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The Effect of Socio-Critical and Problem-Oriented Approaches on Students' Critical Thinking Skills in Green Chemistry Learning

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Abstract
Critical thinking skills play an essential role in enabling students to understand scientific concepts and solve problems logically and reflectively. However, the 2022 PISA results indicate that Indonesian students still demonstrate low performance in this area, particularly in chemistry learning, which often emphasizes memorization rather than reasoning. This study aims to analyze the effect of an integrated Socio-Critical and Problem-Oriented approach on students' critical thinking skills in green chemistry learning at State Senior High School 1 Sintang. This research employed a quantitative method with a pre-experimental One Group Pretest–Posttest Design involving 30 students from class XC. Data were collected through classroom observations and critical thinking tests covering five indicators: interpretation, analysis, evaluation, inference, and explanation, and were analyzed using normality tests, homogeneity tests, and t-tests. The findings reveal a significant improvement in students' critical thinking skills after the implementation of the integrated approach. These results indicate that embedding socio-scientific and contextual environmental issues within problem-oriented green chemistry learning effectively enhances students' critical thinking skills at the senior high school level.

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INTRODUCTION

Critical thinking skills are an individual's ability to analyze, evaluate, and process information logically and objectively to produce appropriate and effective decisions. Critical thinking also reflects the ability to examine an argument in depth and build a more meaningful understanding of an issue (Kartimi, 2012). Furthermore, critical thinking is seen as an intellectual process carried out persistently to test the truth of knowledge through relevant and valid evidence, so that accurate conclusions can be drawn (Asmawati, 2015).

According to Ariadila et al. (2023), critical thinking skills play a crucial role in the learning process. Students who are able to apply these skills tend to understand material more easily, solve problems, and perform better in exams and learning evaluations. Therefore, critical thinking skills need to be developed and instilled early on as part of a continuous educational process. However, the achievement of Indonesian students in the Programme for International Student Assessment (PISA) 2022, as reported by the OECD, shows that students' science literacy remains below the international average (OECD, 2022). Since PISA science assessments emphasize the ability to analyze information, evaluate scientific evidence, and apply scientific concepts in contextual situations, the low performance of Indonesian students indicates limitations in students' critical thinking skills, which are fundamental to effective chemistry learning. This condition highlights the urgency of implementing learning approaches that explicitly develop students' critical thinking skills in chemistry education.

Learning green chemistry requires students to develop critical thinking skills because they are expected to be able to answer questions by connecting chemical concepts to everyday life phenomena as well as social and environmental issues. This aligns with the opinion of Ariadila et al. (2023), who stated that chemistry learning encourages students to apply critical thinking skills by linking chemical concepts to real-life contexts. Therefore, green chemistry is a relevant topic to be implemented in chemistry learning because it requires the use of innovative, contextual, and applicable learning strategies so that students can meaningfully understand the principles of environmentally friendly chemistry. However, in practice, green chemistry learning in schools still tends to be conventional and monotonous, and lacks relevant contextual examples. As a result, students experience difficulties in understanding the material, developing critical thinking skills, and connecting green chemistry concepts to real-life problems (Maulidiningsih & Kusumaningrum, 2023).

The results of the initial measurement conducted among Grade 10 students at State Senior High School 1 Sintang revealed similar conditions. The data showed that only 12% of students demonstrated good levels of critical thinking skills, while the majority were categorized as having adequate to low levels. These findings indicate that chemistry instruction has not yet provided adequate opportunities for students to reason, analyze, and connect chemical concepts with real-life problems, reinforcing the need for innovative and student-centered learning approaches.

Previous studies have further supported this issue. Everett et al. (2018) and Ramos (2018) reported that students' low critical thinking skills are largely attributed to learning processes that remain focused on memorization and offer limited opportunities for exploration, argumentation, and reflective thinking. Conversely, Feierabend and Eilks (2011) demonstrated that learning based on social issues can increase student engagement and foster critical thinking skills. In line with these findings, the Socio-Critical and Problem-Oriented approach proposed by Eilks et al. (2008) emphasizes the integration of social issues into science learning as a means of developing awareness, responsibility, and critical thinking.

