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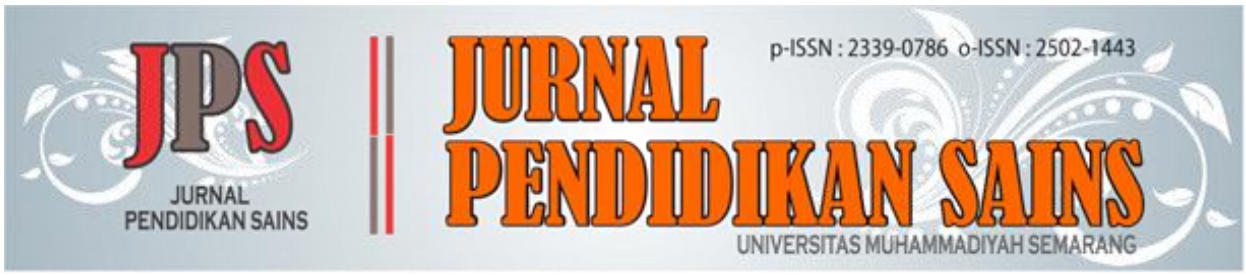


# IMPLEMENTATION OF FLIPPED CLASSROOM BASED ON DISCOVERY LEARNING MODEL TO IMPROVE STUDENTS' CRITICAL THINKING SKILLS IN TEMPERATURE AND HEAT MATERIALS

Rizqi Al Fajri[1*], Muhammad Minan Chusni[2], Adam Malik[3]

[a]Physics Education, Faculty of Education and Teacher Training, UIN Sunan Gunung Djati Bandung, Indonesia
[b]Physics Education, Faculty of Education and Teacher Training, UIN Sunan Gunung Djati Bandung, Indonesia
[c]Physics Education, Faculty of Education and Teacher Training, UIN Sunan Gunung Djati Bandung, Indonesia
Email corresponding author
Rizqialfajri27@gmail.com

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**Abstract**

The purpose of this study is to ascertain how the Discovery Learning Model-Based Flipped Classroom might enhance students' critical thinking abilities about heat and temperature. This study used a nonequivalent control group design and a quasi-experimental methodology. While the control group used the discovery learning model without the assistance of the flipped classroom, the experimental group used the flipped classroom based on the model. All 11th grade classes at SMA 1 Bina Negara Baleendah comprised the research population. Thirty students from the 11th grade Interest A class served as the experimental class, and thirty students from the 11th grade Interest B class served as the control class. The Authentic Assessment Based on Teaching and Learning Trajectory with Student Activity Sheets (AABTLT with SAS) instrument and tests of critical thinking abilities based on five indicators created by Robert Ennis were used to collect data for this study. The Shapiro-Wilk test for normality, the Levene test for homogeneity, the independent sample t-test for hypothesis testing, and N-Gain testing were among the data analysis methods used in the AABTLT with SAS data analysis and critical thinking skills exam data analysis. According to the findings, the experimental class's learning implementation achieved an average of 85.33%, which is

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considered highly effective, whereas the control class's average was 83.66%, which is considered effective. The N-Gain score, which was 0.76 in the experimental class and 0.69 in the control class, demonstrated the improvement in students' critical thinking abilities. The control group was categorized as moderate, and the experimental group as high. A significant value (sig.2-tailed) of 0.001 < 0.05 was obtained from the hypothesis test findings using the independent sample t-test. These findings show that students' critical thinking abilities differ significantly between the experimental and control groups. As a result, students' critical thinking abilities improved more when the Discovery Learning Model-Based Flipped Classroom was implemented than when the Discovery Learning Model was used alone.



**Keyword**

Flipped Classroom
Discovery Learning
Critical Thinking
Temperature and Heat
Learning Management System (LMS)

## 1. INTRODUCTION

Natural phenomena are the subject of physics (Trianingsih et al., 2019) (Fisika & Pilar, 2023). A crucial 21st-century skill, critical thinking fosters the capacity to thoroughly analyze, synthesize, and assess knowledge (Sèna & Etienne, 2022) (Nurohman & Buhera, 2025). Students can acquire critical thinking abilities when studying physics (Puspitasari & Nurhayati, 2019). Thinking is one of the talents in 21st century learning, according to research findings from ATS21S (Assessment & Teaching of 21st Century Skills) state that thinking is one of the skills in 21st century learning (Ruhana et al., 2023). One of the goals of 21st century education is to equip students to deal with the challenges of life and the demands of the modern world by developing their critical thinking abilities. According to (Linussa, 2013) (Hasanah et al., 2023), Ennis describes critical thinking as a process of applying reflective and rational thinking abilities with the goal of making decisions about what to do and what to believe (Ardhini et al., 2021).

