The Effect of the 5E Learning Cycle Model with Learning Journals on Students' Critical Thinking in Thermochemistry

J-PEK
Vol. 10, No. 2, 2025, Page: 90-104

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Abstract

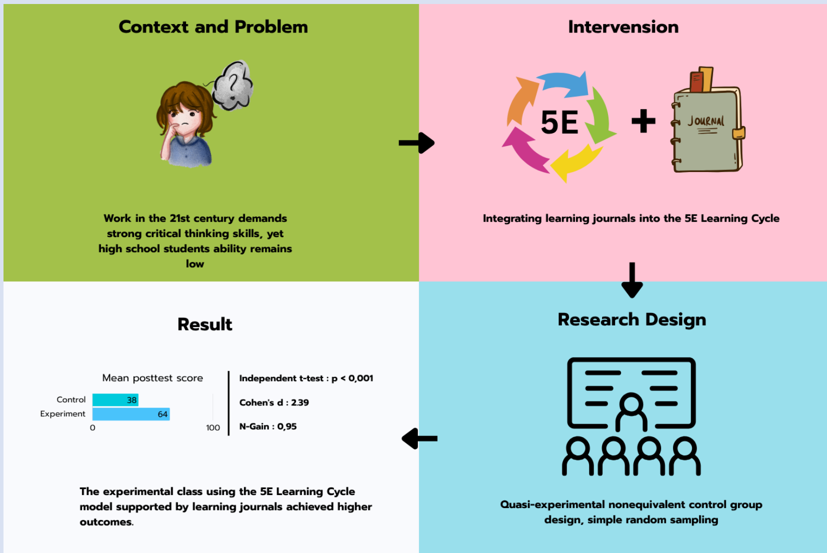
Work in the 21st century demands strong critical thinking skills. However, high school students still exhibit relatively low levels of critical thinking ability. Integrating learning journals into the 5E Learning Cycle model represents an educational innovation that enhances these skills. This study compares the critical thinking abilities of students in experimental and control classes using a quantitative quasi-experimental design with a non-equivalent control group. Two classes were involved: an experimental group (35 students) and a control group (34 students), each receiving different treatments. The sampling technique used was simple random sampling. Data were collected using 10 questions based on Ennis's five aspects of critical thinking. The instrument was validated and showed a reliability coefficient of 0.725. The results showed a difference in critical thinking scores between the control and experimental classes. The experimental class, which used the 5E Learning Cycle model supported by learning journals, achieved higher outcomes. This was confirmed by an independent t-test, which yielded a p-value (<0.001) and a higher post-test mean score in the experimental class (26.05). A Cohen's d value of 2.39 indicated a large effect size, while an N-Gain score of 0.95 showed that the intervention fell into the high category.

Keywords:

5E Learning Cycle, Learning Journal, Critical Thinking

Submitted: May 2025
Revised: June 2025
Accepted: July 2025

Graphical Abstract



Introduction

Work in the Twenty-First Century differs significantly from previous eras, as it demands critical thinking skills to solve increasingly complex problems (Agbi & Yuangsoi, 2022). Unfortunately, the critical thinking abilities of high school students remain relatively low; their success rate on Higher-Order Thinking Skills (HOTS) questions is below 55% (Styawan & Arty, 2021; Sholikhah et al, 2025; Basimin et al, 2025; Lailia, 2025). Therefore, it's not surprising that a lack of critical thinking skills is a major problem in education, largely because teachers haven't made critical thinking a primary focus in their instruction (Purwanto et al., 2022). Acquiring critical thinking skills is not straightforward; it requires a long and integrated process (Kawedhar et al., 2020). Hence, it's crucial to enhance students' critical thinking abilities during their high school years (Siburian et al., 2023).

