



The Effectiveness of Flipped Classroom Integrated with Deep Learning Based on Multiple Representations on Chemical Equilibrium Material to Improve HOTS

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Received: May 25th, 2026 Accepted: July 26th, 2026 Online Published: August 11th, 2026

Abstract: The Effectiveness of Flipped Classroom Integrated with Deep Learning Based on Multiple Representations on Chemical Equilibrium Material to Improve HOTS. Objectives: This study aims to describe the effectiveness of a flipped classroom integrated with a deep learning approach based on multiple representations on chemical equilibrium material in improving students' Higher Order Thinking Skills (HOTS). Methods: This study employed a quasi-experimental method with a nonequivalent pretest-posttest control group design. The sample was selected through purposive sampling, consisting of class XI.F.4 as the experiment class and XI.F.5 as the control class. Data were analyzed using the Independent Sample T-Test. Findings: The average n-gain HOTS of students in the experiment class was 0.35, categorized as moderate and significantly higher than that of the control class. Conclusion: The flipped classroom integrated with deep learning based on multiple representations on chemical equilibrium material was effective in improving students' HOTS.

Keywords: Chemical Equilibrium, Deep Learning, Flipped Classroom, HOTS, Multiple Representations.

Abstrak: Efektivitas Flipped Classroom Terintegrasi Deep Learning Berbasis Multiple Representations pada Materi Keseimbangan Kimia untuk Meningkatkan HOTS. Tujuan: Penelitian ini bertujuan untuk mendeskripsikan efektivitas flipped classroom terintegrasi dengan pendekatan deep learning berbasis multiple representations pada materi keseimbangan kimia dalam meningkatkan keterampilan berpikir tingkat tinggi. Metode: Penelitian ini menggunakan metode kuasi-eksperimen dengan desain nonequivalent pretest-posttest control group. Sampel dipilih menggunakan teknik purposive sampling, dengan kelas XI.F.4 sebagai kelas eksperimen dan XI.F.5 sebagai kelas kontrol. Data dianalisis menggunakan uji Independent Sample T-Test. Temuan: Rata-rata n-gain HOTS peserta didik pada kelas eksperimen sebesar 0,35 yang termasuk dalam kategori sedang dan secara signifikan lebih tinggi dibandingkan kelas kontrol. Kesimpulan: Pembelajaran flipped classroom terintegrasi deep learning berbasis multiple representations pada materi keseimbangan kimia efektif dalam meningkatkan HOTS.

Kata kunci: Chemical Equilibrium, Deep Learning, Flipped Classroom, HOTS, Multiple Representations.

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INTRODUCTION

The development of 21st-century technology demands human resources that are adaptive to change and capable of competing globally. Education plays a crucial role in

preparing generations to face these challenges (Mufit & Wrahatnolo, 2020). In response to this need, the government established the Merdeka Curriculum as the national curriculum starting in the 2024/2025 academic year (Putri & Hartono, 2026), which emphasizes student-centered learning and the mastery of 21st-century skills (6C) (Astuti, 2024). To support this, learning is directed toward the development of Higher Order Thinking Skills (HOTS), which encompass the ability to analyze, evaluate, and create (Handayani et al., 2023; Susilowati, 2020). Conventional, lecture-centered teaching methods are still commonly used. However, these methods are often ineffective in encouraging active participation and developing students' higher-order thinking skills (Agustina & Utami, 2025). Consequently, HOTS implementation in schools remains suboptimal, as evidenced by the low achievement of Indonesian students in the 2022 PISA assessment (OECD 2023, 2022). In chemistry learning, particularly on the abstract topic of chemical equilibrium, this condition is further compounded by the use of conventional teaching methods that fail to actively engage students (Gunawan et al., 2023). Therefore, a learning strategy capable of effectively developing HOTS is urgently needed.

