# The Impact of Integrating Discovery Learning and Differentiated Instruction on Students' Critical Thinking Skills in Heat and Temperature Topics

**Trihartini*, Sabar Nurohman, Rusdiman Buhera**
Master of Science Education Study Program, Yogyakarta State University, Indonesia
*Corresponding Author: trihartini.2023@student.uny.ac.id

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***Abstract -*** *Critical thinking is increasingly recognized as a core skill in education, especially in the context of 21st-century learning. It empowers students to analyze information critically, evaluate evidence, and make logical, reflective decisions. However, many students still struggle to develop strong critical thinking abilities through conventional instructional approaches. This study aimed to examine the effectiveness of integrating discovery learning and differentiated instruction in enhancing students' critical thinking skills, particularly on the topic of heat and temperature. The research employed a pre-experimental design using a one-group pretest-posttest method involving 30 ninth-grade students from SMPN 4 Sentajo Raya. Data were collected through assessments before and after the intervention, using instruments designed to evaluate critical thinking related to the subject matter. The findings revealed a notable improvement in performance, with the average pretest score increasing from 48 to 78 in the posttest. Statistical analysis using a paired samples t-test produced a significance value (2-tailed) of less than 0.05, indicating a statistically significant difference in students' critical thinking skills after the implementation of the integrated instructional model. Accordingly, the null hypothesis ($H_0$) was rejected, and the alternative hypothesis ($H_1$) was accepted. Moreover, the effect size, calculated using Cohen's d, was 1.25, which falls into the large category, suggesting that the intervention had a strong and meaningful impact on students' critical thinking development. These results demonstrate that combining discovery learning with differentiated instruction can be a practical approach to promoting higher-order thinking skills in science education. Future research could further explore the application of this integrated strategy in other scientific topics, across different age groups, and with broader student demographics, as well as examine its influence on other cognitive dimensions such as problem-solving, reasoning, and creativity.*

***Keywords****: Critical thinking skills; Differentiated instruction; Discovery learning*

## INTRODUCTION

Critical thinking is a key 21st-century skill that promotes the ability to analyse, synthesize, and evaluate information in depth (Sèna & Etienne, 2022). In science education, critical thinking supports the development of scientific literacy and informed decision-making (Jamil et al., 2024). Moreover, implementing learning strategies that foster critical thinking has been proven to enhance creativity and problem-solving skills (Lan & Bao, 2022), while also preparing students to adapt to social and professional challenges (Elen & Verburgh, 2023; Mulalić, 2022)

Science learning is vital in developing students' critical thinking skills, especially in understanding and responding to complex and dynamic scientific phenomena (Byrne & Johnstone, 1987). These skills include the ability to ask questions, analyse data, evaluate arguments, and test hypotheses as part of the scientific thinking process rooted in the philosophy of science (Davson-Galle, 2004). Critical thinking is further reinforced through activities such as observation, analysis, and conclusion on natural phenomena encountered in learning contexts (Jamil et al., 2024), which have been shown to improve students' analytical and evaluative abilities (Fahimah et al., 2021).

Teachers play a crucial role in facilitating critical questioning and scientific discussions that encourage students to think more deeply (Jamil, 2021; Forawi, 2016). In addition, metacognitive skills developed through science education contribute significantly to strengthening students' critical thinking (Kusuma & Busyairi, 2023).

In terms of critical thinking performance, studies reveal that only around 16.22% of Indonesian students can reach the stages of interpretation and evaluation when solving PISA-based questions, reflecting a generally low level of higher-order thinking, particularly in analysis, evaluation, and inference indicators (Wulandari & Warmi, 2022). This is supported by other findings indicating that 68.6% of Indonesian students still exhibit low levels of critical thinking (Ulpelina & Sholihat, 2024). One of the main causes is that classroom learning approaches often do not provide sufficient space for students to explore critical thinking through challenging and contextual activities (Azizah et al., 2018). The limited application of innovative learning models and media that support scientific exploration also hinders the development of critical thinking (Wijayanto et al., 2023; Aiman et al., 2020). Therefore, learning models and approaches that effectively foster critical thinking are urgently needed.

The discovery learning model has been proven effective in improving students' critical thinking through active and constructive learning processes (Sejati et al., 2021; Siswanti, 2019). According to research by Solissa et al., (2023) A very high effect was reported with an effect size of 0,90, an N-gain of 0,52, and an experimental class average score of 85,90 compared to 72,10 in the control class. The use of interactive media and worksheets in discovery learning further enhances students' analytical skills (Rizki et al., 2021; Yani & Santoso, 2024). Other studies have shown learning gains in science and mathematics subjects (Azhad et al., 2022). Meta-analyses have also confirmed the effectiveness of this approach, particularly guided discovery, in developing critical thinking skills (Koten & Rohaeti, 2024; Asyari, 2019), In addition, the discovery learning model enhances SPS (Buhera et al., 2025), making it a relevant strategy for supporting 21st-century competencies.