One relevant topic for teaching critical thinking skills to students is Thermochemistry (Purwandari et al., 2023). Thermochemistry provides an ideal context for developing critical thinking because it involves data analysis and the interpretation of experimental results, and it is closely tied to daily life, such as condensation on a glass of ice, making its phenomena directly observable (Muzainah et al., 2024). Given students' low critical thinking skills, Thermochemistry is often used in various studies as a strategic context to improve this ability, given its demanding conceptual and experimental nature. This topic includes concepts such as enthalpy, Hess's Law, and the use of simple calorimeters, which require students to analyse, evaluate, and draw conclusions based on experimental data (Auliyani et al., 2022; Babys et al., 2024). Additionally, the characteristic integration of theory and practice in Thermochemistry makes it an ideal subject for developing higher-order thinking skills through inquiry-based learning and guided discovery approaches (Erna et al., 2020).

Thermochemistry is often seen as a difficult subject for students. A study by Rahmi & Azra (2023) found that only 27% of students understood thermochemical material, while 73% struggled with it. More specifically, 32% of students experienced misconceptions, and 41% simply did not understand the material. Similarly, research by Erna et al. (2020) indicated that more than 50% of students had misconceptions in thermochemistry. According to Zakiyah et al. (2019), the primary reason for students' difficulty in learning thermochemistry is the numerous concepts it contains. Students need to understand several key concepts in thermochemistry, particularly enthalpy change (ΔH), Hess's Law, and calorimetry.

The 5E Learning Cycle model consists of five phases: Engagement, Explore, Explain, Elaborate, and Evaluate. In the Engagement phase, students analyse and construct the concept of enthalpy change (ΔH) by observing the phenomenon of heat energy absorbed or released during charcoal combustion at the beginning of the lesson. Charcoal combustion serves as a practical example for students to analyse enthalpy change (ΔH). Research shows this model significantly improves student learning outcomes, evidenced by studies demonstrating progressive changes in student performance when using the learning cycle approach (Muljati, 2021). During the Explore phase, students are guided to calculate indirect reaction enthalpy (ΔH) by manipulating relevant chemical reaction data. In chemical education, Hess's Law is often used to sharpen students' thermodynamic analysis skills through data-based indirect experiments (Wulandari et al., 2025). For example, if the ΔH of formation of CO_2 and H_2O are known, the ΔH of methane combustion can be calculated without direct combustion experiments, simply by summing the ΔH of formation reactions (Azizi et al., 2025). In the Elaborate phase, students use experimental data, such as measuring water temperature during combustion, to understand the concept of heat capacity. This practical application reinforces theoretical knowledge, as shown in research where students' understanding of energy changes significantly increased through interactive learning methods (Sapina et al., 2024). The integration of experimental data enhances students' ability to connect theory with real-world applications, further strengthening their understanding of thermochemistry (Azura, 2022). Research by Sotáková & Ganajová (2023) indicates that the application of the 5E model significantly improves students' cognitive processes in chemistry learning, including their ability to recall, understand, apply, analyse, and evaluate chemical concepts.

Continuous innovation in learning is crucial for fostering a strong academic culture. One such innovation involves using learning journals to enhance the effectiveness of the 5E Learning Cycle. Learning journals are documents prepared by teachers that serve as a space for students to reflect on the material and learning processes they have experienced. This practice trains students to recognise what they have learned, measure their progress, and identify areas they have not yet understood (Trisnawati et al., 2020). According to Andarini et al. (2024), students' use of learning journals allows for regular and consistent recording of learned material, identification of weak areas, and evaluation of necessary corrective steps, either through self-reflection or teacher guidance. Through this reflection, students can achieve deeper understanding and enhanced metacognitive abilities (Susanti et al., 2024). Several studies demonstrate the effectiveness of learning journals in supporting student learning. Trisnawati et al. (2020) found that learning journals improved students' metacognitive abilities. Similarly, Maharani et al. (2021) showed that learning journal-assisted instruction enhanced the application of the PDCA (Plan-Do-Check-Act) cycle and academic outcomes. This occurs because learning journals provide a space for students to reflect on their learning process; when writing journals, students are encouraged to: (1) review learned concepts, (2) self-assess their understanding of the material, and (3) identify areas requiring further mastery. Through this reflection, students gain greater awareness of their learning strengths and weaknesses, enabling them to take corrective actions—such as seeking teacher or peer assistance to verify concepts. Furthermore, a study by Nisfia and Mubarok (2024) involving high school students in Central Java reported a significant improvement in critical thinking skills on ecosystem topics, with an N-Gain score of 0.327 in the experimental class compared to 0.131 in the control group.