Teaching students to think critically can make them competent and skilled individuals (Alwiyana et al., 2021) (Ridhotin, 2021). Ennis states that critical thinking is a thought process for making decisions about beliefs and actions that can be justified (Setyawan & Kristanti, 2021). Critical thinking is also considered a strong and careful attitude, aimed at distinguishing between effective thinking systems and those that are less involved in comprehensive thinking. For Dewey, the most important thing is what he calls the foundation that supports a conclusion (Wayudi et al., 2020)

In line with several findings from previous studies. Nuryanti et al. (2018) stated that critical thinking skills at the high school level are still very low, as evidenced by the results of an analysis of the average scores of 10th grade students at Bandung State High School, which

revealed that they only received a score of 46.6% for critical thinking. The lack of student-centered instruction is the cause of the poor average score (Wayudi et al., 2020) (Latifah & Utama, 2024). Teachers have a duty to provide an autonomous learning system for pupils since they are among the leaders of education. In order to enhance students' critical thinking abilities in the subject of temperature and heat at SMA 1 Bina Negara Baleendah, the researchers highlight the need for more effective learning, specifically by implementing interactive learning through LMS using the flipped classroom approach and discovery learning model.

Based on preliminary studies involving interviews, observations, and critical thinking tests conducted in class XI MINAT A1 SMA 1 Bina Negara Baleendah, from interviews with physics teachers, it was found that the models used were still limited, because the school only used the lecture method, while most of the learning still relied on books and worksheets. The results of the observation showed that although teachers had tried to develop critical thinking skills, these efforts were still not fully maximized.

The average score of 56% on the thinking skills test administered to 28 pupils in class XI MINAT A1 at SMA 1 Bina Negara Baleendah remained comparatively low. In order to improve students' critical thinking abilities, media that incorporates critical thinking skill indicators must be created. This is because the usage of learning aids like media has not been able to train students' critical thinking skills. This is consistent with the findings of the test of critical thinking abilities that was given. The five critical thinking skill indicators listed by Ennis (2013) providing basic explanation, developing basic support, drawing conclusions, offering additional clarification, and strategy and tactics are referenced in the suggested critical thinking skill indicators.

Learning material can be offered as an LMS as technology develops. LMS, a digital tool for online assignments and materials, can assist professors in evaluating student work both individually and in groups, allowing students to raise the caliber of their education. Using the instructional resources found in LMS, students can develop their critical thinking abilities and come up with new ideas while working on practical projects (Lailiah et al., 2021). The Moodle application, an online learning concept, is used by the LMS. This electronic learning process is a new learning framework model in which students and teachers interact and then work together to develop information and complete tasks. With the help of the Moodle program, the LMS employs the flipped classroom model and is organized using the Discovery Learning syntax. Students' critical thinking abilities in physics, particularly in the area of temperature and heat, can be enhanced by using the Discovery Learning syntax and flipped classroom approach to the digital LMS with the help of the Moodle program (Ruhana et al., 2023).

According to earlier studies, employing traditional learning techniques makes students less engaged in Q&A sessions, bored, and less able to understand the subject matter (Anugraheni, 2017); (Putri, 2023). Discovery learning is one educational approach that gives pupils the chance to develop their critical thinking abilities. According to (Jenirita et al., 2021), the discovery learning model helps students grasp and assimilate the material being studied by requiring student involvement, self-discovery, problem identification, and problem solving instead of simply waiting for the teacher to explain the material (Putri, 2023).

The implementation of learning models, such as the discovery learning model, has a major impact on promoting critical thinking. The discovery technique can help students become more focused in their daily lives by accustoming them to proving a concept in the topic they are studying. When compared to traditional learning, Kadri, M., and Meika Rahmawati (2015: 31–33) claim that the discovery learning approach significantly improves student learning outcomes in the topic of temperature and heat in physics (Nazara et al., 2024).

The application of the discovery learning model can improve students' learning outcomes in the classroom by boosting their enthusiasm and interest in learning, which improves the development of their critical thinking abilities (Novayani et al., 2015); (Ruhana et al., 2023). In the meantime, Effendi (2012) claims that Discovery Learning is an approach to

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education that uses problem-solving to help students expand their knowledge and abilities (Nababan et al., n.d.).

Additionally, because this model is contextual in nature and incorporates real-world issues, it presents students with additional challenges (Muharromah et al., 2019). According to Supliyadi, M. Irham Baedhoni, (2017:209); (Anaperta & Helendra, 2021), the stages of the discovery learning model are as follows: 1) Stimulation (stimulation/providing stimuli); 2) Problem Statement (statement/identification of problems); 3) Data Collection; 4) Data Processing; 5) Verification; and 6) Generalization (drawing conclusions/generalization). (Anaperta & Helendra, 2021)

It is clear from the statement above that critical thinking abilities are not currently supported at the school where the research was done. Therefore, the researcher aimed to develop an LMS that could use the flipped classroom approach to help students learn and practice critical thinking abilities. With this method, students are initially provided with learning videos and learning materials along with LKPD, which they are required to view and study. They are also required to write notes on any parts of the film that they do not understand. On the other hand, discussions and assignments make up the classroom learning session. (SALSABILA, 2023)

One type of blended learning that has gained popularity as a learning strategy is the flipped classroom (FC). Activities that are typically completed in groups in classrooms are switched to outside-of-class activities, while activities that are typically completed outside of individual classes are switched into classroom activities, reversing the learning activities of students. Before learning in the classroom, students engage in extracurricular activities using educational resources that teachers have made available through information and communication technology (ICT), such as videos that are distributed via the Learning Management System (LMS) or other platforms. Activities and the application of knowledge, which are utilized as homework, take up class time that would otherwise be spent listening to lectures. Solving issues, having debates, doing analyses, and interacting well with other students are all examples of classroom activities (Nugraheni et al., 2022).