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The Socio-Critical and Problem-Oriented approach represents a pedagogical framework that differs from commonly used instructional methods such as lectures, direct instruction, and conventional discussions. This approaches students positions as active participants who not only understand chemical concepts but are also encouraged to analyze and critically evaluate chemical problems within social and environmental contexts. This approach also helps students build a thorough and meaningful understanding of concepts. In line with this view, Zeidler et al. (2005) stated that integrating scientific content with social issues enables students to develop a holistic perspective on the application of science in real life. This supports a learning process that is not only theoretical but also relevant to the problems faced by society. Furthermore, learning based on current issues around students can accustom them to critical thinking and better prepare them to face real-world challenges in their environment (Wijaya et al., 2018).

As evidenced by the findings of Purwanto et al. (2022), their research results showed that 50% of students were in the good category and only 10% were in the poor category. Based on these findings, applying a socio-critical and problem-oriented approach in the context of chemistry learning, particularly on the topic of green chemistry, is believed to be an effective strategy for developing students' critical thinking skills. The integration of real-world issues through this approach has been shown to significantly support the development of students' critical thinking skills by promoting reasoning, reflection, and scientifically grounded decision-making.

Moreover, this approach aligns with the principles of green chemistry introduced by Sudarmin (2013), as it encourages students to consider environmentally friendly and sustainable chemical solutions.

Despite these theoretical and empirical supports, chemistry learning at the senior high school level has rarely applied the Socio-Critical and Problem-Oriented approach in an integrated manner within the context of green chemistry. As a result, empirical evidence regarding its effectiveness in systematically improving students' critical thinking skills remains limited. Therefore, this study aims to examine the effectiveness of the Socio-Critical and Problem-Oriented approach in improving students' critical thinking skills through the integration of social and environmental issues in green chemistry learning at the senior high school level.

METHOD

Research Design

This study employed of One Group Pretest-Posttest design aimed at improving students' critical thinking skills through the implementtation of the Socio-Critical and Problem-Oriented approach in green chemistry learning. The research was conducted in the first semester of the 2025/2026 academic year at State Senior High School 1 Sintang. Here is Table 1. Design of One Group Pretest- Posttest:

Table 1. One Group Pretest- Posttest Design

Pretest	treatment	Postest
X1	Y	X2

(Arib et al., 2024)

Description:

X1 : Pretest before the implementation of the Socio-Critical and Problem-Oriented approach.

X : Implementation of the Socio-Critical and Problem-Oriented approach in the learning process.

X2 : Posttest after the implementation of the Socio-Critical and Problem-Oriented approach.

Participants

The participants consisted of 30 students from one randomly selected class (Class XC) at the senior high school level. The sample was determined using cluster random sampling, a probability-based technique in which intact groups (clusters), such as classes, are randomly selected to represent the population; this approach is commonly used in educational research when individual randomization is impractical and group membership is naturally formed by class structures. This sampling technique was applied to ensure practical feasibility while maintaining randomness at the cluster level and minimizing potential selection bias (Ayu et al., 2023).

The sample size of 30 students was determined based on methodological considerations, as it meets the minimum number commonly recommended for basic statistical analyses and supports the use of parametric tests under the assumption of normally distributed data. Within the framework of a One Group Pretest–Posttest Design, this sample size is considered sufficient to detect differences between pre-test and post-test scores and to evaluate the effectiveness of the implemented instructional intervention.

Instrument

The instruments used in this study included lesson modules, worksheets (LKPD), evaluation tests (pre-test and post-test), and documentation. Critical thinking skills were measured using five indicators adapted from Facione (2011), namely interpretation, analysis, evaluation, inference, and explanation.

Procedures

The study followed the One Group Pretest–Posttest Design, referring to Arib et al. (2024). The research procedures consisted of:

1. Selecting participants from class XC using simple random sampling, ensuring that all students who met the inclusion criteria had an equal opportunity to be included in the study sample.
2. Administering a pre-test to measure students' initial critical thinking skills before the intervention.
3. Implementing the Socio-Critical and Problem-Oriented approach in green chemistry lessons, conducted over two consecutive instructional meetings. The application of the Socio-Critical and Problem-Oriented approach in green chemistry learning was carried out over two consecutive learning meetings. At the beginning of each meeting, students were presented with images containing socio-scientific issues to stimulate critical questioning and problem identification. Next, students worked collabo-

ratively through paper-based worksheets containing social and environmental issues to analyze the problems using relevant chemical principles, evaluate the environmental and social impacts of conventional chemical practices, and propose alternative solutions aligned with the principles of green chemistry as articulated by Sudarmin (2013),. Throughout the learning process, the teacher acts as a facilitator by guiding discussions, encouraging evidence-based arguments, and guiding students to reflect on ethical and sustainability aspects. Implementing the learning process over two consecutive sessions allows students to gradually refine their reasoning, link theory to practice, and critically justify proposed solutions within the context of green chemistry.