This study therefore seeks to answer the following research question: How effective is the implementation of flipped classroom integrated with deep learning based on multiple representations in the topic of chemical equilibrium in enhancing students' HOTS? It is hypothesized that this integrated strategy will significantly improve students' HOTS compared to conventional learning, given that students are provided with structured opportunities to learn independently prior to class, deepen their understanding through discussion and experimentation, and consolidate their learning through reflection during the learning process (Eichler, 2022).

Theoretically, deep learning is a pedagogical approach that emphasizes meaningful understanding through the stages of comprehending, applying, and reflecting, while also orienting toward the development of students' competencies and character (Kemendikdasmen, 2025). Deep conceptual understanding as the core of meaningful learning can be achieved through the deep learning approach, a holistic framework that promotes active student engagement by integrating the principles of mindful learning, meaningful learning, and joyful learning (Setiawati et al., 2026). This approach is closely aligned with the development of higher-order thinking skills (HOTS), which enable students to transform their prior knowledge into new understandings by selecting ideas, constructing arguments, solving problems, developing explanations, formulating hypotheses, and simplifying complex concepts (Harahap & Jahro, 2025). The flipped classroom strategy supports this approach by utilizing time outside the classroom for content comprehension and in class time for higher-order thinking activities (Talbert & Bergmann, 2023; Zainuddin et al., 2019). Furthermore, multiple representations assist students in understanding chemical concepts through three levels of representation, namely macroscopic, submicroscopic, and symbolic (Rahmawati et al., 2022), thereby enhancing conceptual understanding and higher-order thinking skills.

Several studies have demonstrated that flipped classroom is effective in promoting deeper chemical thinking and facilitating higher-order learning (Eichler, 2022; Holloway et al., 2024), and that multiple representations deepen students' conceptual understanding while simultaneously improving HOTS (Yang, 2023). However, no study has yet investigated the integration of flipped classroom, deep learning, and multiple representations simultaneously in the context of chemical equilibrium learning. This study therefore addresses that gap by examining the effectiveness of flipped classroom

integrated with deep learning based on multiple representations in the topic of chemical equilibrium to enhance students' HOTS.

▪ METHOD

Population and Sample

The population of this study consisted of 175 eleventh-grade students at SMA Negeri 15 Bandar Lampung in the 2025/2026 academic year, distributed across five classes. Samples were selected using purposive sampling, defined as a sampling technique based on specific criteria or considerations predetermined by the researcher (Creswell & Creswell, 2017), in this case based on relatively equal cognitive abilities across classes. This resulted in two classes: XI.F.4 as the experiment class and XI.F.5 as the control class. The experiment class received instruction using a flipped classroom strategy integrated with deep learning based on multiple representations, while the control class received conventional instruction.

Research Variables

This study employed a quasi-experiment method with a nonequivalent pretest-posttest control group design. The independent variable was the learning strategy applied, namely flipped classroom integrated with deep learning based on multiple representations for the experiment class and conventional learning for the control class, while the dependent variable was students' higher-order thinking skills, with chemical equilibrium specifically the factors affecting the direction of chemical equilibrium shifts serving as the control variable.

Research Instruments

This study utilized two types of data: primary data in the form of students' pretest and posttest HOTS scores covering analyzing, evaluating, and creating skills, as well as supporting data consisting of student activity and learning implementation observations. The learning instruments included a deep learning teaching module and three student worksheets based on multiple representations covering the topics of concentration, pressure and volume, and temperature and catalyst, all validated through expert judgement. The research instruments consisted of nine essay questions measuring HOTS across three indicators based on Anderson & Krathwohl (2001): analyzing (C4), evaluating (C5), and creating (C6). Of the nine items, seven questions measured analyzing skills (C4), one question measured evaluating skills (C5), and one question measured creating skills (C6), all of which addressed the topic of factors affecting the direction of chemical equilibrium shifts. The scoring rubric applied differentiated grading scales according to item difficulty level: a 0–5 scale for high difficulty items, a 0–3 scale for moderate difficulty items, and a 0–2 scale for low difficulty items. Supporting instruments included student activity observation sheets and a learning implementation checklist using a 0–4 scale. Validation of all instruments was carried out through judgment by the expert. The pretest and posttest grids can be seen in Table 1 below.