In order to enhance students' higher-order thinking and communication abilities, an FC-based learning approach gives teachers additional opportunity to engage students in applying their information and interacting with classmates and teachers to exchange ideas and knowledge. By using FC, educators may help students improve their critical thinking (CT) abilities and boost their engagement, success, and learning satisfaction. Additionally, FC gives teachers adequate time to give students more individualized feedback and help, as well as to receive student input and identify the materials that students do not understand (Nugraheni et al., 2022).

In the realm of teaching physics, the flipped classroom paradigm is extremely important. Teachers of physics can use technology and digital resources to create engaging pre-class materials, like interactive activities, simulations, and movies that explain complex ideas. These resources give students the information and comprehension they need for in-depth conversations and hands-on activities in the classroom (Bhakti et al., 2021; N. K. Rapi et al., 2022). (Agusta et al., 2025). This supports the claim made by Sania et al. (2022) that the flipped classroom gives students the chance to actively participate in class discussions and solve problems while learning (Latifah & Utama, 2024).

The reason researchers chose a discovery learning-based flipped classroom for the Temperature and Heat material was because it required learning tools that supported the visualization of the material in order to make the learning process interesting for students so that their critical thinking skills could improve. The implementation of learning on the subject of temperature and heat requires students to systematically and critically analyze various related physical phenomena, such as heat transfer through convection, conduction, and radiation in everyday life. They can consider the effects of substance flow, particle transfer,

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heat transfer without intermediaries, and their practical applications in technology, which can be fulfilled through the implementation of an LMS assisted by the Moodle application in learning.

The implementation of the Discovery Learning-based Flipped Classroom model in temperature and heat material will add variety to the learning model, which is interesting and encourages students to play an active role in the learning process. This learning model, based on previous research, is also expected to facilitate understanding of the material later on with interactive media and improve the quality of the learning process through the flipped classroom approach with the discovery learning model, which can further improve students' critical thinking skills.

## 2. METHOD

The The method used in this study was a quasi-experimental design, a research method that involves administering a specific treatment, measuring its effects, and using experimental units, but without using randomization in the division of groups. As a substitute for randomization, comparisons were made to determine whether the changes that occurred were caused by the treatment (Syahrizal & Jailani, 2023). This quasi-experimental study was conducted in two classes, an experimental class and a control class. The design used was the Nonequivalent Control Group Design, which aims to analyze and compare two different groups. The initial stage of the study began with a preliminary test to measure the critical thinking skills of the students. Next, the treatment was given to the experimental class by implementing a discovery learning-based flipped classroom, while the control class used the discovery learning model without the help of a flipped classroom. After that, a final test was conducted to assess changes in students' critical thinking skills.

Students' critical thinking abilities and their reactions to the flipped classroom learning model based on differentiation tactics were among the data needed for this study. Table 1 displays the research design and the kinds of data that were gathered.

**Table 1.** Research design

| No. | Group | Pretest | Treatment | Posttest |
|---|---|---|---|---|
| 1. | Experiment | $Y_1$ | X | $Y_2$ |
| 2. | Control | $Y_1$ | C | $Y_2$ |

Based on Table 1, the learning activities in both sample classes were basically the same. The difference was in the learning approach applied in the experimental class, which used a flipped classroom approach assisted by a discovery learning model, while the control class used a discovery learning model without the assistance of a flipped classroom approach.

A research instrument is a tool used to measure observed natural and social phenomena. The instruments used in this study were authentic assessments and tests, as shown in Table 2.

**Table 2.** Instruments

| No. | Rumusan Masalah | Instrumen |
|---|---|---|
| 1. | Implementation of discovery learning models based on flipped classrooms and discovery learning models | LKPD assessment assisted by AABLT with SAS |

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|---|---|---|
| 2. | The difference in critical thinking improvement using the flipped classroom-based discovery learning model and the discovery learning model. | 1. Critical thinking pretest<br>2. Critical thinking posttest |

The LKPD assisted by AABTLT with SAS was tested for suitability with the teaching module to be used and its grid before the research was conducted. The assessment rubric for each student's answer was made on a scale of 0-4 with explanations as shown in Table 3.

**Table 3.** Rubrik Penilaian AABTLT with SAS

| Skor | Kriteria |
|---|---|
| 0 | If the respondent does not provide an answer |
| 1 | If the respondent provides an incorrect answer |
| 2 | If the answer provided is correct but incomplete |
| 3 | If the answer provided is correct and complete but not as perfect as expected |
| 4 | If the answer is correct/perfect |

After each respondent's SAS has been scored and totaled, it will be processed, analyzed using descriptive statistics, and reported as a percentage of learning achievement. Table 4 provides the standards for students' average learning achievement.