Research by Purwandari et al. (2023) demonstrated the effectiveness of integrating Ennis's Taxonomy into the Argument-Driven Inquiry (ADI) model, showing a significant improvement in students' critical thinking skills in thermochemistry (N-gain = 0.731; Cohen's d = 1.023). Similarly, Aniq & Peniati (2024) established that integrating Ennis's Taxonomy into the Problem-Based Learning (PBL) model enhanced students' critical thinking in biology (average N-gain = 0.63; mastery level increased from 65% pre-intervention to 92.53% post-intervention). These findings serve as important precedents for developing the 5E Learning Cycle (Engage, Explore, Explain, Elaborate, Evaluate) to be compatible with Ennis's critical thinking dimensions. Ennis (2011) defined critical thinking as "reasonable reflective thinking focused on deciding what to believe or do," which consists of five core dimensions: basic clarification, the bases for a decision, advanced clarification, supposition & integration, and inference.

Table 1. Syntax of 5E Learning Cycle

Ennis's sub-skill	5E Learning Cycle	Activity
Basic Clarification	Engagement	Students observe charcoal combustion, then write a hypothesis in their journal: "Is heat energy a form of chemical energy?"
The Bases for a Decision	Exploration	Students perform basic enthalpy experiments involving two reactions: the melting of ice and the reaction of quicklime with water.
Advanced Clarification	Explanation	Students present their experimental results and engage in group discussions about why the reaction ΔH can be negative or positive.
Supposition and Integration	Elaboration	Redesigning experiments to test Hess's Law using virtual simulation data.
Inference	Evaluation	Concluding the relationship between heat energy and enthalpy change based on all activities.

Based on the description above, the authors aim to develop a 5E Learning Cycle model with learning journals. Therefore, this research will answer the question: Is there a difference in students' critical thinking abilities between the control and experimental classes?

Method

This research was conducted at a high school in Ngawi Regency, East Java, Indonesia, during the 2024/2025 academic year. Data collection took place from September 2, 2024, to September 30, 2024. The study subjects were 34 students from class XI B and 35 from class XI C. The study involved six meetings, totalling 12 lesson hours, with each lesson hour lasting 45 minutes.

This research employed a quantitative, quasi-experimental design with a non-equivalent control group. The study involved two classes: an experimental class and a control class, each receiving different treatments. The experimental class was taught using the 5E Learning Cycle model with learning journals, while the control class received treatment with the 5E Learning Cycle model without learning journals. The overall research design is presented in Table 2. The study population comprised eleventh-grade students in the Science program (Saintek) during the 2023/2024 academic year. The total population is presented in Table 2.

Table 2. Nonequivalent Control Group Design.

Aspect	Prestest	Treatment	Posttest
Experiment	O_1	X_1	O_2
Control	O_1	X_2	O_2

Notes :

O_1 : *Pretest measures initial ability.*
O_2 : *Post-test to measure final ability.*
X_1 : Implementing the 5E Learning Cycle Model with Learning Journals.
X_2 : Implementing the 5E Learning Cycle Model.

In this study, the sample comprised Class XI.B (Science program) with 34 students and Class XI.C (Science program) with 35 students. The sampling technique used in this research was simple random sampling. The critical thinking ability test instrument, once developed, had to be validated by experts, including a subject matter lecturer, before being administered to the research sample. After validation, the instrument was piloted in a class that had already received thermochemistry material, specifically Class XII.

Item validity testing was conducted by three expert validators: two chemistry lecturers and one chemistry teacher. The validation results indicated that the instrument was suitable for trial with students. Subsequently, a questionnaire validity test was conducted with 30 students and analysed using the Pearson Correlation coefficient. The Pearson Correlation analysis was performed using SPSS 16.0 for Windows, yielding the following findings.

