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EFFECT OF IMPLEMENTING PROBLEM-BASED LEARNING USING SCIENTIFIC APPROACH ON ENHANCING CRITICAL THINKING

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ABSTRACT

This study aims to evaluate the impact of implementing a Problem-Based Learning (PBL) model grounded in a scientific approach on enhancing students' critical thinking skills in the topic of reaction rates. The primary issue addressed is the students' limited ability to think critically when grasping abstract chemical concepts. The research employs a quasi-experimental method with a Nonequivalent Control Group Design. The population consists of eleventh-grade science students at SMA Negeri 1 Batauga, with a sample of 40 individuals selected via purposive sampling and divided into a treatment class (20 students) and a comparison class (20 students). Research instruments include essay tests to assess critical thinking skills, observation sheets for learning activities, and student response questionnaires. Data analysis involves N-gain calculations to measure score improvements, along with t-tests to identify significant differences between groups at a 0.05 significance level. Findings reveal that the average post-test score for critical thinking in the treatment class (13.55) exceeds that of the comparison class (10.30). The average N-gain value for the treatment class is 0.28, surpassing the comparison class's 0.20, though both fall into the low category. The t-test yields a t-calculated = 2.230 > t-table = 2.024, indicating a significant difference between the groups. Furthermore, student activities during the science-based PBL instruction reached an outstanding category (82%), and student responses achieved an average score of 2.96 in the good category.

Keywords: Critical Thinking; Problem-Based Learning; Scientific Approach.

INTRODUCTION

Critical thinking skills are one of the essential competencies that students must master in the 21st-century education era, as they serve as a crucial foundation in decision-making processes, problem-solving, and the development of scientific reasoning (Halimah et al., 2023). In chemistry learning, these skills are highly needed because students are required to analyze events, break down problems, and interpret data as well as scientific facts (Imanah et al., 2023). One chemistry topic that demands high cognitive proficiency is reaction rates, which relate to changes in substance concentrations during reactions and influencing factors such as concentration, temperature, surface area, and catalysts (Santa Ira Yustina Mersa et al., 2024). Several studies have found that many students still struggle to understand this concept due to overly theoretical presentations and a lack of connection to real-life situations (Arwin et al., 2025; Sagita et al., 2021).

The Problem-Based Learning (PBL) instructional model is considered adequate for fostering critical thinking skills. PBL focuses on solving contextual problems through group collaboration, independent information seeking, and idea communication (Yulianti & Gunawan, 2019). This approach encourages students to develop scientific thinking methods while enhancing analysis and argumentation abilities ('Adiilah & Haryanti, 2023; Mareti & Hadiyanti, 2021). PBL is also aligned with the scientific approach in the 2013 Curriculum, which includes stages of observing, questioning, experimenting, reasoning, and communicating (Eha et al., 2024). The scientific approach aims to form rational, systematic, and critical thinking patterns during the learning process (Yudha, 2019). Research results demonstrate that integrating PBL and the scientific approach enhances critical thinking skills while deepening students' conceptual understanding (Ariani & Lubis, 2024; Hermayuni et al., 2022).

Students engaged in PBL-based learning demonstrate higher levels of involvement, the ability to construct logical arguments, and more active discussion (Alkamalia, 2024). This method also enables students to connect chemistry concepts with everyday life experiences, thereby fostering motivation to study the material further (Agustinus et al., 2023; Novianti, 2024). Aritonang & Moondra Zubir (2022) affirm that problem-solving-based chemistry learning supports an applicative understanding of chemical reaction processes. Additionally, research by Kusuma & Mujiono (2019) shows that the combination of PBL and the scientific approach can significantly sharpen students' critical thinking abilities.

Not only does it enhance knowledge aspects, but the combination of the scientific approach and the PBL model also has a positive impact on students' scientific attitudes and collaborative skills. Through this strategy, students are encouraged to have high curiosity, perseverance, and greater openness to various perspectives (Hasriyani et al., 2022).

Based on direct observations and discussions with students, as well as interviews with the chemistry teacher at SMA Negeri 1 Batauga, it was found that learning on the reaction rates topic is primarily focused on delivering material from the textbook and solving printed exercises. Students receive insufficient guidance on connecting the learned concepts to everyday phenomena, and teachers rarely present various problems faced by students along with resolution strategies. This limits students' opportunities to develop their thinking skills in addressing diverse issues scientifically through simple experiments using readily available tools and materials in the school environment. Therefore, this research is essential to assess the influence of implementing Problem-Based Learning (PBL) based on a scientific approach in developing critical thinking skills among eleventh-grade students on the reaction rates topic at SMA Negeri 1 Batauga, with the following research questions:

1. Is there a difference in the average critical thinking skills scores between students taught using the PBL model based on a scientific approach and those taught using conventional learning, before and after the intervention?
2. Is there a difference in the average N-gain scores for critical thinking skills between students taught using the PBL model based on a scientific approach and those taught using conventional learning?
3. What are students' responses to the implementation of the PBL model based on a scientific approach on the reaction rates concept?

