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Implementation of the PBL-STEM Model to Improve Students' Critical Thinking on Reaction Rate Material

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Abstract
The application of PBL-STEM can encourage students to be independent in the learning process and emphasize the process of thinking critically and analytically to seek and find answers to a problem in question. This study used a true–experimental design with the Posttest Only Control Design type. The population in this study were all students of class XI SMA Kristen Sunodia Samarinda for the academic year 2022/2023 divided into 2 classes. This study aims to determine the effect of PBL-STEM in improving students' critical thinking skills. Sampling was done by cluster random sampling technique. The instruments used to measure students' critical thinking skills in chemistry were post-test questions, teacher and student observation sheets, and student response sheets (questionnaire). Data analysis was performed by t-test. The results of the t-test with Mann-Whitney obtained sig. (2-tailed) in both classes is 0.00 <0.05, it is concluded that Ha accepted the statement that there is an effect of the application of PBL-STEM on the critical thinking skills of class XI students at Christian Senior High School Sunodia Samarinda regarding reaction rates. The results of the teacher and student activity sheets in the experimental class were both in very good categories, as well as the student response to PBL-STEM learning, namely 77.2% of students agreed with the application of PBL-STEM in learning which can train students' critical thinking skills. This research discusses the analysis of how effective the influence of PBL and STEM integration is to improve critical thinking skills on reaction rate material so that this research can be used as a reference for applying PBL-STEM to other chemistry topics.

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INTRODUCTION

Critical thinking has an important role in developing potential, doing assignments, finding solutions to a problem encountered, and being able to conclude the material that has been taught during the learning process (Nugraha, 2017). Critical thinking is crucial for students since it enables them to solve social, scientific, and practical problems effectively. Thinking skills can boost students' critical analytical power (Nasihah et al., 2019; Purnamasari et al., 2020; Wahdaniyah et al., 2023). However, many students do not participate in teaching and learning activities properly, so when they are asked to conclude the material they have learned, they repeat several sentences about the material and cannot make conclusions. In addition, when students were given practice questions related to the subject matter, many were unable to work on these questions. These learning activities prove that there are obstacles to learning that result in low critical-thinking students (Fasha et al., 2018; Setyorini et al., 2021; Yana & Yusrizal, 2022).

This condition is also evidenced by the low achievement of students in Indonesia in PISA (Program for International Student Assessment) which is caused by several factors, one of which is the weak problem-solving ability of high-level questions that require students to think critically in solving these problems. Thus it can be said that the critical thinking skills of Indonesian students are still relatively low (Munirotus et al., 2020). Based on the various problems that have been described, a learning method is needed that can hone students' critical thinking skills with the help of appropriate learning models (Mayasari et al., 2016; Purnamasari et al., 2020; Setyorini et al., 2021).

The development of students' critical thinking skills can be trained using the STEM (Science, Technology, Engineering, and Mathematics) approach. The STEM approach is a learning approach that requires students not only to memorize concepts but rather how students understand and understand scientific concepts and their relation to everyday life (Rohman et al., 2021). Through learning using STEM students are expected to be able to solve problems, make innovations, design new things, do logical thinking, and master technology (Rika, 2018). In addition to the STEM approach, students also need to be trained with a learning model.

The PBL model can be integrated with the STEM approach (Clarissa et al., 2020). The results of the study show that the application of online PBL-STEM can run well and shows that students' critical thinking skills are improved through better PBL-STEM learning. STEM is an effective way to facilitate and maintain the integration of science, technology, mathematics, and engineering (Estapa & Tank, 2017). According to Febriana & Ekosari (2018), PBL-STEM-based learning has a very significant influence on critical thinking skills and also learning outcomes in the moderate category. In addition, research on the application of the PBL-STEM model is still rare. Based on research by Laforce et al. (2017) indicated that PBL might be one of the strategies to increase students' interest in STEM fields.

Critical thinking skills are important to apply so that students have the capital to analyze problems so that students can apply their ideas in the application of technology, and scientific developments, and find solutions in solving problems they face every day (Adiwiguna et al., 2019). Furthermore, students who will become the next generation must be knowledgeable with science, technology, engineering, and mathematics, as well as having critical and creative thinking skills, in order to fulfill the needs of the twenty-first century (Baucum & Capraro, 2021; Marlina et al., 2021). Based on this, this learning can be combined with the STEM method to support the success of PBL-based learning (Wahdaniyah et al., 2023). Students' critical thinking skills are very necessary and important to link science, technology, mathematics, and engineering in learning, so it is necessary to apply the PBL-STEM model to the subject of reaction rates for class XI SMA Kristen Sunodia Samarinda.