Table 3. Results of the Pearson Correlation Validity Test

No.	1	2	3	4	5	6	7	8	9	10	11
$r_{calculated}$	.409	.517	.681	.374	.230	.470	.515	.703	.531	.635	.662
r_{table}	.349	.349	.349	.349	.349	.349	.349	.349	.349	.349	.349
Criteria	Valid	Valid	Valid	Valid	Invalid	Valid	Valid	Valid	Valid	Valid	Valid

Based on the results of the Pearson Correlation Validity Test, 10 out of 11 questions were declared valid, while 1 question was deemed invalid because its r-calculated value was smaller than the r-table value. Thus, the 10 valid questions can be used by the researchers to conduct the study in both the experimental and control classes. Reliability testing is used to determine whether the developed instrument is reliable and, if so, to categorise its reliability as low, moderate, high, or very high. In this study, reliability testing was conducted using SPSS 16.0 for Windows. The following are the results of the reliability test for the critical thinking ability test instrument.

Table 4. Results of Cronbach's Alpha Reliability Test

Cronbach's Alpha	N of Items
.725	11

Based on Table 4, the results of the Critical Thinking Ability Test Reliability Test indicate that the instrument is reliable, with a high reliability coefficient. Therefore, the critical thinking ability test instrument can be used by the researchers in both the experimental and control classes.

Results & Discussion

Start your results & discussion here. Students' critical thinking abilities were assessed from their responses to the instrument administered before and after the lessons. To enable hypothesis testing and statistical analysis of the research findings, students' critical thinking levels were converted into scores following the scoring rubric. Data on students' critical thinking abilities before and after learning are shown in Table 5.

Table 5. Students' Critical Thinking Ability Data

Class	Number Student	The Lowest Score	The Highest Score	Mean
Control - Pretest	35	4	16	9.20
Control – Post-test	35	20	60	38.18
Experiment - Pretest	34	4	16	9.47
Experiment – Post-test	34	45	92	64.23

Table 5 shows that the average pretest scores for the control and experimental classes were 9.20 and 9.47, respectively. Furthermore, the average post-test scores were 38.18 for the control class and 64.23 for the experimental class. This indicates an improvement in students' critical thinking abilities. To determine whether there was a difference in students' initial abilities between the control and experimental classes, an independent t-test was conducted on the two classes' pretest scores. Then, to test for a difference in critical thinking abilities, the post-test scores of both classes were analysed using an independent t-test. Before conducting hypothesis testing, students' critical thinking ability scores were tested for normality using the Shapiro-Wilk test and for homogeneity using Levene's test. Both of these tests are prerequisites for determining which statistical test to use in hypothesis testing.

Table 6. Shapiro-Wilk Normality test

Data	Class	Normality Test	Category
Pretest	Control	0.143	Normal
	Experiment	0.088	Normal
Posttest	Control	0.584	Normal
	Experiment	0.302	Normal

Table 7. Levene's Homogeneity test

Data	Levene Statistic	p-value	Category
Pretest	0.006	.939	Homogenous
Posttest	3.651	.059	Homogenous

The Shapiro-Wilk normality test indicated that all data were normally distributed ($p > .05$). Furthermore, Levene's homogeneity test confirmed that the data variances were homogeneous between groups (pretest: $p = .939$; post-test: $p = .059$). These results meet the parametric assumptions for further testing. Before analysing differences in critical thinking abilities between students in the experimental and control classes, we first need to determine whether the control and experimental classes are comparable using their pretest scores, which will then be analysed using an Independent T-test.

Table 8. Independent t-Test on Control and Experimental Group Pretest Scores

t-value	df	p-value	Mean Difference
0.280	67	.780	0.27

In the independent t-test analysis of the pretest, the p-value (.780) was greater than α (.05). This result means we fail to reject Ho, indicating that there is no significant difference in the initial abilities of students in the control class compared to the experimental class. The mean difference of 0.27 is considered not significant. To test for differences in students' critical thinking abilities in the experimental class, we will now use the post-test scores and analyse them using an independent t-test.