Table 1. HOTs Pretest and Posttest Grid

Subject Matter	Criteria for Achieving Learning Objectives	HOTs Indicator	Question Number	Maximum Score
Pressure and volume factors on the direction of shift in chemical equilibrium	Identify changes in the number of gas molecules due to changes in pressure and volume compared to initial conditions.	Analyze (organize)	2b	3
	Determine the direction of the equilibrium shift when the pressure is increased (volume is decreased) and the pressure is decreased (volume is increased)	Analyze (organize)	2c	3
	Comparing illustrations of the effect of pressure and volume on chemical equilibrium based on identification results.	Evaluate (criticize)	2e	3
Temperature factor on the direction of shift in chemical equilibrium	Determine the experimental procedure for the effect of temperature on the direction of shift in chemical equilibrium.	Creating (designing)	3	5
	Identify changes in the number of gas molecules that increase and decrease due to changes in temperature that are increased and decreased and compared with the initial conditions.	Analyze (organize)	4c	3
	Identify the direction of equilibrium shift when the temperature is lowered and raised and relate it to the ΔH value.	Analyze (organize)	4d	3
Catalytic factors on the direction of shift in chemical equilibrium	Comparing the initial concentrations of N_2 , H_2 , and NH_3 on the equilibrium system graph without a catalyst and with a catalyst.	Analyze (differentiating)	5a	3
	Comparing the concentrations of N_2 , H_2 , and NH_3 after reaching equilibrium on the equilibrium system graph without a catalyst and with a catalyst.	Analyze (differentiating)	5b	3
	Compare the time it takes to reach equilibrium in the graph of the equilibrium system with a catalyst to the graph of the equilibrium system without a catalyst.	Analyze (differentiating)	5c	2

Research Procedure

The higher-order thinking skills examined in this study refer to the HOTS indicators proposed by Anderson & Krathwohl (2001), which include analyzing (C4), evaluating (C5), and creating (C6). These indicators were systematically embedded across the learning phases through the integration of flipped classroom, deep learning, and multiple representations.

The learning was implemented across three meetings, each structured into out class and in class activities aligned with the deep learning stages of understanding, applying, and reflecting. In the out class phase (understanding stage), students were presented with a real life phenomenon related to chemical equilibrium to stimulate contextual awareness and promote mindful learning. Students were then asked to identify the materials needed and design an experiment procedure, thereby exercising their creating skills (C6). In the in class phase (applying stage), students conducted experiments on the factors affecting the direction of chemical equilibrium shifts, allowing them to apply knowledge contextually in a meaningful and joyful learning experience. Following the experiment, students collected and recorded observational data, then analyzed submicroscopic representations to identify their relationship with the direction of equilibrium shifts, which trained their analyzing skills (C4). In the reflecting stage, students reviewed their preliminary answers in the student worksheet and assessed their correctness, exercising their evaluating skills (C5). Reflective questions were further provided to deepen students' awareness of their own learning process and to promote self-regulation of understanding. Throughout all stages, multiple representations at the macroscopic, submicroscopic, and symbolic levels were incorporated to support students in constructing a comprehensive and meaningful understanding of chemical equilibrium concepts.

Data Analysis Techniques

Calculation of Student N-Gain

The pretest and posttest scores were subsequently used to calculate the normalized gain (n-gain) using the following formula:

$$n\text{-gain} = \frac{\text{posttest score} - \text{pretest score}}{\text{maximum score} - \text{pretest score}}$$

Calculation of Mean N-Gain of Students' HOTS

After obtaining the n-gain for each student in both the experiment and control classes, the mean n-gain was calculated using the following formula:

$$\text{Mean n-gain} = \frac{\sum n\text{-gain of all students}}{\text{total number of students}}$$

The mean n-gain scores were then interpreted based on the classification criteria proposed by Hake (1998), as presented in Table 2. below.

