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Implementation Of Flipped Classroom Based On Discovery Learning Model To Improve Students' Critical Thinking Skills In Temperature And Heat Materials

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Abstract

The development of 21st-century learning requires students to possess critical thinking skills, especially in physics, which emphasizes conceptual understanding and problem-solving. However, classroom learning is still often dominated by conventional methods that limit students' opportunities to construct knowledge actively. This study was motivated by students' low critical thinking skills during physics lessons in class XI at SMA 1 BN Baleendah. This study aims to determine the implementation of the Discovery Learning model-based Flipped Classroom to improve students' critical thinking skills on temperature and heat material. The research used a quasi-experimental design with a nonequivalent control group. Data collection was carried out using the AABTLT with the SAS instrument and a critical thinking skills test based on Ennis indicators. The population consisted of all 11th-grade students at SMA 1 BN Baleendah. The results showed that the N-Gain score in the experimental class was 0.76 (high), and in the control class, 0.69 (moderate), indicating a significant difference between the two classes. Implementing this model encourages students to become more active, independent, and enthusiastic learners. Future studies are recommended to involve larger samples and examine additional variables such as learning motivation and digital literacy.

1. INTRODUCTION

School learning systems can be conducted both online and offline. Online learning typically utilizes the internet, smartphones, laptops, and other devices, while offline learning takes place in the classroom (Puspita et al., 2020). All learning systems are expected to achieve learning objectives. One indicator of whether learning objectives have been met is students' learning outcomes. Currently, students' learning outcomes are not yet optimal. The cause of suboptimal learning outcomes is low critical thinking skills. Improvements in critical thinking skills are directly proportional to improvements in students' learning outcomes.

The low level of critical thinking skills stems from their underdevelopment through instruction; however, they can be cultivated in the classroom. Critical thinking skills require ongoing guidance. Students' low level of critical thinking skills is closely linked to the choice of teaching methods. Currently, the most widely used teaching method is teacher-centred instruction, which views the teacher as the primary source of learning (Siburian et al., 2023).

Critical thinking skills are often assessed using essay tests based on the indicators developed by (Ennis, 1984), known as FRISCO. The six FRISCO criteria are: focus, reason, inference, situation, clarity, and overview. Focus relates to the ability to identify the core of the problem; reason involves providing justifications based on relevant facts; inference involves drawing accurate conclusions that align with the justifications provided to support them; situation involves utilizing all available resources to solve the problem in accordance with the specific conditions of the issue; clarity involves providing explanations using precise and fluent language; and overview involves reviewing the work (Siburian et al., 2023).

Based on the background of the problem described above, the author conducted a preliminary study involving interviews, observations, and critical thinking tests conducted in class XI MINAT A1 SMA 1 BN Baleendah. From interviews with physics teachers, it was found that the models used were still limited because the school relied solely on the lecture method, while most learning still relied on books and student worksheets. The results of the observation show that, even though the teacher has tried to develop critical thinking skills, these efforts have not yet been fully realised.

The average critical thinking skills test results for students at SMA 1 BN Baleendah, conducted on 28 students in class XI MINAT A1, are still relatively low at 56%. The use of learning tools such as media has not been effective in developing students' critical thinking skills, so it is necessary to develop media that incorporate indicators of critical thinking skills to improve students' critical thinking. This is in accordance with the results of the critical thinking skills test that has been given. The critical thinking skill indicators proposed correspond to the five outlined by Ennis: providing basic clarification, building basic support, making inferences, providing further clarification, and strategy and tactics. Currently, many schools use conventional teaching methods. Conventional methods use lectures, which many students find monotonous. This reduces students' interest in learning physics, which is often considered boring, leading many to score below the minimum passing grade.

Physics is a subject that deals with natural phenomena (Haryadi & Pujiastuti, 2019). By studying physics, students can understand concepts, solve problems independently, and relate them to everyday life. In physics learning, students can also develop critical thinking skills. Research conducted by ATS21S (Assessment & Teaching of 21st Century Skills) found that thinking is one of the 21st-century learning skills (Nurohman & Buhera, 2025).