METHOD

The type of research used by researchers in this study is True-Experimental quantitative research (Fraenkel et al., 2012). The real research design used in this study is the Post-test Only Control Design. To see more clearly the research design is presented in Table 1:

Table 1. Research Design

Group	Treatment	Posttest
Experiment	X	O_1
Control	-	O_2

The population in this study were all class XI students of Sunodia Christian High School Samarinda who were divided into 4 classes, namely Chemistry 1, Chemistry 2, Chemistry 3, and Chemistry 4 classes. The sample was all students in Chemistry 2 class and Chemistry 3 class. The sample selection method itself was using a simple random sampling technique. The independent variable in this research is the PBL-STEM model. In the experimental class. were treated using PBL-STEM in learning, while in the control class the learning process was carried out without using PBL-STEM. Meanwhile, the dependent variable is students' critical thinking skills in learning reaction rate.

This critical thinking skill is measured using 5 indicators consisting of giving simple explanations, building basic skills, providing further explanations, concluding, and organizing strategies and tactics. The data obtained through the tests were processed statistically using the Normality test, Homogeneity test, and t-test. The normality test was carried out using the Shapiro-Wilk method with a significant level (α = 5%), then followed by a homogeneity test to determine whether the data came from homogeneous or heterogeneous groups. Homogeneity test results are used to determine the type of statistic that will be used for the t-test. The homogeneity test used is the Levene test with the help of SPSS. The results of Levene's homogeneity test concluded that the data was not homogeneous. Testing the hypothesis that the data is not homogeneous uses non-parametric statistics, namely the Mann-Whitney test. Testing this hypothesis using the SPSS program.

RESULTS AND DISCUSSION

This study is a study that compares students' critical thinking skills between an experimental class taught using PBL-STEM and a control class taught using direct learning. The data is obtained from the results of tests based on 5 indicators of critical thinking skills. The results of the post-test average scores for each indicator of students' critical thinking skills can be seen in Table 2.

Table 2. Average Students' Critical Thinking Skills

	Post-Test Average Score	
Indicators	**Control Class (without using PBL-STEM)**	**Experiment Class (using PBL-STEM)**
Making Simple Explanations	100	100
Building Basic Skills	75	100
Making Conclusions	67	75
Making Further Explanations	66	70
Setting Strategy and Tactics	80	100

The data obtained were then analyzed by normality test, homogeneity test, and then hypothesis testing to find out whether or not there was an effect of the application of PBL-STEM in the experimental class and conventional learning in the control class on the reaction rate material. The results of the analysis of student data in the control and experimental classes are presented in Table 3.

Table 3. Post-test results for students' critical thinking skills in the control class and experimental class

Class	**Average Value of Students**		**F test**	**t test**
	Post Test	**Category**		
Control	77	High	0,031	0,000
Experiment	89	Very High		

Based on Table 3, it can be seen that the experimental class and the control class in the Shapiro-Wilk normality test obtained sig. (2-tailed) respectively $0.301 \geq 0.050$ and $0.050 \geq 0.050$, both of which can be concluded that HO is accepted which means that the samples are normally distributed. Then, the results of Levene's test homogeneity test obtained sig. (2-tailed) of $0.031 \leq 0.050$, it can be concluded that the data is not homogeneous. Testing the hypothesis that the data is not homogeneous uses non-parametric statistics, namely the Mann-Whitney test. Testing this hypothesis using the SPSS program and obtained sig. (2-tailed) in both classes is $0.000 < 0.050$ then Ha is accepted with the statement that there is an effect of the application of PBL-STEM on students' critical thinking skills in the matter of reaction rates.

Students' critical thinking skills in this study were measured using a test instrument consisting of 5 essay questions representing five indicators of critical thinking skills. The indicators provide a simple explanation, and the questions given ask students to explain what is meant by reaction rate. Indicators provide a simple explanation illustrated in the PBL-STEM model step, namely at the problem orientation stage. At this stage, the teacher gives a problem to students related to phenomena caused by human behavior. Students will first understand the problem, then relate it to the chemical concepts they have learned and understand what kind of solution is expected. PBL-STEM is a solution that can be applied to the problems previously described (Adiwiguna et al., 2019; Octafianellis et al., 2021; Putri et al., 2020). According to Lita et al. (2019) that the process of learning new things will be more effective if the learner is in an active condition, by stimulating students to investigate or study the subject matter on their own without prior explanation from the teacher.