**Table 4.** Average SAS criteria

| Average percentage of learning achievement (%) | Criteria |
|---|---|
| < 55 | Ineffective |
| 55-70 | Less Effective |
| 71-85 | Effective |
| >85 | Very Effective |

The research was conducted in stages, which were clearly and systematically described in three stages, including:
(1) Preparation stage. Activities carried out in the preparation stage were: a) Determining the research location and obtaining permits for the research; b) Conducting a preliminary study through interviews with teachers and students, direct observation, and problem-solving skill tests in accordance with the indicators; c) Conducting a literature study of journals, books, and articles to obtain theories about the learning that would be applied; d) Reviewing the curriculum and determining the learning materials; e) Determining the approach, methods, and research design; f) Determining the population and sample to be used; g) Creating a research proposal. h. Designing a learning plan in accordance with the form of learning being tested; I) Creating research instruments consisting of AABTLT with SAS and critical thinking skills tests; J) Reviewing or judging the instruments by expert lecturers or supervisors, namely supervisors 1 and 2; k. Conducting a trial of the critical thinking test instruments; l. Analyzing the results of the trial, including validity, reliability, level of difficulty, and the discriminating power of the test questions; m. Determining the research instruments; n. Creating a schedule of learning activities to be carried out.

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(2) Implementation stage Activities carried out at this stage include the following: a. Conducting initial tests using critical thinking skill questions that have been prepared in the experimental and control classes; b. Implementing learning using the flipped classroom assisted by the discovery learning model and the discovery learning model without the assistance of the flipped classroom; c. Observing student activities during the learning process using AABTLT with SAS data; d. Conducting a final test using the same questions as before the treatment or initial test.
(3) Final stage Activities carried out in the final stage are as follows: a. Processing and analyzing the data obtained, including data on implementation and initial and final test results; b. Discussing the research results in the form of a final report; c. Drawing conclusions based on data processing and analysis.

## 3. RESULTS AND DISCUSSION

### Data on the Implementation of the Flipped Classroom Model with a Discovery Learning Approach

The implementation of learning during 3 meetings by applying the flipped classroom model and discovery learning approach was carried out on Wednesday, November 12, 2025, with discussion material on Changes in the Form of Substances, Heat Transfer, External Work, and Heat Capacity. These three sessions were attended by 30 students from class XI Interest B. The time allocation for this learning was 120 minutes or three lessons and was assessed using AABTLT with SAS authentic assessment at each stage of learning. The percentage of the average learning effectiveness score by implementing the flipped classroom assisted by the discovery learning model in three sessions is presented in Table 5.

**Table 5.** Recapitulation of Average Effectiveness Data Learning Effectiveness for Each Meeting

| Pertemuan | Effectiveness of Learning | |
|---|---|---|
| | Percentage (%) | Interpretation |
| 1 | 82 | Effective |
| 2 | 86 | Highly Effective |
| 3 | 88 | Highly Effective |
| Average | 85.33 | Highly Effective |

Based on Table 5 above, which presents a summary of the effectiveness of learning implementation in each meeting by applying the flipped classroom assisted by the discovery learning model, it shows that the effectiveness of learning increased from meeting to meeting. In the first meeting, the effectiveness of learning was recorded at 82% with an effective interpretation. Subsequently, effectiveness increased to 86% in the second meeting and 88% in the third meeting, both of which were categorized as highly effective. Overall, the flipped classroom assisted by the discovery learning model was able to be implemented very well in supporting learning implementation in the classroom.

### Average Data on the Implementation of Each Learning Stage

Based on the results of analysis using the AABTLT with SAS method during three learning meetings that applied the flipped classroom assisted by the discovery learning model in the experimental class, data was obtained on the average percentage of implementation of each

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learning stage. A summary of the effectiveness of the implementation of each learning stage is presented in Table 6.

**Table 6.** Recapitulation of the Effectiveness of the Implementation of Each Stage of Learning

| Learning Stages | Meeting No. 1 | | Meeting No. 2 | | Meeting No. 3 | | Average | |
|---|---|---|---|---|---|---|---|---|
| | Percentage (%) | Interpretation | Percentage (%) | Interpretation | Percentage (%) | Interpretation | Percentage (%) | Interpretation |
| Perception | 87 | Very Effective | 86 | Very Effective | 87 | Very Effective | 86.6 | Very Effective |
| Initial Concept | 85 | Effective | 90 | Very Effective | 89 | Very Effective | 88 | Very Effective |
| Stimulation | 80 | Effective | 79 | Effective | 84 | Effective | 81 | Effective |
| Data Collection | 84 | Effective | 84 | Effective | 88 | Very Effective | 85.3 | Very Effective |
| Data Processing | 78 | Effective | | | 88 | Very Effective | 83.3 | Effective |
| Conclusion | 75 | Effective | 88 | Very Effective | 89 | Very Effective | 84 | Effective |
| Reflection | 85 | Effective | 89 | Very Effective | 88 | Very Effective | 87.3 | Very Effective |
| Average | 82 | Effective | 86 | Very Effective | 88 | Very Effective | 85.3 | Very Effective |