Table 9. Independent t-Test on Control and Experimental Group Post-test Scores

t-value	df	p-value	Mean Difference	Cohen's d
-9.86	67	< .001	26.05	2.39

Based on Table 9, the independent samples t-test results indicate a difference in critical thinking abilities between the experimental and control classes. The experimental class, which utilised the 5E learning cycle model with learning journals, achieved a higher average score compared to the control class without journals, with a difference of 26.05 points. This finding is further supported by a p-value (< .001), which is lower than the significance level ($\alpha = .005$), confirming the rejection of H_0 and acceptance of H_a. The magnitude of the intervention's impact is evident from Cohen's d = 2.39 (d > 0.8), indicating that the learning journals significantly enhanced students' critical thinking skills.

The N-Gain results show a clear difference between the control and experimental classes. The N-Gain score for the control class was 0.34, placing it in the "medium" category. In contrast, the N-Gain score for the experimental class was .95, categorised as "high." This indicates that the effectiveness of the 5E Learning Cycle model with learning journals is higher than that of the model alone.

The Impact of the 5E Learning Cycle with Learning Journals on Students' Critical Thinking Skills.

Based on the independent t-test results from the pretest, there was no significant difference between the control and experimental classes. This means both classes were considered to have a similar starting point. However, the independent t-test results from the post-test showed a significant difference in students' critical thinking abilities between the control and experimental classes. The improvement in students' critical thinking skills, as indicated by their indicators, is shown in the following figure.

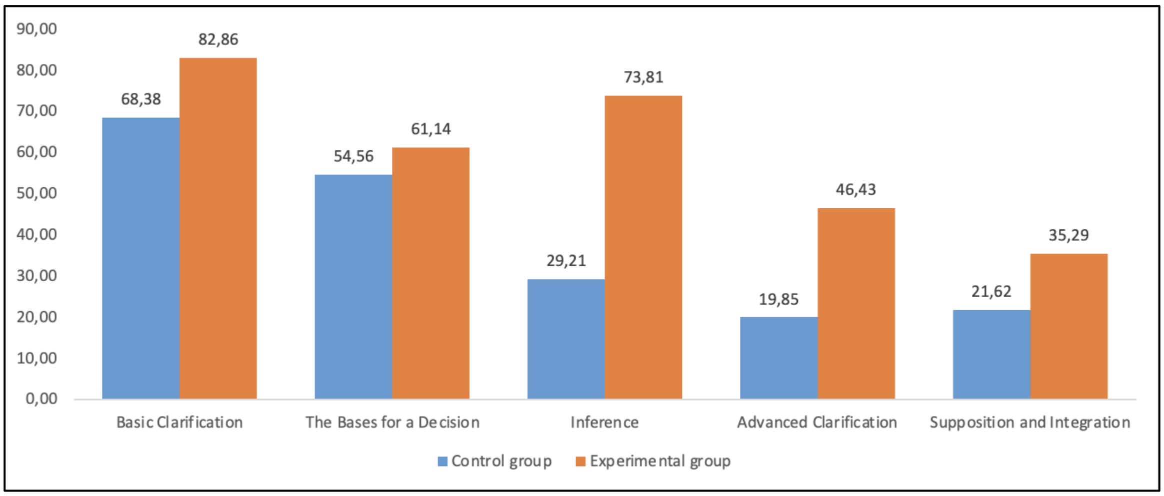
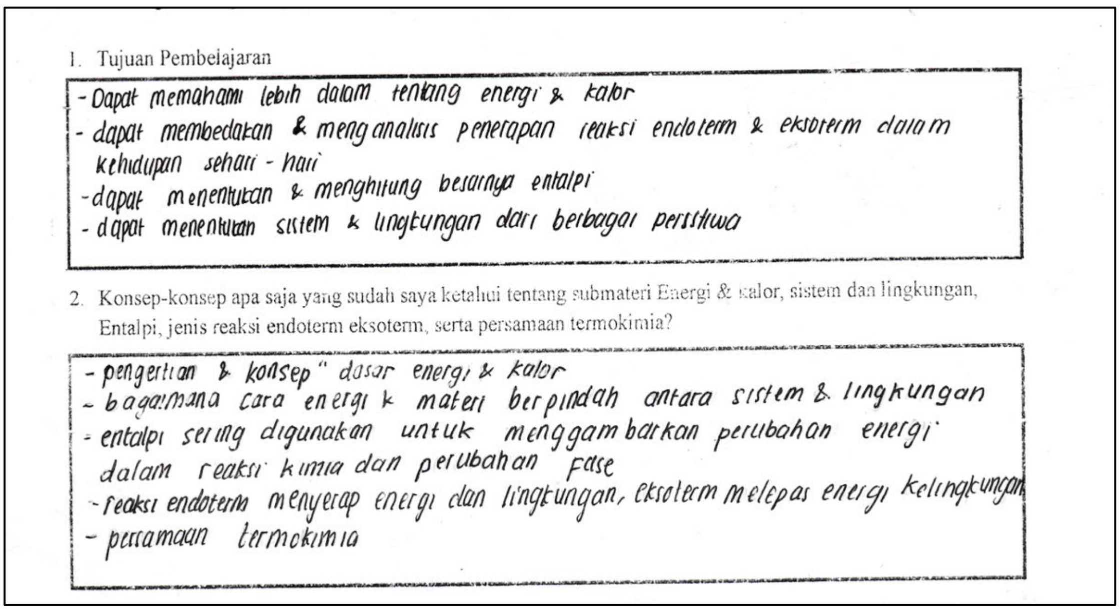