21st-century learning aims to prepare students to face the demands of the times and respond to life's challenges. One of the things that needs to be prepared for is improving individual skills, specifically effective critical thinking (Hasanah et al., 2023). Teaching students to think critically can make them competent and skilled individuals (Septarini, R. A., & Kholiq, 2021). Critical thinking is an important 21st-century skill that supports the ability to analyse, synthesise, and evaluate information in depth. Ennis defines critical thinking, as quoted by Linussa (Ardhini et al., 2021), as the process of using reflective and rational thinking skills to make decisions about what to do and what to believe.

Based on previous research, critical thinking skills in physics learning are considered important for students because physics is not only about understanding theoretical concepts, but also about applying scientific principles to solve real problems. According to Siwardani, critical thinking skills are very important considering the nature of physics, which requires a deep understanding of concepts and the ability to connect theory with practical applications in everyday life (Viskaali, H., Helmi, H., & Arafah, 2025).

This aligns with several findings from previous studies. Nuryanti stated that critical thinking skills at the high school level are still very low, as evidenced by an analysis of the average scores of 10th-grade students at Bandung State High School, which showed that their critical thinking score was only 46.6%. The low average score is due to teaching methods that are not suitable for students' needs (Wayudi et al., 2020). As one of the spearheads of education, teachers have an obligation to create an independent learning system for students.

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. Discovery learning is an educational approach that allows pupils to develop their critical thinking skills. According to Jenirita, 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). Discovery-based learning is a learning strategy that emphasizes student engagement in acquiring knowledge through the concept of discovery (Frima et al., 2020).

As technology advances, learning media can be delivered through a Learning Management System. A Learning Management System is a digital tool for online assignments and materials that can help teachers assess student activity individually and in groups, thereby enabling students to improve the quality of their learning. The learning management system helps students improve their critical thinking skills and create new work by conducting practical work using the teaching materials available in the System (Lailiah et al., 2021). The Learning Management System is supported by Moodle, an online learning platform that provides a new learning framework for teachers and students to meet, collaborate, and create content simultaneously (Ruhana et al., 2023).

The flipped classroom is a form of blended learning which has become popular as a learning model. The flipped classroom reverses the learning activities of learners: activities that are usually carried out in groups in the classroom are moved outside, and activities that are usually carried out individually outside the classroom are moved into the classroom. Learning activities outside the classroom are conducted before classroom learning, using learning materials provided by educators and supported by information and communication technology, for example, in the form of videos delivered through the Learning Management System or other platforms. Class time that is normally used for listening to lectures is diverted to activities and application of knowledge, which are used as homework. Classroom activities can take the form of problem-solving, discussions, analysis, and positive interactions with other students (Nugraheni et al., 2022).

The flipped classroom is a pedagogical strategy or model in which the traditional teaching model is reversed: lectures are studied outside the classroom, while the classroom session is devoted to learning activities and applications, such as case studies, exercises, and syntheses. In addition, several studies have indicated the potential of flipped classrooms for developing students' soft skills (Elkhalladi et al., 2025).

The flipped classroom paradigm is highly significant in physics education. Physics educators can use digital resources and technology to develop captivating pre-class materials, such as videos that elucidate intricate concepts, simulations, or interactive exercises. These materials serve to equip students with the necessary knowledge and understanding for in-depth discussions and practical exercises during class sessions (Agusta et al., 2025). This aligns with Sania & Sayono's (2022) view that the flipped classroom provides opportunities for students to actively participate in class discussions and solve problems during the learning process (Latifah & Utama, 2024).

Although the flipped classroom is said to offer advantages, it also presents challenges, such as teacher control over student readiness before class and student involvement in group discussions (Ramadoni, R., & Mustofa, 2022). In addition, some literature reports failures in its application to students' critical thinking skills. In a quasi-experimental study, Tolbern reported no increase in critical thinking skills between classes that used the flipped classroom method and those that used traditional teaching methods (Nurfadillah et al., 2020). In line with this study, Gillette's research (Oudbier et al., 2022) found that, even though both classes used active learning, the flipped classroom was no more effective than traditional classes.

Based on the above explanation, the school where the research was conducted does not yet support critical thinking skills. Therefore, the researcher aims to develop a Moodle-assisted Learning Management System that facilitates students' learning and practice of critical thinking skills through the flipped classroom approach. The Learning Management System, powered by Moodle, is structured around the Discovery Learning model and employs a flipped classroom approach. The Discovery Learning syntax and flipped classroom approach, applied in the digital Learning Management System assisted by the Moodle application, can train critical thinking skills and improve students' critical thinking in physics, especially in Temperature and Heat material (Ruhana et al., 2023).