RESEARCH METHODS

This research employs a quasi-experimental method with a Nonequivalent Control Group Design (Sugiyono, 2019). The research subjects consist of two classes with balanced academic ability levels.

The first class is designated as the experimental group, which receives treatment in the form of implementing the Problem-Based Learning model based on a scientific approach. The second class serves as the control group, taught using a traditional teaching model, namely lectures and question-and-answer sessions. Both classes receive different treatments, followed by the administration of identical post-tests in the form of essay questions.

During the implementation of the learning process, student activities are monitored using observation instruments. Additionally, to explore students' views on the use of the Problem-Based Learning model based on a scientific approach, the researcher distributes questionnaires after the learning process is completed. Thus, the data obtained come not only from test results but also from direct observations and student responses.

The research population includes all XI IPA students at SMA Negeri 1 Batauga, Buton Regency, Southeast Sulawesi Province, totaling 80 individuals. The research sample is selected through purposive sampling, comprising 40 students, divided equally between the experimental class (20 students) and the control class (20 students). This sample selection is carried out to ensure alignment with the research objectives.

The instruments used for data collection include Critical Thinking Skills Test on reaction rates, observation sheets, and questionnaires. The tests, in the form of essay questions, are used to measure students' critical thinking abilities. The effectiveness of the learning model implementation is analyzed by calculating the normalized gain (N-gain) to compare the two groups. According to Hake (1999), the N-gain calculation is performed using the formula explained in (Rohmah et al., 2021)

$$g = \frac{S_{post} - S_{pre}}{S_{maks} - S_{pre}}$$

In the formula, g represents the normalized gain value (N-gain), with Spost as the post-test score, Spre as the pre-test score, and Smaks as the maximum score that can be obtained. The N-gain assessment categories are divided into three: high ($g \geq 0.7$), medium ($0.3 \leq g < 0.7$), and low ($g < 0.3$). These criteria are used to interpret the extent of improvement in students' critical thinking abilities that occurs after the treatment is administered.

Student activities during the learning process are assessed through observation sheets using a scale of 0–4. This scale includes categories: excellent (3.01–4.00), good (2.01–3.00), sufficient (1.01–2.00), and poor (0.00–1.00). All obtained scores are averaged and then presented qualitatively to provide a comprehensive overview of students' engagement in learning activities.

Meanwhile, students' perceptions of the learning are collected through a Likert-scale questionnaire with four response alternatives: strongly agree (SA), agree (A), disagree (D), and strongly disagree (SD). For positive statements, the scoring weights are set as SA = 4, A = 3, D = 2, and SD = 1. Conversely, for negative statements, the scores are reversed so that SA = 1, A = 2, D = 3, and SA = 4 (Ruseffendi, 1998). The questionnaire results are then analyzed qualitatively through the overall average score of the respondents.

The critical thinking skills test instrument was developed based on critical thinking indicators within the context of the reaction rate topic. The constructed essay items were then validated by three experts, namely two chemistry education lecturers and one senior high school chemistry teacher. Before being used in the main study, the test was piloted on a limited sample of 34 students in grade XII science, who had already studied the reaction rate topic, to ensure the quality of the instrument. The pilot data were used to calculate validity and reliability in order to determine the level of the instrument's internal consistency.

RESULTS AND DISCUSSION

Validity and Reliability Test

Based on the validity test conducted, the results are presented in the following Table 1.

Table 1. Critical Thinking Skills Validity Test

Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Validity	0,500	0,494	0,564	0,451	0,700	0,772	0,761	0,735	0,694	0,558
r_{table}	0,339	0,339	0,339	0,339	0,339	0,339	0,339	0,339	0,339	0,339
Criteria	valid	valid	valid	valid	valid	valid	valid	valid	valid	valid

Based on the validity test, all 10 items have validity coefficients ranging from 0.451 to 0.772, all of which are greater than the r-table value of 0.339. Thus, all items are declared valid and suitable for use as a test instrument in the research.

Based on the reliability test carried out, the results are presented in Table 2 below.