Differentiated instruction plays a crucial role in developing students' critical thinking skills by tailoring teaching strategies to their needs, interests, and learning styles. This approach promotes active engagement in the learning process, which is essential for fostering analytical and evaluative thinking (Nahdhiah & Suciptaningsih, 2024; Sutrisno, 2023). Through differentiation of content, process, and product, students are given the autonomy to choose learning methods that suit them, ultimately strengthening their critical thinking abilities (Stavrou & Koutselini, 2016; Marlina et al., 2019). According to Tirtawati, (2024), critical thinking skills improved from 36,39% (low) to 62,72% (high) following the implementation of differentiated instruction. Research also shows that personalized learning facilitates intellectual exploration and the ability to solve complex problems, key indicators of critical thinking (Chandra et al., 2024; Wantini et al., 2023).

This study offers novelty by integrating the discovery learning model with the Differentiated Instruction approach into a unified instructional strategy to enhance students' critical thinking skills. This combination was specifically tested on the topic of heat and temperature, which requires conceptual understanding and higher-order thinking. The approach enables active exploration while adapting the

learning process to students' characteristics, interests, and readiness. The aim of this study was to examine the influence of integrating both approaches on students' critical thinking abilities, helping them gain deep conceptual understanding, think reflectively, and solve problems in ways that align with their individual learning styles.

The topic of heat and temperature was deliberately chosen because it is often perceived as abstract and conceptually challenging for students. It involves invisible phenomena that are difficult to grasp without proper visual representations and experimental experiences, making it prone to misconceptions particularly the distinction between heat and temperature. Previous studies have shown that this topic effectively fosters students' critical thinking skills (Sundari & Sarkity, 2021; Fitriani et al., 2021; Sumardiana et al., 2019), as it naturally requires the interpretation of experimental data, conceptual reasoning, and reflective analysis. Despite its potential, no prior research has explicitly integrated discovery learning and Differentiated Instruction within this topic. Therefore, this study fills a gap in science education research by combining these two student-centered learning models to address the cognitive demands of heat and temperature while supporting individual differences and promoting the development of critical thinking skills.

## RESEARCH METHODS

This research employed a pre-experimental design using a one-group pretest-posttest model, as shown in Table 1.

**Table 1.** One-Group Pretest-Posttest Design

| Pretest | Treatment | Posttest |
|---|---|---|
| $O_1$ | X | $O_2$ |

Description:
$O_1$ : Test before treatment
X : Using discovery learning integrated with differentiated instruction
$O_2$ : Test after treatment

The research subjects were 30 ninth-grade students from class IX-A at SMPN 4 Sentajo Raya. The research instrument was a critical thinking test based on five indicators: interpretation, analysis, evaluation, explanation, and conclusion, which were synthesised from Facione, (2009) and Ennis, (2011). The syntax of the discovery learning model is synthesized from Bruner, (1961) and Hosnan, (2014) includes the following steps: stimulation, problem formulation, data collection, data processing, verification, and generalization. The instrument consisted of 15 multiple-choice questions covering the topic of temperature and heat. The distribution of questions based on critical thinking indicators is presented in Table 2.

**Table 2.** Distribution of Questions Based on Critical Thinking Indicators

| Indicator | Description | Question Numbers | Cognitive Level |
|---|---|---|---|
| Interpretation | Interpretation of graphs and heat transfer phenomena | 1, 2, 11 | C3, C4 |
| Analysis | Analysis of experimental data and natural phenomena | 8, 9, 15 | C4 |
| Evaluation | Evaluation of opinions and thermometer selection | 3, 10, 12 | C4, C5 |
| Explanation | Explanation of material use and heat transfer phenomena | 4, 5, 13 | C3, C4 |
| Conclusion | Concluding graphs and heat transfer principles | 6, 7, 14 | C3, C4, C5 |

This instrument was validated, and an Aiken's V index 1 was obtained. It was also analyzed for suitability with the Rasch model using the QUEST program, which showed that the Infit MNSQ values ranged from 1.20 to 0.86, with a reliability estimate of 0.91. These results indicate that the instrument is valid and fits the Rasch model.