The application of learning models is very influential in triggering critical thinking, one of which is the discovery learning model. The discovery model can help students learn to prove a concept in the material they are studying, making it more focused on everyday life. In their research, (Widiyana et al., 2021) found that Discovery Learning is a learning model that can improve students' scientific literacy. Problem-solving activities in learning activities will have implications for the emergence of curiosity, high attitudes, and sensitivity for students. In addition, Discovery learning is an excellent model since it provides a scientific approach that allows students to investigate facts, data, and issues to develop an understanding of key ideas (Jamallika et al., 2024). Kadri and Meika Rahmawati state that the discovery learning model significantly improves student learning outcomes in the subject of temperature and heat in physics compared to conventional learning (Nazara et al., 2024).

The use of the discovery learning model can increase students' motivation and interest in learning, thereby influencing the development of their critical thinking skills and improving classroom learning outcomes (Ruhana et al., 2023). Meanwhile, according to Effendi, discovery learning is a learning process that involves students in problem solving to develop knowledge and skills (Nababan et al., 2023). The stages of the discovery learning model consist of 6 stages according to Supliyadi, namely: 1) Stimulation (stimulation/stimulus), 2) Problem Statement (statement/problem identification), 3) Data Collection, 4) Data Processing, 5) Verification, 6) Generalisation (drawing conclusions/generalisation) (Anaperta & Helendra, 2021).

The researchers chose a discovery-learning, flipped classroom for the Temperature and Heat material because it required learning tools that supported visualisation to attract students' interest and thereby improve their critical thinking skills.

The implementation of learning on the subject of temperature and heat requires students to systematically and critically analyse various related physical phenomena, such as heat transfer through convection, conduction, and radiation in everyday life. They can consider the effects of substance, particle, and heat transfer without intermediaries, and their practical applications in technology, which can be realised through the implementation of a Moodle-assisted Learning Management System.

Based on this background and the inconsistent results of the application of the flipped classroom method to improve students' critical thinking skills, the researcher decided to conduct a re-examination entitled "Implementation of the Discovery Learning Model-Based Flipped Classroom to Improve Critical Thinking Skills on Temperature and Heat Material in Senior High School 1 BN Baleendah."

2. METHOD

The subjects of this study were 60 eleventh-grade students at SMA 1 BN Baleendah. The method used in this study was a quasi-experimental design. This research method involves administering a specific treatment, measuring its effects, and using experimental units, but without randomising group assignments. As a substitute for randomisation, comparisons were used to determine whether the observed changes were caused by the treatment (Syahrizal & Jailani, 2023).

This quasi-experimental study was conducted across two classes: an experimental and a control class. The design used was the Nonequivalent Control Group Design (Abraham, I., & Supriyati, 2022), which compares two groups.

The research procedure began with a pretest to measure students' critical thinking skills. The experimental class received treatment through a discovery-learning-based flipped classroom, while the control class used the discovery-learning model without a flipped classroom. After the learning process, a posttest was conducted to determine changes in students' critical thinking skills.

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 used in the experimental class, which employed a flipped classroom supported by a discovery learning model. In contrast, the control class used a discovery learning model without a flipped classroom.

The data required in this study were students' critical thinking abilities and the implementation of the learning model during the learning process. Students' critical thinking abilities were obtained through pretest and posttest results, while learning implementation data were obtained through student activity observations using AABTLT with SAS.

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.	Problem Formulation	Instruments
1.	Implementation of discovery learning models based on flipped classrooms and discovery learning models	Student Worksheet assessment assisted by AABLT with SAS
2.	The difference in critical thinking improvement using the flipped classroom-based discovery learning model and the discovery learning model.	1. Critical thinking pretest 2. Critical thinking posttest

One assessment technique that can measure students' scientific attitudes is the Authentic Assessment Based on Teaching and Learning Trajectory (AABTLT) with the Student Activity Sheet (SAS) technique. (1) At this stage, the scores obtained from the AABTLT with SAS authentic assessment are converted to determine the percentage of implementation and used to determine the criteria for implementation (Rochman et al., 2018).

The Student Activity Sheet, assisted by AABTLT with SAS, has been tested for suitability with the learning module to be used and its grid before the research was conducted. The assessment guidelines for each student's answer were based on a scale of 0-4, with explanations listed in Table 3.