Table 2. N-Gain Classification

N-gain Criteria	Criteria
$n\text{-gain} \geq 0,7$	High
$0,3 \leq n\text{-gain} < 0,7$	Medium
$n\text{-gain} < 0,3$	Low

Normality Test

A normality test was conducted to determine whether the sample data were normally distributed, using the Kolmogorov-Smirnov test in SPSS version 26.0. The hypothesis stated that H_0 was accepted if the data were normally distributed and H_1 was accepted if otherwise, with the criterion that a significance value of ≤ 0.05 indicated non-normal distribution, while a value of > 0.05 indicated normal distribution. The results of this test determined whether parametric or non-parametric statistical tests would be applied in subsequent analyses.

Homogeneity Test

A homogeneity test was conducted using the Levene Statistic in SPSS version 26.0 to determine whether the research samples came from a homogeneous population, which in turn determined the statistical test used for hypothesis testing. H_0 was accepted if the sample populations were homogeneous, and H_1 was accepted if otherwise, with the criterion that H_0 was accepted when the significance value was > 0.05 and rejected when < 0.05 .

Hypothesis Testing

A two-sample mean difference test was conducted to determine the significance of the difference between the average HOTS n-gain scores of the experiment and control classes using the Independent Sample t-Test with Equal Variance Not Assumed, since the data were normally distributed but not homogeneous, analyzed using SPSS Statistics 26.0. H_0 stated that the average HOTS n-gain score of the experiment class was lower than or equal to that of the control class ($\mu_1 \leq \mu_2$), while H_1 stated that it was higher ($\mu_1 > \mu_2$). H_0 was accepted if Sig. (2-tailed) > 0.05 and H_1 was accepted if Sig. (2-tailed) < 0.05 .

▪ RESULT AND DISCUSSION

The effectiveness of the flipped classroom strategy integrated with deep learning based on multiple representations in improving students' Higher Order Thinking Skills (HOTS) on chemical equilibrium material was determined through the analysis of HOTS n-gain scores and hypothesis testing.

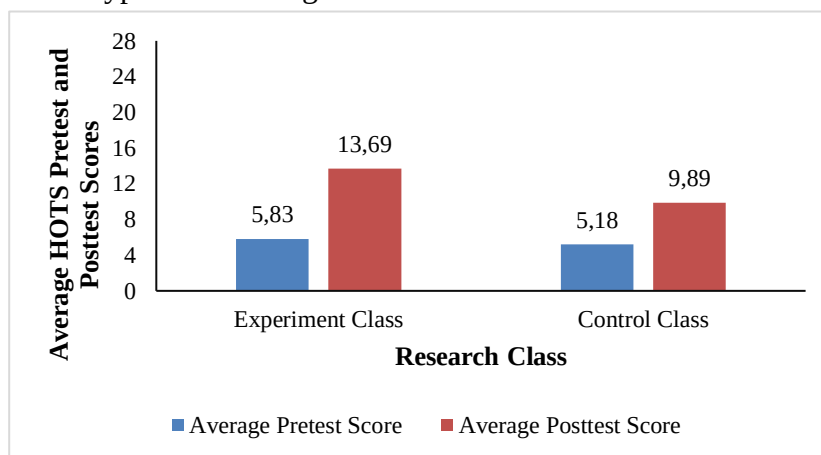


Figure 1. Average HOTS Pretest And Posttest Scores In The Experimental And Control Classes.

The maximum score for both the pretest and posttest was 28. The average pretest and posttest HOTS scores of both classes are presented in Figure 1. As shown in Figure 1, the average pretest scores of the experimental and control classes were relatively similar, indicating comparable initial abilities. Following the treatment, the experimental class showed a higher average posttest score than the control class by 3.8 points, suggesting that the flipped classroom strategy integrated with deep learning based on multiple representations contributed to a greater improvement in HOTS compared to conventional learning.

