PBL learning model guides students to find facts, construct hypotheses, and draw conclusions in problem-solving. With the PBL model syntax, students are trained to analyze, solve, and make solutions to problems so that students are trained in critical thinking. Students can understand real-life problems faced and provide convenience in conducting investigations to obtain data for solutions to these problems. This indicator can also be seen when students observe experiments on PhET. In PhET, there is a visual display and interaction between students and the concepts taught, which helps develop understanding. Virtual laboratories can provide dynamic visualizations in sub-macroscopic (color, solid, liquid) and microscopic (atoms and molecules) to help students' learning comprehension (Amin et al., 2020a; Chan et al., 2021; Salame & Makki, 2021).

The second indicator is building basic skills. Building these basic skills includes considering the credibility of sources and making observational considerations. This indicator is seen when students discuss in groups to produce appropriate problem-solving solutions. Such learning allows the exchange of opinions between students about understanding problems, how to solve problems, and solutions to these problems. Critical thinking leads students to look directly at the problem from multiple points of view and evaluate it through a rigorous process of intellectual activity (Amin et al., 2020b; Ennis, 2011; Santos-Meneses et al., 2023). This activity produces evidence empirically, depending on experiments or experiments sourced from real-world experience. The third indicator is to draw conclusions. Drawing conclusions means identifying the elements needed to draw conclusions from data, principles, judgments, beliefs, or opinions. This can be seen after students see PhET simulations and conduct experiments using PhET virtual laboratories. Students can capture conceptions of the material learned and conclude them before presenting them in front of the class. Problem-based learning guides students in finding facts, making hypotheses, and drawing conclusions on problem-solving. Then, students must choose the best solution to the problem. Students actively build knowledge and critical thinking habits during the PBL model. The fourth indicator provides further explanation. Providing further explanation consists of defining terms considering definitions using appropriate criteria, and identifying assumptions. This indicator is seen when students are able to explain back data, events, provisions, and steps that have been carried out in experiments using PhET. In PhET simulations, there are elements about molecules, molecular types, temperature, energy, and the number of molecules that react and are produced. In this PhET simulation, students are directed to provide appropriate explanations and dare to convey the results of discussions obtained from conducting the experiment about collision theory. This indicator gets the lowest percentage because students do not understand how to define, assume, and express what is understood and known well, correctly, and precisely (Amin et al., 2020b; Khoirunnisa & Widia, 2020; Santos-Meneses et al., 2023). The fifth indicator is to develop strategies and tactics. Developing these strategies and tactics is the stage of proposing and evaluating a number of possible actions. This indicator can be seen when students divide assignments into groups. Then after making a presentation, students evaluate the material discussion that has been carried out. When students discuss, they can solve problems around them because students try hard to solve existing problems (Amin et al., 2020b; Sadhu et al., 2019). In the *problem-based learning* model, students are given problems related to real life so as to train and grow, and develop thinking and literacy skills, especially chemical literacy Sanova et al., 2021). In its learning syntax, the problem-based learning model trains students to analyze, solve, and create solutions to solve problems so that students will be trained in critical thinking. In the learning process, the application of the PBL model needs to be considered in the syntax of group discussions because students with less ability tend to experience difficulties so that in the formation of groups it is necessary to be based on the initial ability of students. In the PBL model, the teacher plays the role of a facilitator so that the teacher is not a learning center because if the teacher is the center of learning, the students' critical thinking skills are not trained optimally. Critical thinking leads students to look directly at the problem from multiple points of view and evaluate it through a rigorous process of intellectual activity (Amin et al., 2020a; Santos-Meneses et al., 2023). This activity produces evidence empirically, depending on experiments or experiments sourced from real-world experience.

This research has implications that problem-based learning models can affect students' chemical literacy and critical thinking skills with an implementation that is adjusted to the context and material in this study, namely reaction rate. In this study, the highest chemical literacy skills are on the indicator of chemical material knowledge with sub-indicators explaining the dynamics of processes and reactions. While the highest critical thinking skills lie in the aspect of drawing conclusions. This study has limitations that only use two research groups, this study uses elements of subjectivity so that generalizations cannot be made to different subjects. The study also only focused on the cognitive aspects of chemical literacy and critical thinking skills. Based on the limitations of this study, researchers recommend several things for future researchers, including further research about indicators that have low achievements, namely sub-indicators explaining phenomena using chemical concepts and critical thinking skills, especially in the aspect of providing further explanation. Researchers are then expected to conduct further research on the influence of students' chemical literacy and critical thinking skills on affective aspects or other variables regarding *problem-based learning models*.

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4. CONCLUSION

The problem-based learning model affects students' chemical literacy and critical thinking skills on reaction rate material. The effect can be seen from the average posttest obtained by the experimental group is higher than the control group. This can also be seen from the Kruskal-Wallis-test which shows that there is an effect of problem-based learning models on students' chemical literacy and critical thinking skills. This means that the application of the PBL model can significantly improve students' chemical literacy and critical thinking skills compared to learning methods that do not use the model.

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