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Problem Based Learning Model to Improve Analytical Thinking Skills of Grade XI Senior High School Students

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Abstract

Thermochemistry remains one of the most challenging topics in senior high school chemistry because students are required to understand abstract concepts, perform quantitative reasoning, and connect chemical phenomena with real-life contexts. However, students' analytical thinking skills in thermochemistry are often still limited, particularly in differentiating, organizing, and attributing information during problem-solving activities. This study aimed to examine the effect of the Problem Based Learning model on improving Grade XI students' analytical thinking skills in thermochemistry. The research employed a quasi-experimental method with a non-equivalent control group pretest-posttest design. The study was conducted at SMA Negeri 1 Kabila during the first semester of the 2025/2026 academic year, involving 49 students divided into an experimental class taught using Problem Based Learning and a control class taught using conventional instruction. Data were collected using a nine-item essay test and analyzed through normality, homogeneity, independent-samples t-test, and N-Gain analysis. The results showed that the data were normally distributed and homogeneous. The independent-samples t-test indicated a significant difference between the two classes, with tcount = 4.055 exceeding ttable = 1.678. The N-Gain results also showed that the experimental class achieved higher improvement across all analytical thinking indicators than the control class. These findings imply that Problem Based Learning is an effective instructional model for strengthening students' analytical thinking skills in thermochemistry.

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1. INTRODUCTION

As a foundational branch of natural science, chemistry encompasses the examination of matter's structure, properties, and composition, as well as the transformations it undergoes and the energy implicated in those processes (Chang & Goldsby, 2016). Within chemistry instruction, learners are expected to build interconnected conceptual frameworks that enable them to address real-world problems encountered in daily life (Sudjana, 2020). Among the various topics within this discipline, thermochemistry is consistently identified as particularly challenging, given its focus on the relationship between thermal energy and chemical change (Fitriani et al., 2023).

Learning thermochemistry requires students to understand energy-related concepts and apply analytical reasoning to solve chemical problems. Students must move beyond merely understanding abstract concepts such as heat, enthalpy, and energy transformations; they are also expected to perform quantitative calculations and interpret contextual problems grounded in everyday situations (Widodo, 2023). Among thermochemistry topics, enthalpy change calculations, including the application of Hess's Law and bond energy, consistently present substantial learning difficulties and are

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associated with low student achievement (Rahmawati & Hasanah, 2024). Students frequently struggle to determine the correct thermochemical equations, apply mathematical relationships, and distinguish between exothermic and endothermic processes (Pratiwi & Lestari, 2021). These concepts are highly relevant to everyday life because they underpin practical phenomena such as calculating the energy efficiency of fuels, understanding heat transfer in cooking, explaining the operation of instant hot and cold packs, and evaluating the energy released during combustion processes. Therefore, inadequate understanding of thermochemistry not only limits students' academic performance but also constrains their ability to apply scientific reasoning to real-world energy-related problems.

Analytical thinking is a higher-order cognitive capacity encompassing three interrelated sub-processes: differentiating, organizing, and attributing information as a means of solving problems (Anderson & Krathwohl, 2021). Within the context of chemistry education, these competencies are essential because they enable students to identify relationships among key concepts, such as heat transfer, enthalpy change, and exothermic or endothermic reactions, and to apply these relationships when solving contextual problems. For example, students are expected to analyze the energy efficiency of fuels, explain heat transfer during cooking processes, or calculate enthalpy changes in combustion reactions based on real-life situations (Nurfaidah & Kurniawan, 2021).

Among the instructional strategies proposed to enhance students' analytical thinking, Problem Based Learning (PBL) has garnered considerable attention. This approach centers on authentic problem-solving tasks pursued through collaborative inquiry, group deliberation, and structured investigative procedures (Mohamad et al., 2023). When implemented systematically, PBL encourages greater learner engagement and has been shown to promote the progressive development of analytical reasoning (Saija et al., 2024).