Figure 1. Average Results of Students' Critical Thinking Ability Tests in Experimental and Control Classes

The average results of students' critical thinking ability tests were categorised into five indicators of critical thinking skills, according to Ennis & Philosophy Documentation Centre (2011): Basic Clarification, The Bases for a Decision, Inference, Advanced Clarification, and Supposition and Integration. There was a clear distinction between the experimental and control groups, as evidenced by the average post-test scores. As shown in Figure 1, improvements in critical thinking skills, broken down by indicator, are evident in the difference in average scores between the experimental and control classes. Specifically, Basic Clarification showed a difference of 14.48 points; The Bases for a Decision, 6.58 points; Inference, 44.6 points; Advanced Clarification, 26.58 points; and Supposition and Integration, 13.67 points. The most substantial improvement was noted in the Inference phase.

The Inference phase was implemented during the Evaluation stage of the 5E Learning Cycle. The learning journals provided to the experimental class contained various reflective questions specifically designed to encourage students to formulate conclusions. This aligns with research by Penggabean et al. (2023), which found that reflective learning journals can enhance students' ability to draw conclusions. Providing learning journals prompted students to engage with the material earlier, enabling them to draw conclusions more easily, as depicted in Figure 2.

In the experimental class, pre-learning journals were distributed at the end of the lesson before the thermochemistry unit began. These journals contained essay questions crafted to encourage students to prepare for the upcoming chapter. The questions included: what are the learning objectives for the next unit, what concepts do you already know, what difficulties did you encounter while studying, what topics do you want to learn more about, and how can you learn these concepts more easily?


1. Tujuan Pembelajaran

- Dapat memahami lebih dalam tentang energi & kalor
- dapat membedakan & menganalisis penerapan reaksi endoterm & eksoterm dalam kehidupan sehari - hari
- dapat menentukan & menghitung besarnya entalpi
- dapat menentukan sistem & lingkungan dari berbagai peristiwa

2. Konsep-konsep apa saja yang sudah saya ketahui tentang submateri Energi & kalor, sistem dan lingkungan, Entalpi, jenis reaksi endoterm eksoterm, serta persamaan termokimia?

- pengertian & konsep" dasar energi & kalor
- bagaimana cara energi & materi berpindah antara sistem & lingkungan
- entalpi sering digunakan untuk menggambarkan perubahan energi dalam reaksi kimia dan perubahan fase
- reaksi endoterm menyerap energi dan lingkungan, eksoterm melepas energi kelingkungan
- persamaan termokimia