4. Administering a post-test after the two-day treatment to assess students' final abilities.
5. Comparing pre-test and post-test scores to measure improvements in students' critical thinking skills, as reflected in their ability to analyze problems, evaluate evidence, and formulate reasoned conclusions as a result of implementing the Socio-Critical and Problem-Oriented learning approach.

The percentage score of critical thinking skills was calculated using the following formula. The percentage score was calculated using the formula:

$$P = \frac{R}{SM}\ x\ 100$$

Description:
P = percentage score
R = score obtained
SM = maximum score
100 = Determination.
The interpretation criteria followed Arikunto (2013), as shown in Table 2.

Table 2. Interpretation of Critical Thinking Score

Value Range (%)	Category
81 – 100	Very Good
61 – 80	Good
41 – 60	Fair
21 – 40	Poor
0 – 20	Very Poor

Data Analysis

Normality Test

The normality test is one of the statistical tests used to find out whether a data set is from a normal distribution population or not. normal or not (Nurhaswinda et al., 2025). In this study, the data contains the results of the initial and final test of the sample, the normality test is tested with the aim of distributing data on a data group or distributing normally.

Homogeneity Test

Homogeneity testing is a statistical test procedure that is intended to show that two or more sample data groups are from populations that have the same variance. In this study, the data contains the results of the initial and final test of the sample, the homogeneity test is tested with the aim that the data set studied has the same characteristics (Nurhaswinda et al., 2025).

Paired Sample t-Test

Paired sample t-test is one of the test methods used to assess the effectiveness of treatment, marked by differences in the average before and after treatment. For the results of the Paired T-Test, if there is a difference in the critical thinking skills test score before and after treatment, the result is a score ($p < 0.05$), which means that there is a significant difference in the critical thinking skills test score before and after treatment (Rahmani et al., 2025).

Paired Sample Effect Size

Effect size is a statistical measure used to determine the extent of influence of one variable on another variable in a study. This measure indicates the effectiveness of a treatment or independent variable in impacting the dependent variable. Effect size also illustrates the practical significance of research results, expressed through the magnitude of the relationship, difference, or influence of one variable on another (Santoso, 2010). Cohen's d effect size is a statistical measure used to determine the magnitude of a treatment's influence on a dependent variable based on the mean difference normalized by the standard deviation. Interpretation of Cohen's d values refers to the categories of small (<0.2), medium (≈0.5), and large (≥0.8). Values included in the large category indicate that the treatment has a significant practical impact on the research results (Lakens, 2013; Field, 2018).

RESULTS AND DISCUSSION

The implementation of research on the application of socio-critical and problem-oriented approaches to students' critical thinking skills in green chemistry learning was carried out in two meetings. The activity began with the provision of initial tests (pre-actions), then continued with the

implementation of learning actions, and ended with the provision of final tests. The application of a socio-critical and problem-oriented approach to students' critical thinking skills in green chemistry learning is evidenced by the increase in final test scores of students in class XC of State Senior High School 1 Sintang. One of the reasons for this increase in final test scores is due to the majority of students being more motivated and active when learning chemistry in green chemistry materials. This is in accordance with the research of Feierabend and Eilks (2011) which states that social issue-based learning is able to increase student involvement and strengthen critical thinking skills. To provide a clearer comparison of student achievement before and after the implementation of the Socio-Critical and Problem-Oriented approach, the percentage of scores obtained in the pretest and posttest are visualized in a bar chart in Figure 1. as follows.

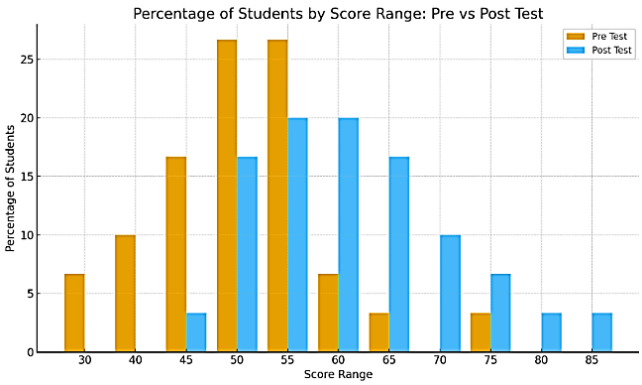

Figure 1. Comparison of Students' Percentage Scores in The Pretest and Posttes

Based on the results in Figure 1, it can be seen that the distribution of students' grades has experienced a clear shift from the low score range to the higher score range. On the pretest, most students were concentrated in the 45–55 grade range as indicated by the dominance of the percentage of orange bars, while the higher grade range (65–85) barely contributed, indicating that the students' initial abilities were still relatively low prior to the implementation of the Socio-Critical and Problem-Oriented approach. On the other hand, in the posttest there was a significant increase, marked by an increase in the percentage of students in the 60–85 score range through the dominance of blue bars, especially in the 60–70 range and even reaching 80–85.