HOTS N-Gain Scores

The comparison of the average HOTS n-gain scores between the experiment and control classes is presented in Figure 1. The experiment class obtained a higher average HOTS n-gain score (0.35) than the control class (0.20). According to Hake's (1998) classification, the experiment class was categorized as moderate while the control class was categorized as low. Although the experiment class achieved a moderate category, it is important to note critically that an n-gain of 0.35 still reflects a relatively limited improvement, suggesting that certain aspects of HOTS development were not yet fully optimized within the three-meeting instructional period. This limitation may be attributed to students' initial unfamiliarity with the flipped classroom structure, particularly in the first meeting, where both out class preparation and in class participation were still suboptimal. Nevertheless, the result still indicates that students who learned using the integrated strategy experienced meaningfully greater HOTS improvement compared to those in the conventional class.

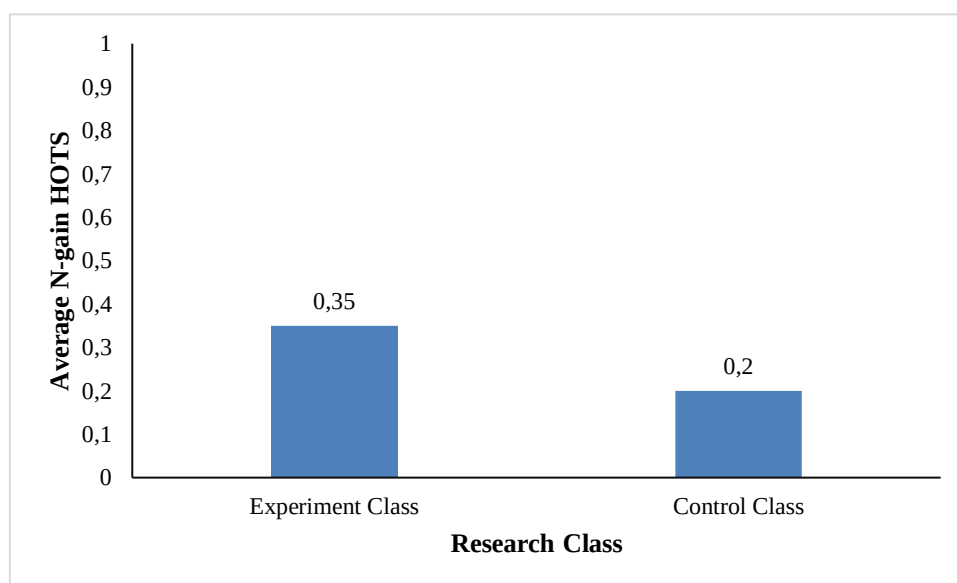


Figure 1. Average HOTS N-gain Scores of Experiment and Control Class

To determine whether the difference between the two classes was statistically significant, an Independent Sample t-Test with Equal Variance Not Assumed was conducted because the data were normally distributed but not homogeneous, as confirmed by the Kolmogorov-Smirnov normality test (experiment class: sig. = 0.075; control class: sig. = 0.102) and Levene's homogeneity test (sig. = 0.018). The result of the hypothesis test is presented in Table 3.

Table 3. Independent Sample t-Test Result of HOTS N-Gain Scores

Class	Sig. (2-tailed)	Decision
Experiment and Control	0.001	H ₁ accepted

The significance value of 0.001 was lower than 0.05, indicating that the average HOTS n-gain score of the experiment class was significantly higher than that of the control class. This finding is consistent with Eichler (2022) and Holloway et al. (2024), who reported that flipped classroom learning effectively facilitates higher-order learning and promotes deeper understanding in chemistry. The significant difference between classes can be attributed to the structured integration of three complementary approaches: the flipped classroom provided students with out class preparation time so that in class sessions could focus on analysis, discussion, and problem solving rather than passive content delivery. The deep learning framework ensured that learning progressed through understanding, applying, and reflecting stages that progressively engaged higher cognitive processes. Multiple representations connected abstract chemical equilibrium concepts across macroscopic, submicroscopic, and symbolic levels, enabling students to construct more comprehensive understanding. The synergy of these three elements created learning conditions that were more conducive to HOTS development compared to conventional instruction.