Table 3. Assessment Section AABTLT with SAS

Skor	Criteria
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 totalled, it will be processed, analysed using descriptive statistics, and reported as a percentage of learning achievement (Rochman et al., 2018).

Table 4. Average SAS criteria

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

Data analysis is a stage used to formulate research results that are useful for answering each problem formulation and testing hypotheses. The data obtained during the research are then compiled into a list and presented in Table 5.

Table 5. Data Analysis Techniques

No	Problem Statement	Data Analysis Techniques
1	Implementation using the flipped classroom-based discovery learning model and the discovery learning model	1) Assessment of student worksheets assisted by AABTLT with SAS
2	Differences in critical thinking improvement using the flipped classroom-based discovery learning model and the discovery learning model	1) N-Gain value 2) Prerequisite tests: a. Normality test b. Homogeneity test 3) Hypothesis testing

The N-Gain test was used to determine the improvement in students' critical thinking skills between the pretest and posttest results. Before hypothesis testing, normality and homogeneity tests were conducted to ensure that the data met the statistical assumptions required for further analysis.

3. RESULTS AND DISCUSSION

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

The implementation of learning across 3 meetings using the flipped classroom model and the discovery learning approach was conducted on Wednesday, November 12, 2025, with discussion materials 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 achieved through the flipped classroom assisted by the discovery learning model across three sessions is presented in Table 6.

Table 6. Recapitulation of Average Effectiveness Data Learning Effectiveness for Each Meeting

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

Based on Table 6 above, which summarises the effectiveness of learning implementation in each meeting using the flipped classroom assisted by the discovery learning model, the effectiveness of learning increased from one meeting to the next. In the first meeting, the learning effectiveness 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 categorised as highly effective. Overall, the flipped classroom, supported by the discovery learning model, was implemented very well to enhance classroom learning.

Average Data on the Implementation of Each Learning Stage

Based on the results of the AABTLT analysis using the SAS method during three learning meetings that applied the flipped classroom assisted by the discovery learning model in the experimental class, data were obtained on the average percentage of implementation for each learning stage. A summary of the effectiveness of each learning stage's implementation is presented in Table 7.

Table 7. Recapitulation of the Effectiveness of the Implementation of Each Stage of Learning

Learning Stages	**Perception**	**Stimulation**	**Data Collection**	**Conclusion**	**Reflection**
	Average				
	Percentage (%)		**Interpretation**		
Meeting No.1	82		Effective		
Meeting No.2	86		Very Effective		
Meeting No.3	88		Very Effective		
Average	85.3		Very Effective		

Based on Table 7, the effectiveness of implementing each learning stage is generally in the effective to very effective range. The stage with the highest average is initial conception at 88%, which is categorised as very effective, indicating that teachers can 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 categorised as highly effective. Meanwhile, several stages, such as data processing (83.3%) and conclusions (84%), still showed good effectiveness, even though they were categorised as effective. Only one stage, namely stimulation, was less effective in the first meeting and declined in the second meeting, but increased in the following meeting, resulting in an average of 81% and placing it in the effective category overall. In general, these results show that the flipped classroom, supported by the discovery learning model, can be implemented effectively in the classroom, with stages carried out consistently and effectively across three meetings.

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

Three learning sessions using the discovery learning model, without 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 average learning effectiveness score for the discovery learning model without a flipped classroom across three sessions is presented in Table 8.

Table 8. 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 8 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 categorised as effective to highly effective. The first and second meetings received scores of 81% and 84%, respectively, both of which were categorised as effective. Meanwhile, the third meeting showed an increase in effectiveness with a score of 86%, which was categorised as highly effective. These results indicate that the discovery learning model without a flipped classroom can still be effectively applied to support the learning process.

Average Data on the Implementation of Each Learning Stage

Data on the average percentage of implementation for each learning stage were collected based on the study's findings using the AABTLT with the SAS approach across three learning sessions that applied the discovery learning model without a flipped classroom in the control class. Table 9 summarises the extent to which each learning level was implemented.