Based on Table 6, the effectiveness of the implementation of each learning stage shows results that are generally in the effective to very effective category. The stage with the highest average is initial conception at 88%, which is categorized as very effective, indicating that teachers are able to provide very clear directions and instructions before the main activity begins. Other stages that also received high averages were reflection (87.3%), apperception (86.6%), and data collection (85.3%), all of which were categorized as highly effective. Meanwhile, several stages, such as data processing (83.3%) and conclusions (84%), still showed good effectiveness, even though they were categorized as effective. Only one stage, namely stimulation, was less effective in the first meeting and declined in the second meeting, but showed an increase in the following meeting, resulting in an average of 81% and falling into the effective category overall.

In general, these results show that the application of the flipped classroom assisted by the discovery learning model can be implemented very well in the classroom, with stages that are carried out consistently and effectively during three meetings.

**Data on the Implementation of the Discovery Learning Model without the Use of the Flipped Classroom**

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Three learning sessions using the discovery learning model without the use of the flipped classroom were held on Wednesday, November 19, 2025, covering topics such as changes in the form of matter, heat transfer, external work, and heat capacity. These three sessions were attended by 30 grade XI students majoring in A. The time allocation for this learning was 120 minutes or three lessons and was assessed using AABTLT with SAS authentic assessment at each stage of learning. The percentage of the average learning effectiveness score by applying the discovery learning model without the assistance of a flipped classroom in three sessions is presented in Table 7.

**Table 7.** Recapitulation of Average Effectiveness Data Learning Effectiveness for Each Meeting

| Meeting | Average Learning Effectiveness | |
|---|---|---|
| | Percentage (%) | Interpretation |
| 1 | 81 | Effective |
| 2 | 84 | Effective |
| 3 | 86 | Very Effective |
| Average | 83.66 | Effective |

Table 7 presents a summary of the effectiveness of learning implementation in the control class using the discovery learning model without the flipped classroom approach. The results show that all meetings were categorized as effective to highly effective. The first and second meetings received scores of 81% and 84%, respectively, both of which were categorized as effective. Meanwhile, the third meeting showed an increase in effectiveness with a score of 86%, which was categorized as highly effective. These results indicate that the discovery learning model without a flipped classroom can still be applied effectively in supporting the learning process.

**Average Data on the Implementation of Each Learning Stage**

Data on the average percentage of implementation of each learning stage was collected based on the findings of the study using the AABTLT with SAS approach during three learning sessions that applied the discovery learning model without the assistance of a flipped classroom in the control class. Table 8 summarizes how well each learning level was implemented.

**Table 8.** Recapitulation of the Effectiveness of the Implementation of Each Stage of Learning

| Learning Stages | Meeting No. 1 | | Meeting No. 2 | | Meeting No. 3 | | Average | |
|---|---|---|---|---|---|---|---|---|
| | Percentage (%) | Interpretation | Percentage (%) | Interpretation | Percentage (%) | Interpretation | Percentage (%) | Interpretation |
| Apperception | 84 | Effective | 83 | Effective | 86 | Very Effective | 84,3 | Effective |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Initial Conception | 80 | Effective | 83 | Effective | 89 | Very Effective | 84 | Effective |
| Stimulation | 80 | Effective | 81 | Effective | 86 | Very Effective | 82,3 | Effective |
| Data Collection | 79 | Effective | 86 | Very Effective | 87 | Very Effective | 84 | Effective |
| Data Processing | 82 | Effective | | | 85 | Effective | 84,3 | Effective |
| Conclusion | 79 | Effective | 91 | Very Effective | 87 | Very Effective | 85,6 | Very Effective |
| Reflection | 82 | Effective | 83 | Very Effective | 84 | Effective | 83 | Effective |
| Average | 81 | Effective | 84 | Effective | 86 | Very Effective | 83,6 | Effective |

Based on Table 8, which summarizes the effectiveness of each stage of learning in the control class, it was found that most stages were in the effective category, with some stages showing very effective results. The conclusion stage recorded the highest average of 85.6%, which is in the very effective category, indicating that teachers consistently explained the learning objectives very well. Most of the other stages, such as apperception, initial conception, stimulation, data collection, data processing, and reflection, were in the effective category, with average scores ranging from 82.3% to 84.3%. Meanwhile, reflection, despite receiving a low score in the first meeting, showed improvement in the following meetings, with a final average of 83%, which was also in the effective category. Overall, these results show that the application of the discovery learning model without the help of a flipped classroom can be carried out well at every stage of learning, although its effectiveness is slightly lower than that of the experimental class that used a flipped classroom.