Grounded in this theoretical and empirical backdrop, the present study was undertaken with the following research focus: ***"The Effect of Problem Based Learning on Improving Students' Analytical Thinking Skills in Thermochemistry for Grade XI Senior High School Students."***

2. METHOD

A quasi-experimental research design was adopted for this study, specifically employing a non-equivalent control group pretest-posttest structure within a quantitative paradigm. The investigation sought to evaluate the extent to which the Problem Based Learning model influenced students' analytical thinking performance. Data collection was carried out at SMA Negeri 1 Kabila throughout the first semester of the 2025/2026 academic year. The accessible population comprised 49 Grade XI students. A purposive sampling technique was employed to select two intact classes based on their comparable academic characteristics and schedule availability. Class XI-4 was designated as the experimental group, while Class XI-2 served as the comparison group. The experimental group underwent instruction structured around the PBL model, while the comparison group was taught through conventional pedagogical methods.

Analytical thinking skills were assessed using a nine-item essay instrument administered as both a pretest and a posttest.

Table 1. Results of Instrument Validity and Reliability Analysis

Item	Correlation (r)	Sig.	Decision
1		< 0,001	Valid
2		< 0,001	Valid
3		< 0,001	Valid
4		< 0,001	Valid
5		< 0,001	Valid
6		< 0,001	Valid
7		< 0,001	Valid
8		< 0,001	Valid
9		< 0,001	Valid
Reliability Analysis			
Statistic		Value	
Cronbach's Alpha		0.925	
Number of Items		9	
Sample size		53	
Interpretation		Excellent internal consistency	

Table 1 presents the results of the validity and reliability analyses of the analytical thinking skills test. Item validity was evaluated using Pearson product–moment correlation by examining the correlation between each item score and the total test score. The results indicate that all nine items achieved positive and

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statistically significant item–total correlation coefficients ($p < .001$), with correlation values ranging from 0.731 to 0.881. Specifically, Item 3 exhibited the highest correlation coefficient ($r = 0.881$), followed by Item 8 ($r = 0.862$) and Item 7 ($r = 0.837$), whereas Items 5 and 6 showed the lowest coefficients ($r = 0.731$). Nevertheless, all correlation coefficients exceeded the commonly accepted minimum criterion of 0.30, indicating that every item contributed adequately to measuring students' analytical thinking skills and was therefore retained for the final instrument.

The reliability analysis further demonstrated that the instrument possessed excellent internal consistency. Based on responses from 53 participants, the analytical thinking skills test yielded a Cronbach's Alpha coefficient of 0.925 across the nine items. This value exceeds the recommended threshold of 0.70, indicating a high level of consistency among the items in measuring the same construct. Therefore, the analytical thinking skills test can be considered both valid and highly reliable, supporting its use as the primary research instrument in this study.

The analytical framework applied to the resulting data encompassed four stages: normality testing to ascertain distributional characteristics, Levene's homogeneity test to examine variance equality across groups, N-Gain computation to quantify learning gains, and an independent-samples t-test to evaluate the significance of group differences in PBL's effect.

3. RESULT AND DISCUSSION

3.1. Result

The primary objective of this study was to assess the influence of the Problem Based Learning (PBL) model on the development of analytical thinking skills among Grade XI students in thermochemistry. Pretest and posttest data were systematically gathered from both the experimental and control classes, then subjected to statistical analysis selected in accordance with the properties of the dataset. In total, 49 students participated 21 in the experimental class and 28 in the control class. The experimental class received instruction through the PBL framework, while the control class followed a conventional instructional sequence.

Statistical analyses were performed using IBM SPSS Statistics version 29 and covered normality testing, homogeneity testing, hypothesis testing, and N-Gain analysis. Analytical thinking skills data distribution was first examined through the Shapiro–Wilk test, with outcomes presented in Table 2.

Table 2. Normality Test Result

Data	Hypothesis	Test Criterion	Data Type	Test Result	Decision
Analytical Thinking Skills	The data are normally distributed	If $p \geq 0.05$, fail to reject H_0 (variances are homogeneous); if $p < 0.05$, reject H_0 (variances are not homogeneous).	Experimental and Control Classes	Sig: 0.22	H_0 accepted; data are normally distributed

The Shapiro–Wilk test returned a significance value of 0.222, which exceeds the 0.05 threshold. Accordingly, the null hypothesis was retained, confirming that the data conformed to a normal distribution.

Variance homogeneity was subsequently assessed using Levene's Test, also conducted in IBM SPSS Statistics version 29. The outcomes are detailed in Table 3.