Table 2. Reliability Test of Critical Thinking Skills

Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Variance	1,077	1,533	0,910	0,986	1,119	0,851	1,205	0,734	0,928	0,474
Sum of Variances	9,817									
Total variance	37,05536									
r_{11}	0,817				**Reliability Criteria**					

The reliability test on the 10 critical thinking skills items produced a reliability coefficient of [insert value here], which falls into the high category. Thus, the test instrument is declared reliable and consistent for measuring students' critical thinking skills.

2. Improvement in Critical Thinking Skills

The results of data processing in the form of pre-test scores, post-test scores, and N-gain values that describe critical thinking abilities on the reaction rate material, both in the treatment class and the comparison class, can be seen briefly in the following Table 3.

Table 3. Description of Critical Thinking Ability Scores for Reaction Rate Concept

	Treatment Class			**Comparison Group**		
	Pre-test	***Post-test***	**N-Gain**	***Pre-test***	***Post-test***	***N-Gain***
Avarage	3.20	13.55	0.28	3.15	10.30	0.20
Standard Deviation	1.20	5.37	0.14	1.53	4.38	0.10
Number of Students	20	20	20	20	20	20

Note: Ideal Score = 40

Based on the data in Table 1, the average post-test score for students' critical thinking abilities in the treatment class reached 13.55, while in the comparison class it was 10.30. This indicates that the average achievement of the treatment class is higher than that of the comparison class. Additionally, the standard deviation of the treatment class is larger than that of the comparison class, meaning that the distribution of critical thinking ability scores in the comparison class is narrower or less varied. Thus, the critical thinking abilities of students on the reaction rate material in the treatment class are more diverse compared to the comparison class.

The results in Table 1 also show that the average N-gain value for critical thinking abilities on the reaction rate concept for students in the treatment class is 0.28. In contrast, the comparison class obtained an average of 0.20. Both values are still classified in the low category, although the achievement of the treatment class approaches the medium category. These findings indicate an improvement in critical thinking abilities after learning, where the treatment class shows better results compared to the comparison class.

In this study, the critical thinking abilities evaluated involve three main aspects, namely: (1) evaluating simple descriptions, for example, determining important elements and revealing similarities and differences; (2) developing basic abilities, which include presenting justifications and conveying reports from observation findings; and (3) drawing conclusions, both by applying principles and constructing inferences. The achievement of each indicator is analyzed using pre-test scores, post-test scores, and N-gain values. The average N-gain results for each indicator in both classes are visualized in the form of a diagram in Figure 1.

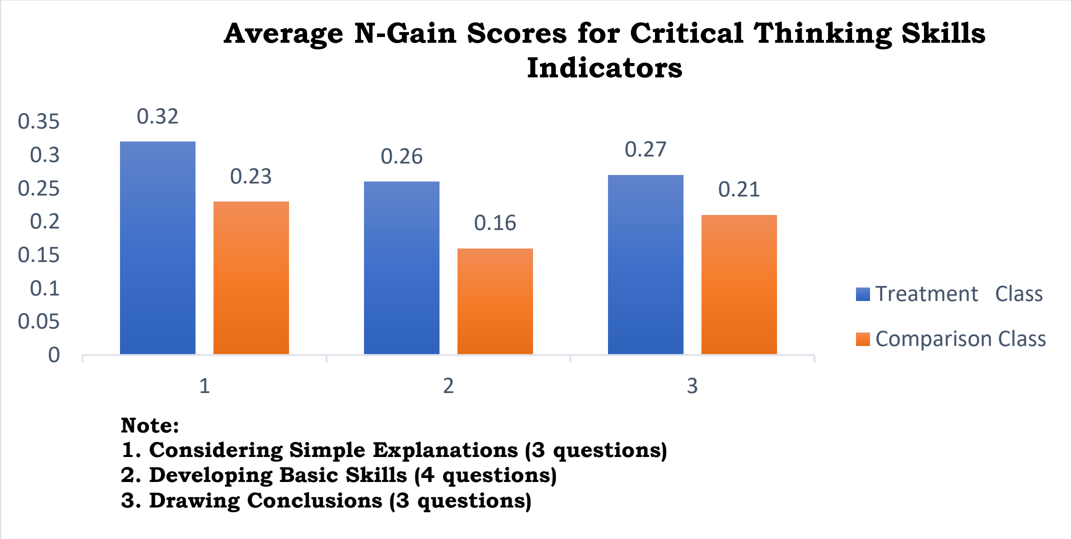

Figure 1. Average N-Gain Scores for Each Critical Thinking Skill Indicator

Based on Figure 1, it is evident that both in the treatment class and the comparison class, there is an improvement in students' critical thinking abilities on each indicator. The lowest N-gain value is found on the Developing Basic Skills indicator, namely 0.26 in the treatment class and 0.16 in the comparison class. Conversely, the highest score is on the Considering Simple Explanations indicator, with achievements of 0.32 for the treatment class and 0.23 for the comparison class. These analysis results show that, overall, students in the treatment class who underwent the learning process by applying the PBL model based on a scientific approach achieved an N-gain improvement, demonstrating superior performance compared to the comparison class that applied the traditional teaching model.