Figure 2. T Student Responses in the Pre-Learning Journal

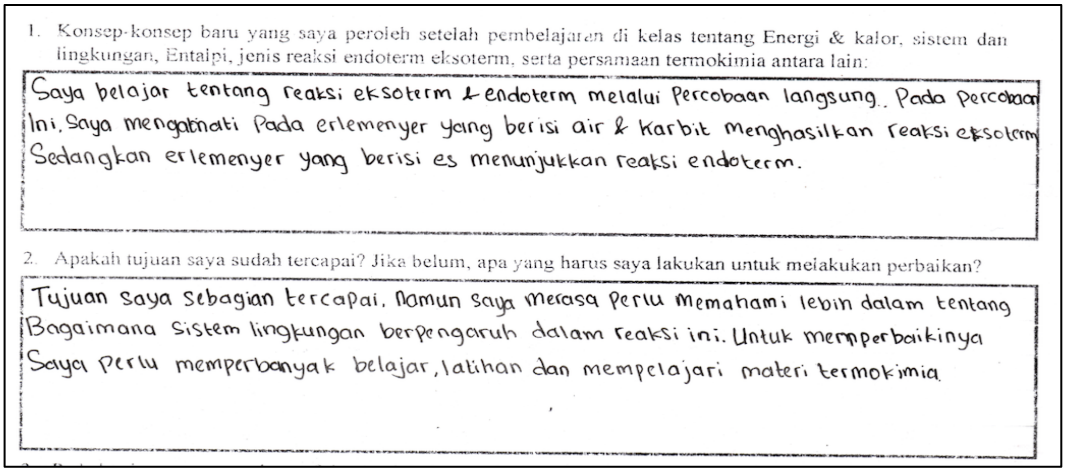
In Figure 2, students are shown writing their answers in the pre-learning journal. Their responses indicated that they had already begun studying the upcoming material. They understood what they were about to learn, the learning objectives, and had even developed learning strategies for the subsequent sessions.

The first phase of the 5E Learning Cycle is Engagement, where students are expected to identify problems and ask relevant questions about the topic. This Engagement phase aligns with Ennis's critical thinking phase, Basic Clarification. The teacher introduced a real-world thermochemistry phenomenon: fire. In this example, the teacher brought twigs and charcoal. During this initial phase, students learned to form simple hypotheses from the concrete examples provided. A student's question, "Sir, why does fire give off heat?" clearly showed they could connect the phenomenon presented by the teacher with thermochemistry concepts. This aligns with Amaliyah et al. (2023), who state that the ability to connect learning concepts with surrounding phenomena is a key indicator of achieving the goals of the 5E Learning Cycle. Conversely, in the control class, more prompting questions were needed from the teacher: "What do you think happens when this wood turns into charcoal?" The results showed the experimental class achieved an average score of 82.86, while the control class scored 68.38.

The second phase of the 5E Learning Cycle is Exploration, which also overlaps with Ennis's critical thinking stage, The Bases for a Decision. After students formulated simple hypotheses during the Engagement phase, they were then guided to explore thermochemistry concepts using simple experiments prepared by the teacher. Through this exploration, students gained a deeper understanding of the concepts learned and developed their analytical skills. There was a noticeable difference in average scores, with the experimental class achieving 61.14 and the control class 54.56.

After the exploration activity, students moved into the Explanation phase, which parallels the Advanced Clarification stage. In this phase, students practiced explaining their findings and presenting them publicly, allowing them to accurately identify and articulate problems. These Explanation sessions were two-way, enabling other class members and the teacher to provide constructive feedback to refine student understanding. This feedback is crucial as it significantly enhances critical thinking skills by promoting metacognition, reflective interaction, and active collaboration within a supportive learning environment (Chakarvarti, 2023). However, the results showed a significant difference between the experimental and control classes, with scores of 46.43 and 19.85, respectively.

The fourth stage of the 5E Learning Cycle is Elaboration, which aligns with the Supposition and Integration indicator. Students collaborated with their group members to refine their findings based on feedback from both the teacher and peers. In this phase, students were also encouraged to collaborate and hone their thermodynamic analysis skills through data-based indirect experiments. They were asked to find the enthalpy change (ΔH) of H_2O sublimation, using provided supporting data. There was a striking difference between the experimental and control classes, with scores of 35.29 and 21.62, respectively. The fifth stage is Evaluation, which aligns with the Inference indicator. Here, students were expected to draw logical conclusions from their activities. Notably, a highly significant difference in average scores was observed between the experimental and control classes: 73.81 and 29.21. In the experimental class, which used the 5E Learning Cycle model with learning journals, students were asked to record several aspects in their learning journals. These included: what concepts they successfully understood, whether the learning objectives were achieved, which areas needed concept reinforcement, their strengths and weaknesses in learning the taught concepts, and their overall impressions of learning the concepts. Below is an example of a post-learning journal entry written by a student.