Table 3. Homogeneity test result

Data	Hypothesis	Test Criterion	Test Result	Decision
Analytical Thinking Skills	The data have equal variances (homogeneous)	If $p \geq 0.05$, fail to reject H_0 (variances are homogeneous); if $p < 0.05$, reject H_0 (variances are not homogeneous).	Sig. = 0.81	H_0 accepted; data are homogeneous

Levene's Test produced a significance value of 0.810, surpassing the 0.05 benchmark. This result led to the retention of the null hypothesis, establishing that the variance of analytical thinking scores was homogeneous across both groups.

Hypothesis testing was subsequently carried out using an independent-samples t-test with IBM SPSS Statistics version 29. Results are presented in Table 4.

Table 4. Hypothesis testing

Test Type	Hypothesis	Test Criterion	Test Result	Decision
Independent-Samples t-test	There is no effect of the Problem Based Learning model on students' analytical thinking skills at SMA Negeri 1 Kabila	Decision Rule (α = 0.05; df = 47): Accept H_1 if tcount > ttable (ttable = 1.678); otherwise, fail to reject H_0.	t_{count} = 4.05	H_0 rejected; H_1 accepted

The t-value of 4.055 exceeded the critical value of 1.678 at α = 0.05 and df = 47. Consequently, the null hypothesis was rejected in favor of the alternative hypothesis, providing statistical evidence that PBL exerted a significant influence on students' analytical thinking skills at SMA Negeri 1 Kabila.

N-Gain analysis was then applied to quantify the magnitude of improvement attributable to the respective instructional approaches. Figure 1 illustrates the N-Gain scores disaggregated by analytical thinking indicator for both classes.

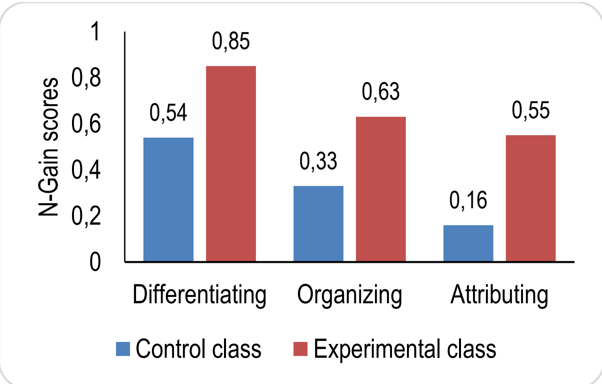

Figure 1. N-Gain for each indicator of analytical thinking skills in the experimental and control classes

Across all three analytical thinking indicators, the experimental class consistently outperformed the control class in terms of N-Gain. For the differentiating indicator, the experimental class attained an N-Gain of 0.85 (high category), whereas the control class recorded 0.54 (moderate category). In the organizing indicator, the experimental class reached 0.63 (moderate), compared to 0.33 (moderate) in the control class. Regarding the attributing indicator, the experimental class achieved 0.55 (moderate), while the control class obtained only 0.16 (low category).

These findings collectively suggest that the PBL model demonstrated greater efficacy than conventional instruction in cultivating analytical thinking. The underlying mechanism appears to be rooted in the learning activities embedded within PBL, wherein students were regularly required to analyze problems, engage in collaborative discourse, articulate reasoning, and relate chemistry concepts to authentic situations all of which collectively accelerated the growth of their analytical capacities.

3.2. Discussion

An The findings of this study indicate that the implementation of the Problem Based Learning (PBL) model significantly improved students' analytical thinking skills in thermochemistry. This conclusion is supported by the independent-samples *t*-test, in which the obtained *t*-value (4.055) exceeded the critical *t*-value (1.678) at α = 0.05. Consequently, the null hypothesis was rejected, indicating that students taught through the PBL model achieved significantly better analytical thinking skills than those who received conventional instruction. These findings are consistent with the view that analytical thinking involves the ability to distinguish relevant information, organize relationships among concepts, and formulate logical explanations when solving scientific problems (Laksono et al., 2017).