**Overall Initial Test, Final Test, and N-Gain Scores**

Pretest and posttest procedures were used in the evaluation, which was based on the Critical Thinking Skills assessment rubric. Two classes, class XI Interest A as the control class and class XI Interest B as the experimental class, participated in the physics critical thinking skills test on temperature and heat material at SMA 1 Bina Negara Baleendah. Students in the experimental class improved their critical thinking abilities by using the flipped classroom approach in conjunction with the discovery learning model. On the other hand, without the aid of the flipped classroom, comparable abilities were taught in the control group using the discovery learning methodology. A test instrument comprising 12 essay questions that reflected Robert Ennis's five KBK indicators was used to assess learning results in both classes, with an emphasis on the topics of temperature and heat. Following a quantitative analysis, all test result data were displayed in Table 9.

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**Table 9.** Overall Average Scores for Initial Tests, Final Tests, and N-Gain

| Class | Average | | | |
|---|---|---|---|---|
| | Initial Test | Final Test | N-Gain | Interpretation |
| Experimental | 36.88 | 85.21 | 0.76 | High |
| Control | 32.50 | 79.31 | 0.69 | Medium |

With reference to Table 9, students in the experimental class had an average initial test score of 36.88 prior to the learning therapy, compared to 32.50 in the control group. These results reveal that students' initial critical thinking skills were inadequate and that there was no discernible difference between the two classes. Therefore, it may be said that the experimental class and the control class had very similar initial conditions.

Learning outcomes increased in both groups following the use of the flipped classroom with the help of the discovery learning model in the experimental class and the discovery learning model without the help of the flipped classroom in the control class. The experimental class's average final test score increased to 85.21, whereas the control group's score was 79.31. This demonstrates a notable rise in KBK following the administration of therapy. Furthermore, the N-Gain analysis yielded a value of 0.69 in the moderate category for the control class and 0.76 in the high category for the experimental class. As a result, both learning models were successful in raising students' KBK; however, the experimental class's higher N-Gain value suggested that using the flipped classroom in conjunction with the discovery learning model produced better outcomes than using it alone.

**Initial Test, Final Test, and N-Gain Scores for Each Sub-Material**

The improvement in students' critical thinking skills was also analyzed based on the test results for each sub-material on temperature and heat, namely Changes in the Form of Substances, Heat Transfer, and External Work and Heat Capacity. Each of these sub-topics was assessed using a test instrument that referred to five critical thinking skill indicators developed by Robert Ennis. The average scores from the pre-test, post-test, and N-Gain scores for each sub-topic are presented in Table 10.

**Table 10.** Average Scores for Initial Tests, Final Tests, and N-Gain for Each Sub-Subject

| Subtopics | Experimental Class | | | | Control Class | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial Test | Final Test | N-Gain | Interpretation | Initial Test | Final Test | N-Gain | Interpretation |
| Changes in the State of Matter | 41.67 | 86.67 | 0.76 | High | 39.58 | 81.25 | 0.69 | Medium |
| Heat Transfer | 38.54 | 84.79 | 0.75 | High | 33.13 | 80.83 | 0.71 | High |
| External Work and Heat Capacity | 30.42 | 84.17 | 0.77 | High | 24.79 | 75.83 | 0.68 | Medium |
| Average | 36.88 | 85.21 | 0.76 | High | 32.50 | 79.31 | 0.69 | Medium |

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The improvement in students' critical thinking abilities for each Newton's Law subtopic in the experimental class and control class was examined using Table 10. The experimental class received an average initial test score of 41.67 and a final test score of 86.67 in the sub-material on changes in the shape of matter, with an N-Gain score of 0.76, falling into the high category. The control group, on the other hand, received a moderate N-Gain of 0.69, an average beginning test score of 39.58, and a final test score of 81.25. This demonstrates that using the flipped classroom approach in conjunction with the discovery learning model is more successful in enhancing critical thinking abilities in this particular subject. Both the experimental class and the control class recorded N Gain values in the high category for the heat transfer sub-material: 0.75 for the experimental class and 0.71 for the control class. The experimental class's average final test score (84.79) was marginally higher than the control class's (80.83), despite the N-Gain values being similar. This suggests that the flipped classroom had a beneficial impact on students' abilities.

Additionally, the experimental class demonstrated an increase with an N-Gain value of 0.76 (high category) in the sub-material on External Work and Heat Capacity, greater than the control class's 0.69. Additionally, the experimental class's average final test score was higher 84.17 as opposed to the control class's 79.31. Overall, the three subtopics demonstrated that the experimental class continuously outperformed the control class in terms of N-Gain and final test results. This supports the finding that using the flipped classroom approach in conjunction with the discovery learning model improves students' KBK in a variety of temperature and heat-related topics.

**Initial Test Scores, Final Test Scores, and N-Gain for Each Critical Thinking Skill Indicator**

The results of the initial test, final test, and N-Gain scores for each of Robert Ennis's critical thinking ability indicators can also be used to see how much the students' critical thinking abilities have improved. Table 11 displays the mean scores for the pre-test, post-test, and N-Gain for each CKS indication.