The first stage was the normality test using Shapiro–Wilk, which showed that both the pre-test and post-test data had a significance value greater than 0.05. These results indicate that the data distribution is under normal conditions so that it meets the basic assumptions for advanced analysis.

The next stage is the variance homogeneity test which is used to ensure the uniformity of the variance between the two measurement groups. The test results show a significance value above 0.05, so it can be concluded that the data variance is homogeneous and the parametric test can be applied appropriately. Once these two prerequisites are met, the analysis is continued with a paired t-test to determine the significance of the difference between the pre-test and post-test scores. The results of which are presented in the following Table 3.

Table 3. Paired Samples Test Results

Statistic	Value
Comparison	Pretest – Posttest
Mean Difference	−11.00
Standard Deviation (SD)	5.783
Standard Error (SE)	1.056
95% CI Lower	−13.160
95% CI Upper	−8.840
t value	−10.418
Degrees of Freedom (df)	29
Sig. (2-tailed)	< .001

The results of the paired t-test are shown in Table 3, showed a statistically significant difference between the pre-test and post-test scores (Sig. 2-tailed = 0.000). Because the significance value is less than 0.5, this means that the hypothesis *H0*, which states that "there is no influence of socio-critical and problem-oriented approaches on students' critical thinking skills in green chemistry learning," is rejected.

The rejection of *H0* results in the acceptance of *H1*, which states that there is an influence of socio-critical and problem-oriented approaches on students' critical thinking skills in green chemistry learning. The acceptance of this hypothesis is evidenced by the difference in the average pretest and posttest scores, where the average posttest score is higher than the average pretest score. The following results of the effect size calculation are presented in Table 4. The results of the effect size test Seen using Cohen's d correction, obtained a value of −1.877, which when viewed through the Cohen's d effect size interpretation guide shows a very large influence of learning treatment on student learning outcomes.

Table 4. Paired Samples Effect Sizes

Statistic	Value
Comparison	Pretest – Posttest
Effect Size Type	Cohen's d
Standardizer (SD)	5.783
Point Estimate (d)	−1.902
95% CI Lower	−2.500
95% CI Upper	−1.292

The large effect size is also supported by the increase in the number of students who received moderate to high posttest scores on critical thinking skills interpretation, as shown in Table 5 below.

Table 5. Distribution of Students' Critical Thinking Skills Categories in Pretest and Posttest

Kategori	Pretest	Posttest
Rendah	60%	20%
Sedang	36,67%	56,67%
Tinggi	3,33%	23,33%

Table 5 shows that the distribution of students' critical thinking skills categories has changed. In the pretest, the majority of students were in the low category (60%), but in the posttest, this percentage decreased to 20%. Conversely, the medium category increased from 36.67% in the pretest to 56.67% in the posttest, and the high category increased from 3.33% to 23.33%. These changes indicate that the applied approach is able to improve students' critical thinking skills. The results of this study are in line with the findings of Purwanto et al. (2022) who stated that the application of socio-critical and problem-oriented approaches influences students' critical thinking skills in green chemistry learning.

CONCLUSION

The use of a socio-critical and problem-oriented approach has proven effective in improving students' critical thinking skills in green chemistry learning. This is evident in the dominance of moderate to high critical thinking skills in the post-test results. This improvement is reinforced by the increase in average post-test scores after implementing the socio-critical and problem-oriented approach in green chemistry learning.

RECOMMENDATION

To achieve a more optimal improvement in students' critical thinking skills in green chemistry learning, it is recommended that future studies allocate a longer instructional duration to allow students sufficient time to adapt to the Socio-Critical and Problem-Oriented approach. Further research is also encouraged to examine additional factors that may influence learning outcomes, such as students' learning motivation, interest in learning, prior knowledge, and classroom learning environments. In addition, the integration of varied learning media and contextual socio-scientific issues is suggested to enhance student engagement and support deeper conceptual understanding (Purwanto et al., 2022; Setianingsih et al., 2024).

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