Indicators for building basic skills (basic support) are indicators that aim to train students to be skilled in solving problems based on proper procedures and several appropriate sources (Arung, 2022). In this indicator, students are given questions about the order of the reaction and ask students to determine what the order of the reaction is. The second syntax in PBL-STEM is a student organization in the form of activities to process data obtained from problems that have been formulated and then describe the answers or problems that exist. This shows that the application of the PBL-STEM model can make students skilled in critical thinking and able to solve problems based on appropriate procedures on how to calculate reaction orders. This statement is in line with research conducted by Adiwiguna et al. (2019) and Octafianellis et al. (2021), in STEM-oriented Problem-Based Learning (PBL) there is an identification process, in which students build basic skills in critical thinking.

Indicators provide further explanations aimed at providing opportunities for students to collect relevant information and train students to make a conclusion that can be used as a shared principle for all the same problems. In this indicator, researchers analyze critical thinking skills in the form of defining terms and considering definitions using appropriate criteria, and identifying assumptions. Indicators provide further explanations illustrated in the PBL-STEM step, namely at the guiding investigation stage, that invites students to work together to explain concepts using prior exploratory experiences as a foundation, followed by proof, and introduces new terminology or concept explanation definitions (Putri et al., 2020; Setyorini et al., 2021).

At this stage, students are given problems, then required to record all information related to existing problems and make conclusions about the factors that influence the rate of reaction associated with the collision theory. The flow of good thinking and some concepts are interrelated and integrated so that students can explain the reaction rate factor associated with collision theory. This shows that PBL-STEM makes students able to think critically in providing an argument and processing the information that has been obtained about the reaction rate factors associated with collision theory. Cahyaningsih & Roektiningroem (2018) state that the PBL-STEM model can improve critical thinking skills and cognitive learning outcomes. Through PBL-STEM students demonstrate positive attitudes, achieve integrated conceptual and procedural knowledge, and demonstrate active behavioral intentions (Lou et al., 2011; Putri et al., 2020).

Making conclusions means identifying the elements needed to conclude data, reports, principles, judgments, beliefs, or opinions (Ika et al., 2016). The concluding indicator is illustrated in the PBL-STEM step, namely at the stage of analyzing and evaluating the problem-solving process. The answers given by students to this question on average students answered correctly. This shows that students can think critically in concluding the fastest iron rusting process. This study is in line with Lita et al. (2019), the influence of the PBL-STEM model on students' mastery of concepts occurs because students are allowed to solve problems related to the concept of subject matter that must be achieved during the lesson. In the process of solving problems and presenting integration through the STEM approach, students are required to master knowledge from the four fields related to the problems presented to find the right solution to the problem (Ariyatun & Octavianelis, 2020).

Indicators governing strategies and tactics are indicators that aim to train students to think critically in solving problems and determining actions based on evidence and appropriate procedures and appropriate sources (Arung, 2022). The indicators governing strategy and tactics are reflected in the PBL-STEM step, namely guiding investigations, in the form of processing data obtained from the problems that have been formulated and then describing the answers or problems that exist. Based on the answers given by the students, they were able to solve the questions correctly according to the right steps. This indicates that PBL-STEM students can think critically in analyzing and processing data, and in this case, it shows that students are actively involved in learning activities as evidenced by students who are very enthusiastic during learning (Ariyatun & Octavianelis, 2020; Putri et al., 2020). This research is in line with the research of Nars & Ramadan (2008) which says that PBL-STEM learning can help students to think critically especially when the problems given are related to the real world. This can encourage students to be passionate about learning.

There was an influence on students' critical thinking skills in the experimental class because the experimental class was given the treatment of applying PBL-STEM to make students more active and provide curiosity so that students can easily solve problems with their knowledge based on evidence and facts. STEM integration in the learning process can also improve students' critical thinking skills because STEM provides students with opportunities to identify real-life problems and find a solution, which is by the characteristics of PBL, so that the integration of PBL and STEM can be applied and can provide more effective results in improving students' critical thinking skills (Wahdaniyah et al., 2023). The PBL-STEM model, when applied with different learning delivery, can make students more enthusiastic when learning takes place. Thus, it will have an impact on increasing critical thinking skills and learning achievements of these students (Reza et al., 2020).

CONCLUSION

Based on the results of this analysis, it can be concluded that there is an effect of the application of PBL-STEM on critical thinking skills in the matter of reaction rate. This study showed a positive effect, namely the average post-test of the experimental class was better than the control class.

RECOMMENDATIONS

Based on the research that has been done, the researcher proposes several suggestions, namely:

1. Based on the results of this study, it can be used as initial information for future researchers on the application of PBL-STEM to improving students' critical thinking skills in chemistry with other chemistry subjects.
2. It is necessary to prepare well before starting learning so that it makes it easier for students to accept learning.

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