The superiority of the PBL model is further supported by the N-Gain analysis, which showed that the experimental class consistently achieved higher learning gains than the control class across all analytical thinking indicators. The highest improvement was observed in the differentiating indicator, with an N-Gain score of 0.85 (high category), compared with 0.54 (moderate category) in the control class. This finding suggests that presenting authentic and contextual problems at the beginning of instruction effectively encourages students to identify relevant information and distinguish it from irrelevant information before proposing solutions. Such learning activities strengthen students' analytical reasoning through active engagement in problem identification and investigation, supporting the findings of Zahro and Lutfianasari (2024), who reported that problem-based learning effectively enhances students' analytical abilities through early exposure to meaningful problems.

The organizing indicator also demonstrated better improvement in the experimental class, achieving an N-Gain score of 0.63 (moderate category), whereas the control class obtained 0.33 (moderate category). This result indicates that collaborative discussion and investigation within the PBL model assist students in organizing information into coherent conceptual structures. Throughout the learning process, students were encouraged to connect thermochemistry concepts, evaluate available evidence, and formulate logical explanations based on scientific principles. These activities are consistent with the findings of Siti et al. (2024), who emphasized that collaborative learning environments facilitate students' ability to organize and integrate scientific concepts into meaningful understanding.

Although the attributing indicator recorded the lowest improvement among the three indicators in the experimental class (N-Gain = 0.55, moderate category), it still exceeded the achievement of the control class (N-Gain = 0.16, low category). This result indicates that PBL contributes to students' ability to construct scientific explanations and justify conclusions using evidence. However, attributing requires more complex reasoning because students must explain causal relationships underlying thermochemical phenomena rather than merely identify or organize information. The abstract nature of thermochemistry concepts makes this aspect particularly challenging, as misconceptions frequently persist in topics involving enthalpy change and energy transfer (Dewi et al., 2018). Consequently, improvements in attributing skills tend to occur more gradually than improvements in differentiating and organizing skills. This variation across indicators also supports the argument of Jusniar et al. (2024) that the effectiveness of PBL differs according to the cognitive complexity required by each analytical thinking process.

The statistical findings are reinforced by the N-Gain analysis, which consistently demonstrated the superiority of the PBL model over conventional instruction. While the experimental class achieved a high category in differentiating and moderate categories in organizing and attributing, the control class remained within the moderate category for differentiating and organizing and the low category for attributing. Similar patterns have been reported by Laeli and Kasmui (2024), who found that conventional teacher-centered instruction provides fewer opportunities for students to develop higher-order thinking skills than student-centered learning approaches such as PBL.

Overall, the effectiveness of PBL can be explained by its learning process, which actively engages students in identifying problems, collecting and analyzing information, evaluating alternative solutions, and presenting evidence-based conclusions. These activities shift the learning process from passive knowledge acquisition to active inquiry, enabling students to develop analytical thinking skills through meaningful learning experiences (Wulandari & Supiah YL, 2023). Because thermochemistry requires students to interpret abstract concepts and solve contextual scientific problems, integrating PBL into chemistry instruction provides an appropriate learning environment for fostering analytical thinking. Therefore, the findings of this study reinforce previous evidence that PBL represents an effective instructional approach for developing analytical thinking skills and other higher-order cognitive abilities in secondary chemistry education (Antara, 2022; Fauziah et al., 2024).

4. CONCLUSION

This study concludes that the Problem Based Learning (PBL) model effectively improves Grade XI students' analytical thinking skills in thermochemistry. Compared with conventional instruction, PBL produced greater improvements across all analytical thinking indicators, demonstrating its effectiveness in fostering students' ability to differentiate relevant information, organize concepts, and construct scientific explanations. These findings indicate that engaging students in authentic problem-solving and collaborative inquiry provides meaningful opportunities for developing higher-order thinking skills.

The findings contribute to the growing body of evidence supporting the use of PBL as an effective instructional approach for enhancing analytical thinking in chemistry education. From a practical perspective, the study suggests that chemistry teachers may integrate PBL into thermochemistry instruction to create more student-centered learning experiences that promote active inquiry and analytical reasoning. As this study was conducted within a limited sample and focused solely on thermochemistry, future research is recommended to examine the effectiveness of PBL across different chemistry topics, larger and more diverse student populations, and longer implementation periods to provide broader evidence of its educational impact.

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