Table 9. Recapitulation of the Effectiveness of the Implementation of Each

Learning Stages	Perception	Stimulation	Data Collection	Conclusion	Reflection
	Average				
	Percentage (%)		Interpretation		
Meeting No.1	81		Effective		
Meeting No.2	84		Effective		
Meeting No.3	86		Very Effective		
Average	83.6		Effective		

Based on Table 9, which summarises the effectiveness of each stage of learning in the control class, most stages were in the effective category, with some 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, improved in subsequent meetings, with a final average of 83%, which was also in the effective category. Overall, these results show that the discovery learning model can be applied effectively at every stage of learning without a flipped classroom. However, 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 skills through the flipped classroom approach combined 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 critical thinking skills indicators was used to assess learning outcomes in both classes, with an emphasis on temperature and heat. Following the quantitative analysis, all test results were displayed in Table 10.

Table 10. 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

Referring to Table 10, before the learning treatment was carried out, the average initial test score for students in the experimental class was 36.88, while in the control class it was 32.50. These values indicate that students' initial critical thinking ability was low and that there was a significant difference between the two classes. Thus, the initial conditions in the experimental class indicate that the discovery learning model-assisted flipped classroom can better support the learning process than in the control class.

After treatment with the flipped classroom approach assisted by the discovery learning model in the experimental class and the discovery learning model without the flipped classroom in the control class, learning outcomes increased in both groups. The average final test score in the experimental class rose to 85.21, while in the control class it reached 79.31. This shows a significant increase in critical thinking skills after treatment. In addition, N-Gain analysis yielded 0.76 in the high category for the experimental class and 0.69 in the moderate category for the control class. Thus, both learning models proved effective in improving students' critical thinking skills. However, the higher N-Gain value in the experimental class indicates that the flipped classroom, combined with the discovery learning model, yields better results than the discovery learning model alone.

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

The improvement in students' critical thinking skills was also analysed based on test results for each sub-material on temperature and heat: 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, posttest, and N-Gain scores for each sub-topic are presented in Table 11.

Table 11. 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

Based on Table 11, the improvement in students' critical thinking skills was analysed for each sub-topic of Temperature and Heat in both the experimental and control classes. In the sub-topic of changes in the form of matter, the experimental class obtained an average initial test score of 41.67 and a final test score of 86.67, with an N-Gain score of 0.76, which is in the high category. Meanwhile, the control class obtained an average initial test score of 39.58, a final test score of 81.25, and an N-Gain of 0.69, which is in the moderate category. This shows that the flipped classroom, combined with the discovery learning model, is more effective at improving critical thinking skills in this sub-topic.

In the sub-material on heat transfer, both the experimental and control classes recorded an N-Gain of 0.75 in the experimental class and 0.71 in the control class, both in the high category. Although the N-Gain values were similar, the experimental class's average final test score (84.79) was slightly higher than the control class's (80.83), indicating a positive effect of the flipped classroom on students' performance.

Furthermore, in the sub-material on External Work and Heat Capacity, the experimental class showed an increase with an N-Gain value of 0.76 (high category), higher than the control class, which obtained 0.69. The average final test score of the experimental class was also higher, namely 84.17, compared to 79.31 in the control class. Overall, the three sub-topics showed that the experimental class consistently had better final test scores and N-Gain than the control class. This reinforces the conclusion that the flipped classroom, supported by the discovery learning model, is more effective at improving students' critical thinking skills across various topics in Temperature and Heat.

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

The improvement in students' critical thinking skills can also be observed in the results of the initial and final tests and in N-Gain scores for each of the critical thinking skill indicators proposed by Robert Ennis. The average scores for the initial test, final test, and N-Gain for each critical thinking skill indicator are presented in Table 12.

Table 12. Average Scores for Initial Tests, Final Tests, and N-Gain for Each Critical Thinking Skill Indicator

Indicators Critical Thinking Skills	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	High	38.33	81.67	0.70	High
Building basic skills (Basic support)	30.42	84.17	0.76	High	23.33	76.67	0.69	Medium
Making inferences (Inference)	42.92	82.50	0.68	Medium	37.50	79.17	0.67	Medium
Providing further explanations (Advanced Clarification)	48.33	85.00	0.69	Medium	40.00	81.67	0.69	Medium
Strategies and tactics (strategies and tactics)	29.72	85.28	0.79	High	25.00	77.22	0.69	Medium
Average	38.19	84.81	0.74	High	32.83	79.28	0.69	Medium

Five indicators developed by Robert Ennis were used to analyse progress in students' critical thinking abilities, based on the data shown in Table 12. 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 effectiveness of the improvement, nevertheless.