N-Gain per HOTS Indicator

The improvement of HOTS was further analyzed based on each indicator, namely analyzing (C4), evaluating (C5), and creating (C6), as presented in Figure 2. The experiment class outperformed the control class across all three indicators, with analyzing showing the highest improvement (experiment class 0.20 higher than control), followed by evaluating and creating (both 0.03 higher than control). All indicators in the experiment class ranged from low to moderate criteria, while the control class remained at low criteria across all indicators.

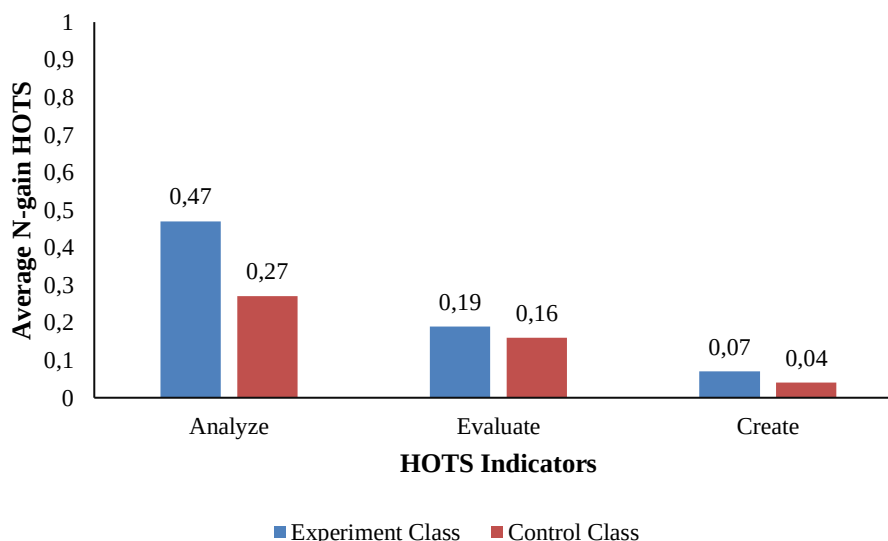


Figure 2. Average n-gain Scores for Each HOTS Indicator

The analyzing indicator showed the greatest improvement because it was explicitly and repeatedly trained across all three meetings through multiple

representations at macroscopic, submicroscopic, and symbolic levels. Students analyzed color changes, molecular interactions, gas molecule quantities, equilibrium shift directions, temperature effects on K values, and catalyst roles through experiments and LKPD discussions. The use of submicroscopic visualizations was particularly impactful, as it helped students connect observable phenomena with particle level interactions, making abstract concepts more accessible for analysis. This finding aligns with Basimin *et al.* (2023), who reported that visual representations effectively improve students' HOTS in chemistry learning. Furthermore, Anggraini *et al.* (2025) confirmed that deep learning experiences involving understanding, applying, and reflecting stages improve students' cognitive abilities because students actively construct and apply knowledge throughout the process.

The evaluating indicator also showed improvement, though smaller than analyzing. Students were trained to assess the correctness of statements related to chemical equilibrium concepts during the reflecting stage across all three meetings. Observations showed a progressive improvement in students' evaluating responses. There was meeting 1, students could explain the reasoning but did not explicitly state whether a statement was correct or incorrect, by meeting 2, students began to state their judgment before providing reasoning, and by meeting 3, students provided complete and accurate evaluations with logical scientific justification. This development indicates that reflective learning activities supported the growth of students' critical judgment, consistent with the deep learning principle of mindful learning where students actively regulate and reflect on their own understanding.