Data were analyzed using statistical tests. The research hypotheses were as

follows: the Null Hypothesis ($H_0$): There is no significant difference in students' critical thinking skills before and after the implementation of the discovery learning model integrated with the differentiated instruction approach; and the Alternative Hypothesis ($H_1$): There is a significant difference in students' critical thinking skills before and after the implementation of the discovery learning model integrated with the differentiated instruction approach. If the Sig. (2-tailed) value is < 0.05, then $H_0$ is rejected and $H_1$ is accepted (indicating a significant difference). If the Sig. (2-tailed) value is > 0.05, then $H_0$ is accepted and $H_1$ is rejected (indicating no significant difference). In addition, the effect size can be interpreted based on Cohen's *d* as categorized by Cohen, (1988) into three categories: small (< 0.20), medium (0.20 – 0.80), and large (> 0.80).

## RESULTS AND DISCUSSION.

### Results

The results of this study present the pretest and posttest scores of students' critical thinking skills in class IX-A at SMPN 4 Sentajo Raya. These scores reflect students' performance before and after receiving instruction using the integrated discovery learning and differentiated instruction approach. The pretest was administered to assess students' baseline critical thinking abilities before the intervention, while the posttest measured the improvement in those abilities after the learning process. The comparison of these scores provides insights into the effectiveness of the instructional model implemented. A detailed overview of the pretest and posttest results, including the trends and differences in each critical thinking indicator, can be seen in Figure 1.

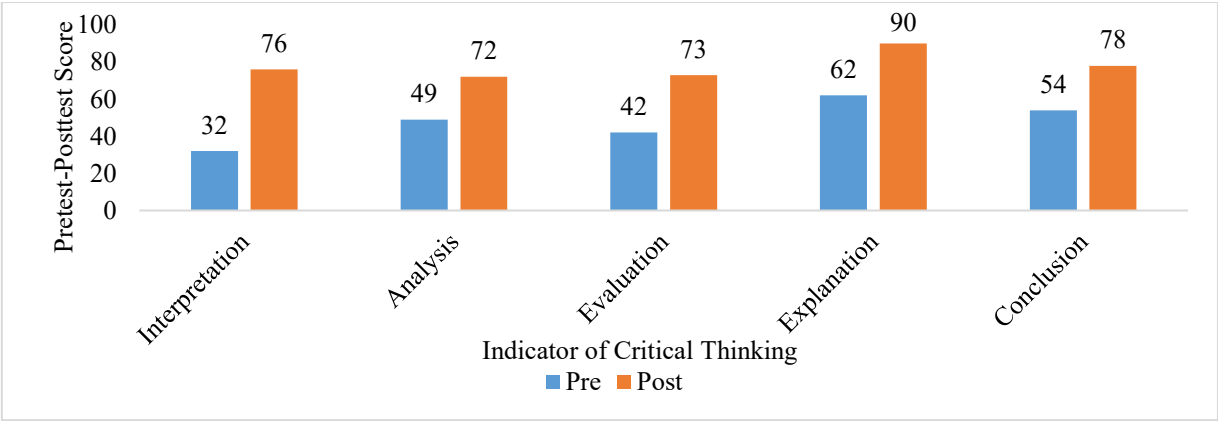


**Figure 1.** Pretest-Posttest Scores for each Indicator

Figure 1, which compares the pretest and posttest scores for each critical thinking indicator, shows a significant increase across all aspects. The most tremendous improvement occurred in the interpretation indicator, rising from a score of 32 to 76, indicating a strong influence of the learning model on students' ability to understand and interpret information. The explanation indicator also showed the highest posttest score of 90, up from 62. Meanwhile, the analysis, evaluation, and conclusion indicators experienced score increases from 49 to 72, 42 to 73, and 54 to 78, respectively. These findings indicate that the implemented learning model effectively improved students' critical thinking skills comprehensively. Therefore, statistical analysis, such as the paired sample t-test, must confirm the significance of the differences between pretest and posttest scores.

Assuming that the pretest-posttest data are normally distributed and homogeneous, a paired sample t-test was conducted, and the results are presented in Table 3.

**Table 3.** Paired Samples Test

| | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | t | df | Sig. (2-tailed) | Cohens' d |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Lower | Upper | | | | |
| Pretest-Posttest | -29.5555 | 23.59839 | 4.3084 | -38.3673 | -20.743 | -6.86 | 29 | 0.000 | 1.25 |

Table 3 shows that the significance value (2-tailed) is less than 0.05. Thus, the null hypothesis ($H_0$) is rejected, and the alternative hypothesis ($H_1$) is accepted. This indicates a significant difference in students' critical thinking skills before and after implementing the discovery learning model, which is integrated with differentiated instruction. Furthermore, the Cohen's d value is 1.25, which indicates a very large effect size. This suggests that the implementation of the learning model and differentiated instruction had a substantial and meaningful impact on improving students' critical thinking skills.