**Table 11.** Average Scores for Initial Tests, Final Tests, and N-Gain for Each Critical Thinking Skill Indicator

| Indicators KBK | Experimental Class | | | | Control Class | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial Test | Final Test | N-Gain | Interpretation | Initial Test | Final Test | N-Gain | Interpretation |
| Providing simple explanations (Elementary clarification) | 39.58 | 87.08 | 0.78 | Tinggi | 38.33 | 81.67 | 0.70 | Tinggi |
| Building basic skills (Basic support) | 30.42 | 84.17 | 0.76 | Tinggi | 23.33 | 76.67 | 0.69 | Sedang |
| Making inferences (Inference) | 42.92 | 82.50 | 0.68 | Sedang | 37.50 | 79.17 | 0.67 | Sedang |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Providing further explanations (Advanced Clarification) | 48.33 | 85.00 | 0.69 | Sedang | 40.00 | 81.67 | 0.69 | Sedang |
| Strategies and tactics (strategies and tactics) | 29.72 | 85.28 | 0.79 | Tinggi | 25.00 | 77.22 | 0.69 | Sedang |
| Average | 38.19 | 84.81 | 0.74 | Tinggi | 32.83 | 79.28 | 0.69 | Sedang |

Five indicators created by Robert Ennis were used to analyze the progress in students' critical thinking abilities based on the data shown in Table 11. All critical thinking skill markers improved in both experimental and control classes, according to the analysis's findings. The experimental class outperformed the control class in terms of the improvement's effectiveness, nevertheless.

The indication gives a straightforward description of the two groups' most notable progress. Both the experimental class and the control class had N-Gain values in the high range (0.78 and 0.70, respectively). This demonstrates how well students in both classes were able to concentrate and evaluate arguments from difficulties following the learning process. The experimental class's N-Gain in the Building Basic Skills indication was 0.76, suggesting a high category, while the control class's N-Gain was 0.69, indicating a moderate category. These findings demonstrate that when it comes to teaching students to observe and take into account the outcomes of their observations in order to solve issues, flipped classrooms supported by the discovery learning model outperform those that do not. While they continued to fall into the moderate group, the indicators of Concluding and Making Further Explanations showed a comparatively smaller increase. N-Gain values for the two indicators were 0.68 and 0.69 for the experimental class and 0.67 and 0.69 for the control group. These results show that even with advancements, students still require more assistance when it comes to constructing methodical calculating procedures and applying physics concepts contextually. Regarding the Strategy and Tactics indicator, the control group received an N-Gain of 0.69 (moderate category), but the experimental group had an N-Gain of 0.79 (high category). This demonstrates how the flipped classroom approach aids in the development of students' logical and cohesive critical thinking processes. In general, the experimental class had greater N-Gain values than the control class for every KPM indicator. These results provide credence to the idea that using the flipped classroom in conjunction with the discovery learning paradigm improves students' KBK more thoroughly in every area evaluated.

**Normality Test**

The purpose of this study's normality test was to determine whether the test data, both starting and final, had a normal distribution. Using the Shapiro-Wilk method at a significance level of 5% ($\alpha$ = 0.05), the test was performed using SPSS Statistics version 31 software. This test's goal is to confirm

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that the data satisfies the normal distribution assumption, which is a need for parametric statistical testing. Table 12 summarizes the findings of the normalcy test.

**Table 12.** Normality Test Results

| Class | Test Type | *N* | Significance | Description |
|---|---|---|---|---|
| Experimental | Initial Test | 30 | 0,91 | Normal |
| | Final Test | 30 | 0,69 | Normal |
| Control | Initial Test | 30 | 0,89 | Normal |
| | Final Test | 30 | 0,96 | Normal |

The significant values for all data, both for the experimental class and the control class, exceeded the significance limit of 0.05, according to the findings of the normality test shown in Table 12. The first test's significance value in the experimental class was 0.91, whereas the final test's was 0.69. The initial test's significance value in the control group was 0.89, and the final test's was 0.96. It may be inferred that the data from both classes were normally distributed because all significant values were more than 0.05. As a result, the data satisfied a need for parametric statistical test analysis, namely the independent sample t-test in the subsequent analysis phase.

**Homogeneity Test**

In order to ascertain if the variance of the final test results between the experimental class and the control class was homogenous or uniform, the homogeneity test was used in this investigation. The Levene test was administered using SPSS Statistics version 31. Table 13 displays the test's results.

**Table 13.** Homogeneity Test Results

| | Uji Levene |
|---|---|
| Sig. Based on Mean | 0,58 |
| Description | Homogen |

The Levene test yielded a significance value of 0.58 based on the homogeneity test findings shown in Table 13. It can be inferred that the variance of the final test data between the experimental class and the control class is homogeneous as this number is higher than the significance criterion of 0.05. This indicates that the variance of the two groups is not significantly different. This condition shows that the assumption of variance homogeneity has been satisfied, allowing for the valid and suitable application of parametric statistical tests in the subsequent stage of analysis.