The creating indicator showed the lowest n-gain improvement among all HOTS indicators. This outcome is closely related to the limited frequency of creating practice, which only appeared once across the three meetings, specifically during the out class activity of meeting 3, where students designed experiment procedures for investigating the effect of temperature on equilibrium shifts. While students were generally able to determine appropriate tools, materials, and procedural steps, many still had difficulty specifying complete details such as equipment sizes, quantities, and systematic step by step sequences. The infrequent exposure to creating tasks within the LKPD meant that students did not have sufficient opportunities to develop this skill optimally. This finding is in line with Aydın & Mutlu (2023), who stated that low student performance in C6 cognitive tasks is largely due to insufficient practice at that level. Therefore, future implementations would benefit from incorporating creating tasks more frequently across all meetings to provide students with greater opportunities to develop this complex cognitive skill.

Student Activity

Supporting evidence for the effectiveness of the integrated strategy is further provided by student activity observation data. The average percentage of student activity across meetings is presented in Figure 3.

Based on Figure 3, student activity observations in the experimental class showed a consistent increase across meetings. Activity in meeting 2 increased by 4.62% from meeting 1, and activity in meeting 3 increased by a further 12.97%, reaching a high criterion based on Arikunto (2002) classification. The dominant activity across all meetings was group discussion, followed by expressing opinions and asking questions, all of which increased progressively. This pattern reflects students' growing adaptation to the flipped classroom structure, wherein prior out class preparation enabled more

confident and active in class participation. This finding is consistent with Ayuningsih et al. (2025), who reported that flipped classroom allows students to learn at their own pace, resulting in greater preparedness and active engagement during classroom sessions, and with Agustini (2021), who found that flipped classroom improves student activity and learning outcomes.

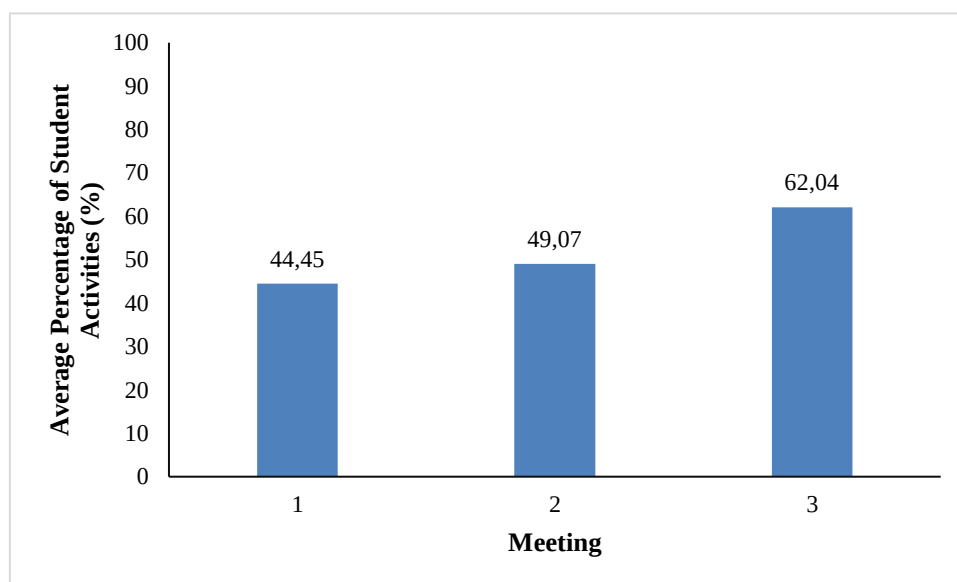


Figure 3. Average Percentage of Student Activity at Each Meeting in The Experiment Class

Learning Implementation

The learning implementation data for both out class and in class phases across meetings are presented in Figure 4.