## Discussion

The research findings show that the average pretest score of the students was 48, while the posttest score increased to 78. Based on the results of the paired samples test with a significance value (2-tailed) less than 0.05, the null hypothesis ($H_0$) was rejected and the alternative hypothesis ($H_1$) was accepted. This indicates a significant difference in students' critical thinking skills before and after implementing the discovery learning model integrated with the differentiated instruction approach. Therefore, the integration of discovery learning and differentiated instruction has a positive influence on the improvement of students' critical thinking abilities, with a very large effect size.

The explanation indicator achieved the highest score because the applied discovery learning model encouraged students to actively express their opinions, explain findings, and present logical reasoning throughout the learning process. The support of differentiated instruction also allowed students to convey their understanding in a manner that suited their learning styles, thereby enhancing their ability to explain concepts effectively. Moreover, activities such as discussions, presentations, and report writing during the lessons further strengthened students' ability to explain ideas and arguments systematically.

Despite its effectiveness in improving students' critical thinking skills. Integrating discovery learning and differentiated instruction also presents several limitations. One key challenge is the limited classroom time, as discovery-based activities and personalized tasks often require more time for exploration, discussion, and reflection. Additionally, the success of differentiated instruction is highly dependent on the teacher's preparedness and skill in designing varied learning materials and strategies that accommodate students' diverse needs. Without sufficient training and support, teachers may struggle to implement differentiation effectively, which can reduce the overall impact of the model.

The discovery learning model creates an active learning environment that encourages students to explore concepts, solve problems, and think rationally (Rahmawati et al., 2021). Critical thinking skills can also be enhanced through

discovery-based learning implemented in various contexts, such as momentum and impulse in physics (Ekayanti et al., 2022) as well as mathematics at the elementary level (Nugraha et al., 2020). Furthermore, online discovery learning using platforms like Google Meet has also shown similar effectiveness in improving students' critical thinking skills and interaction (Mustikaningrum et al., 2021; Dewi et al., 2023). The differentiated instruction approach allows teachers to tailor learning strategies to students' needs and learning styles, which positively impacts their motivation and critical thinking development (Susanti & Purbandari, 2024).

Both discovery learning and differentiated instruction offer clear advantages in enhancing modern education. Discovery learning promotes active student engagement through exploration and direct experiences, making learning more meaningful and improving both motivation and academic performance (Risma, 2022; Pebrian & Fitria, 2022). This approach has also been proven to develop critical thinking, creativity, and problem-solving skills, as students are directly involved in discovering concepts (Zakiy et al., 2023; Kustiyono, 2023). Meanwhile, differentiated instruction adjusts methods, content, and learning pace to meet students' individual needs, thereby increasing engagement and creating a more inclusive learning experience (Rumsariadi et al., 2023; Masani, 2022). The combination of them is considered adequate because it accommodates individual differences while encouraging active participation in learning (Pebrian & Fitria, 2022).

Thus, integrating discovery learning and differentiated instruction is highly relevant for addressing the demands of 21st-century education, which requires higher-order thinking skills and learning approaches responsive to student diversity.

## CONCLUSION

Based on the research findings, it can be concluded that implementing the discovery learning model integrated with a differentiated instruction approach significantly enhances students' critical thinking skills. This is evidenced by the increase in the average score from 48 on the pretest to 78 on the posttest, as well as the results of the paired samples test, which showed a significance value (2-tailed) of less than 0.05. Therefore, the null hypothesis ($H_0$) is rejected and the alternative hypothesis ($H_1$) is accepted, indicating a clear improvement in students' critical thinking abilities before and after the learning intervention. Furthermore, the effect size analysis, using Cohen's d, resulted in a value of 1.25, indicating a very large effect. This suggests that the learning intervention was not only statistically significant but also practically impactful in enhancing students' cognitive development.

Practically, this learning model can be adopted for other conceptual topics, such as human body systems, social change, or energy concepts. These topics require a deep understanding and critical reasoning, making them well-suited for exploration through a discovery-based and differentiated instruction. With its flexibility and emphasis on depth, this model can create more adaptive and meaningful learning experiences for students.

For future research, it is recommended that follow-up studies be conducted using a control group design to strengthen the validity and causal inference of the findings. Additionally, implementing this model at different educational levels, such as in senior high school or higher education, would provide broader insight into its applicability across diverse contexts and developmental stages.

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