To ensure the presence of significant differences between the two classes, hypothesis testing was conducted using a t-test. The calculation yielded a t-calculated value = 2.230, while the t-table value at a significance level of 0.975 is 2.024. Because t-calculated > t-table, H0 is rejected. Thus, the average N-gain score of students' critical thinking abilities who learned using the Problem-Based Learning model based on a scientific approach is significantly higher compared to students who received traditional teaching.

Student Activities during the Learning Process of the PBL Model Based on a Scientific Approach

Student Activities

The observation results of student activities in the implementation of the PBL model, based on a scientific approach, are presented in Table 2. The results show that the most prominent activity during learning is students' readiness to participate in the practicum, with a percentage reaching 100%. This condition occurs because, from the beginning of the meeting, the teacher has directed each group to prepare the necessary tools and materials. Meanwhile, the activity with the lowest percentage is the group discussion, which reaches only 64%. In general, the classroom atmosphere appears quite dynamic and enthusiastic, evident from the active interactions between teachers and students during the practicum. The overall implementation level of the learning stages falls into the excellent category with a percentage of 82%.

Table 4. Student Activity Data in the PBL Model Based on the Scientific Approach

No.	Activity Type	Max Score	Average Activity (%)			Overall Average (%)
			Meet.1	Meet.2	Meet.3	
1	Student preparation for practicum or demonstration	2	100	100	100	100
2	Distribution of student worksheets in groups	3	67	90	90	82
3	Student activeness in practicum activities	3	67	67	67	67
4	Group discussion activities	3	67	57	67	64
5	Presentation of work results	2	100	90	90	93
6	Feedback on the presentation of work	3	83	90	90	88
Overall Average						82

Student Responses to the Use of the PBL Model Based on a Scientific Approach

The analysis of the student response questionnaire results regarding the implementation of the PBL model, based on a scientific approach to the reaction rate concept, can be summarized in Table 5.

Table 5. Average Scores of Student Responses to the PBL Model Based on a Scientific Approach

No	Student Responses	Average Score
1.	The Problem-Based Learning Model Based on a Scientific Approach is a new learning model for students	2.88
2.	The Problem-Based Learning Model Based on a Scientific Approach is a learning model that motivates students and is interesting	2.95
3.	The Problem-Based Learning Model, based on a Scientific Approach can overcome students' difficulties in understanding chemistry	2.95
4.	Students' liking or disliking of group learning in the Problem-Based Learning Model Based on a Scientific Approach	2.75
5.	Utilization of Student Worksheets in Understanding Chemistry	3.20
6	The Problem-Based Learning Model, based on a Scientific Approach, can overcome students' difficulties in completing tasks given by the teacher	2.98
7	The Problem-Based Learning Model, based on a Scientific Approach, can improve students' skills in using practical tools	2.78
8	The Problem-Based Learning Model, based on a Scientific Approach, can foster students' thinking skills	3.18
	Average	**2.96**

Based on Table 3, students responded positively to the implementation of the Problem-Based Learning Model based on a Scientific Approach, as it is considered capable of improving critical thinking abilities and is expected to be applied to other chemistry materials as well. Overall, students' responses to the Problem-Based Learning Model based on a Scientific Approach obtained an average score of 2.96, which falls into the good category.

CONCLUSIONS

Based on the research findings, it can be concluded that (1) There is no significant difference in the average score of critical thinking skills between students taught using the PBL model with a scientific approach and those taught using conventional learning before the intervention, as indicated by t-count = 0.12 < t-table = 2.024 at $\alpha = 0.05$. However, after the intervention, the average score of critical thinking skills of students taught using the PBL model with a scientific approach was significantly better than that of students taught using conventional learning, as indicated by t-count = 2.97 > t-table = 2.024 at $\alpha = 0.05$. (2) The average N-gain score of critical thinking skills of students taught using the PBL model with a scientific approach was significantly better than that of students taught using conventional learning, as indicated by t-count = 2.230 > t-table = 2.024. (3) Student responses to the application of the PBL model of scientific approach to the topic of reaction rates showed positive results in terms of efforts to improve critical thinking skills.

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