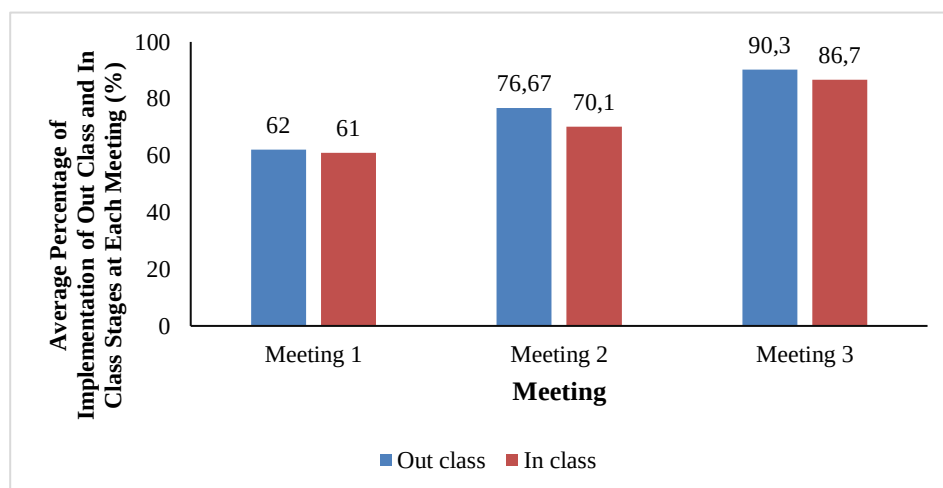


Figure 4. Average Percentage of Implementation of Out Class and In Class Stages at Each Meeting

Based on Figure 4, the out class implementation percentage increased by 13.67% from meeting 1 to meeting 2 (high criterion) and by a further 13.63% in meeting 3 (very high criterion). In the first meeting, out class implementation was still low because students were unfamiliar with the flipped classroom workflow; the teacher subsequently provided reminders via WhatsApp group for meeting 2, which contributed to the improvement. The in class implementation also increased progressively, rising by 9.1% from meeting 1 to meeting 2 and by 16.6% from meeting 2 to meeting 3, reaching a very high criterion. The improvement in learning implementation reflects the teacher's increasing effectiveness in managing discussion, guiding multiple representation analysis, and facilitating active student participation across meetings. The high quality of learning implementation across both phases further supports the validity of the HOTS improvement observed in the experimental class.

Overall, these findings demonstrate that integrating flipped classroom, deep learning, and multiple representations creates a synergistic learning environment that supports the development of all three HOTS indicators. The flipped classroom structure optimized in class time for higher-order activities, the deep learning framework ensured progressive cognitive engagement through understanding, applying, and reflecting, and multiple representations bridged the gap between abstract chemical concepts and student understanding. This integrated approach can therefore serve as an effective and innovative strategy for improving HOTS in chemistry learning, particularly on abstract topics such as chemical equilibrium.

▪ CONCLUSION

The implementation of the flipped classroom strategy integrated with deep learning based on multiple representations was found to be effective in improving students' Higher Order Thinking Skills (HOTS) on chemical equilibrium material, as evidenced by the experimental class achieving an average n-gain of 0.35 (medium category) and a significantly higher mean compared to the control class. This finding implies that integrating student-centered learning with multiple forms of chemical representation not only supports deeper conceptual understanding but also creates a more meaningful and engaging learning environment that systematically trains students' analytical, evaluative, and creative thinking abilities. However, this study has several limitations, including the short duration of only three meetings and the unequal distribution of HOTS indicators in the learning instruments, particularly the limited exposure to evaluating and creating tasks, which may have constrained the overall HOTS improvement. Future research is therefore encouraged to extend the duration of implementation, design more proportional HOTS-based tasks across all cognitive levels, and explore the integration of this strategy across other chemistry topics or broader science subjects. Chemistry teachers are also encouraged to optimize the use of submicroscopic visualizations and interactive representations to facilitate students' understanding of abstract chemical concepts, as these elements were shown to play a key role in supporting higher-order thinking development in this research.

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