**Hypothesis Testing**

In order to determine whether there was a significant difference in KBK improvement between students in the experimental class and the control class, hypothesis testing was done. The independent sample t-test, a parametric statistical test, was used to continue hypothesis testing once it was determined that the data satisfied the assumptions of normality and homogeneity, which meant that

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the data was normally distributed and had uniform variance. The independent sample t-test uses the following foundation for decision-making:

a. *H*0 is accepted and *H*1 is rejected if the Sig. (2-tailed) value is ≥ 0.05. This indicates that there is no discernible difference in the development of critical thinking abilities between the experimental and control groups.

b. If the Sig. (2-tailed) value is less than 0.05, then *H*0 is rejected and *H*1 is accepted, indicating a significant difference between the experimental class's and the control class's improvement in critical thinking abilities. The findings of this test, which was carried out using SPSS Statistics version 31, are shown in Table 14.

**Table 14.** Hypothesis Test Results

| Variable | Assumptions | t-count | *df* | Sig. (2-tailed) | Average difference | Note. |
|---|---|---|---|---|---|---|
| Students' Critical Thinking Skills | Homogeneous Data | 4,22 | 58 | 0,001 | 4,90 | Significant ($p$<0.05 |
| | Non-Homogeneous Data | 4,22 | 57,3 | 0,001 | 4,90 | Significant ($p$<0.05 |

Since the variance between the experimental class and the control class is known to be homogenous based on the hypothesis test results shown in Table 13, the homogeneous data results in the hypothesis test table are more applicable. These findings indicate that the significance value (Sig. 2-tailed) is 0.001. The fact that this significance value is less than the significance level of 0.05 suggests that the two groups' improvements in critical thinking abilities differ significantly. As a result, the alternative hypothesis (H1) is accepted and the null hypothesis (H0) is rejected. In summary, the development of students' critical thinking abilities differs significantly between classrooms that employ the discovery learning paradigm in conjunction with a flipped classroom and those that do not.

**Improvement in Students' Critical Thinking Skills**

The improvement in critical thinking skills (KBK) in this study was analyzed by comparing the results of the pre-test and post-test administered before and after the treatment. According to Facione, critical thinking is the ability to form an opinion in solving something (judging) whereby a person can define, describe, consider, and conclude, using evidence, concepts, and methods based on contextual considerations (in Nuryanti et al., 2018) (Arini & Rahayu, 2023).

Using critical thinking during studying Physics is crucial because it can aid students in gaining a thorough understanding of physics topics, honing their problem-solving abilities, and applying their knowledge to real-world scenarios as a kind of critical thinking (Pendidikan & Indonesia,

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2023)(Hashim et al., 2019)(Sefriani, 2023). Analytical, logical, and reflective thinking abilities are all part of critical thinking in physics education (Suprapto et al., 2020)(Pradana et al., 2020). Students will become more proficient learners (Kahar et al., 2021) and be able to overcome obstacles in comprehending physics and its application in daily life (Martawijaya et al., 2023)(Putranta et al., 2021) (Sefriani, 2023).

Students in the experimental class scored an average of 36.88, whereas those in the control class scored an average of 32.50, according to the initial test results. These results show that the KBK in both classes was equivalent and still in the low category prior to the treatment.

Both courses saw a notable rise following the learning process. Students in the experimental class had an average final test score of 85.21, compared to 79.31 in the control group. This demonstrates that the use of the discovery learning paradigm improved critical thinking abilities both with and without the flipped classroom. Additionally, N-Gain calculations were used to assess this improvement's efficacy. N-Gain values for the experimental and control groups were 0.76 and 0.69, respectively. The normalized gain classification interpretation places both in the high category. These results show that using the discovery learning methodology in both classes improved students' critical thinking abilities.

## 4. CONCLUSION

The following results were reached after data from the study on the use of a flipped classroom based on discovery learning to enhance students' critical thinking abilities in the subject of temperature and heat was processed and analyzed at SMA 1 Bina Negara Baleendah:

a. With an average implementation rate of 85.3%, the use of a flipped classroom based on the discovery learning approach to teach about temperature and heat is considered very effective. In the meantime, learning utilizing the SIMAS ERIC model without PhET's help achieved an average implementation percentage of 83.66%, which is considered effective.

b. Following the deployment of the discovery learning model-based flipped classroom, students in class XI Interest B at SMA 1 Bina Negara Baleendah showed a gain in critical thinking abilities of 0.76, which is considered high, according to the results of the N-Gain value calculation. In contrast, class XI Interest A's N-Gain score of 0.69, which is considered moderate, indicates that students' critical thinking abilities increased following the implementation of the discovery learning paradigm without the aid of a flipped classroom. The significance value (Sig. 2-tailed) is 0.001 < 0.05 based on the findings of the independent sample t-test hypothesis test. Therefore, it can be concluded that there is a difference in the increase in students' critical thinking skills between those who use a discovery learning model without the assistance of a flipped classroom in class XI Interest A on the subject of Temperature and Heat at SMA 1 Bina Negara Baleendah and those who use a discovery learning-based flipped classroom in class XI Interest B. This is because the null hypothesis (H0) is rejected and the alternative hypothesis (H1) is accepted.

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