1. Konsep-konsep baru yang saya peroleh setelah pembelajaran di kelas tentang Energi & kalor, sistem dan lingkungan, Entalpi, jenis reaksi endoterm eksoterm, serta persamaan termokimia antara lain:

Saya belajar tentang reaksi eksoterm & endoterm melalui Percobaan langsung. Pada percobaan Ini, Saya mengamati Pada erlemenyer yang berisi air & karbit menghasilkan reaksi eksoterm Sedangkan erlemenyer yang berisi es menunjukkan reaksi endoterm.

2. Apakah tujuan saya sudah tercapai? Jika belum, apa yang harus saya lakukan untuk melakukan perbaikan?

Tujuan saya sebagian tercapai. Namun saya merasa perlu memahami lebih dalam tentang Bagaimana sistem lingkungan berpengaruh dalam reaksi ini. Untuk memperbaikinya Saya perlu memperbanyak belajar, latihan dan mempelajari materi termokimia.

Figure 3. Example of students' answer

In Figure 3, a student is seen detailing the concepts they have understood and those requiring further reinforcement in their post-learning journal. The teacher will review these journal entries and, based on the student's reflections, will conduct a concept reinforcement session at the beginning of the next lesson.

The findings of this study highlight the significant potential of learning journals as a tool to enhance self-reflection, conceptual understanding, and student engagement in the thermochemistry learning process. Teachers can implement these learning journals in future thermochemistry lessons, as they can effectively engage students' critical thinking. While this research offers valuable insights, it is important to acknowledge several limitations that may affect the interpretation of the findings.

One aspect not explored in this study was students' learning interests. The researchers did not investigate learning interest in either the experimental or control classes. This study directly measured students' initial abilities, followed by the intervention, and then final abilities, without considering students' learning interests. Consequently, the researchers are unaware of students' learning interest in thermochemistry, which could potentially influence student learning outcomes. Therefore, for future research, students' learning interests should be included as a measurable variable. Additionally, the single research location in this study might yield different results if conducted elsewhere. Thus, for subsequent research, additional research locations should be included.

Conclusion

Start your conclusion here. Based on the research findings and discussion concerning the influence of the 5E Learning Cycle model with learning journals on the critical thinking skills of 11th-grade students in thermochemistry at a high school in East Java, this study reveals the following: There is a difference in critical thinking ability scores between the control class and the experimental class, with the experimental class, which utilized the 5E learning cycle supported by learning journals, performing higher. This is evidenced by an independent t-test showing a p-value (<0.001) which is lower than the significance level (0.005). The experimental class achieved a better average posttest score of 26.05. A Cohen's d value of 2.39 indicates that the use of learning journals within the 5E learning cycle had a large impact. The N-Gain results further demonstrate that the use of the 5E learning cycle model assisted by learning journals yielded a high category value, with an N-Gain of 0.95.

Although this research highlights the potential of using the 5E learning cycle with learning journals to enhance students' critical thinking skills, these calculations were performed without considering other variables such as students' learning interest and the limitation of a single research location. Therefore, future research needs to address these aspects to obtain more comprehensive and robust findings.

AI-assisted technology statement

While preparing this work, the authors used AI models, specifically DeepSeek, Gemini, and ChatGPT, to summarise relevant journal articles, identify key information, and assist with initial drafting and language refinement. After utilising these tools, the authors reviewed and edited the content as needed and took full responsibility for the publication's content.

Acknowledgement

I extend my sincere gratitude to the entire family of SMAN 1 Jogorogo, and my fellow 2021 Master's students in Chemistry Education at UM.

Conflict of Interest Statement

All authors declare that they have no competing financial or personal interests that could have influenced the work reported in this paper.

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