The indication gives a straightforward description of the two groups' most notable progress. Both the experimental and control classes 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 despite 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 consider the outcomes of their observations to solve issues, flipped classrooms supported by the discovery learning model outperform those without it. 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, despite advancements, students still require more assistance in developing systematic calculation procedures and applying physics concepts in context.

Regarding the Strategy and Tactics indicator, the control group had an N-Gain of 0.69 (moderate), while the experimental group had an N-Gain of 0.79 (high). This demonstrates how the flipped classroom approach supports the development of students' logical, cohesive critical thinking. In general, the experimental class had greater N-Gain values than the control class for every CTS indicator. These results provide support for the idea that using the flipped classroom in conjunction with the discovery learning paradigm improves students' CTS more thoroughly across all evaluated areas.

Normality Test

The normality test in this study was intended to determine whether the initial and final test data were normally distributed. The test was conducted using SPSS Statistics version 31, using the Shapiro-Wilk test at a significance level of 5% ($\alpha = 0.05$). The purpose of this test is to ensure that the data meets the assumption of normal distribution, which is one of the prerequisites in parametric statistical testing. A summary of the normality test results is presented in Table 1 above.

Based on the normality test results in Table 1, the significance values for all data, both in the experimental and control classes, exceeded the 0.05 significance threshold. In the experimental class, the significance value for the initial test was 0.91, and for the final test was 0.69. Meanwhile, in the control class, the significance values for the initial and final tests were 0.89 and 0.96, respectively. Since all significance values are above 0.05, it can be concluded that the data from both classes are normally distributed. Thus, the data meet one of the prerequisites for parametric statistical tests, namely the independent-samples t-test, in the next stage of analysis.

Homogeneity Test

The homogeneity test in this study was conducted to determine whether the variances of the final test results between the experimental and control classes were homogeneous. The test was performed using the Levene test through SPSS Statistics software version 31. The results of this test are shown in Table 1 above. Based on the homogeneity test results listed in Table 1, the Levene test yielded a p-value of 0.58. Since this value is greater than the significance limit of 0.05, it can be concluded that the variance of the final test data between the experimental class and the control class is homogeneous. This means that there is no significant difference in variance between the two groups. This condition indicates that the assumption of variance homogeneity has been met, allowing the use of parametric statistical tests in the next stage of analysis.

Hypothesis Testing

To determine whether there was a significant difference in CTS improvement between students in the experimental and control classes, hypothesis testing was conducted. The independent-samples t-test, a parametric statistical test, was used to continue hypothesis testing after it was determined that the data met the assumptions of normality and homogeneity, indicating normality and uniform variance. The independent sample t-test uses the following foundation for decision-making:

a. $H0$ is accepted, and $H1$ 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 $H0$ is rejected, and $H1$ 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 13.

Table 13. 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 and control classes is known to be homogeneous based on the hypothesis test results shown in Table 13, the results in that 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 0.05 significance level 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 alongside a flipped classroom and those that do not.

Jerome Bruner's Discovery Learning in the Learning Process

In the learning process, Bruner emphasised that children construct their own knowledge by integrating new concepts and procedures into existing mental structures (Ndoa et al., 2024). One of Bruner's major contributions is the concept of discovery learning, which encourages students to explore and discover new information with minimal teacher guidance. This approach aims to foster students' curiosity and critical thinking skills. Additionally, Bruner introduced the spiral curriculum, a learning strategy that revisits basic concepts at progressively more complex levels. This helps students deepen their understanding as they grow older, and their abilities develop (Arsyad et al., 2024).

Jerome S. Bruner's cognitive theory is highly relevant to meaningful learning strategies in the digital age. According to Bruner, the learning process is not only about receiving information but also about constructing knowledge through experience and symbolic representation (Tandhim, 2023). The Discovery Learning model, introduced by Jerome Bruner, answers this need. The Discovery Learning model allows learners to discover concepts through direct experience, experimentation, and active interaction with their learning environment (Mandar, 2025).

Improvement in Students' Critical Thinking Skills

The improvement in critical thinking skills in this study was analysed by comparing pre- and post-test scores. The findings indicate a substantial increase in students' performance, with the experimental class improving from a mean score of 36.88 to 85.21, and the control class from 32.50 to 79.31. Furthermore, the N-Gain values of 0.76 and 0.69, respectively, are categorised as high, indicating that both instructional approaches were effective in enhancing students' critical thinking skills.

These findings are theoretically grounded in Facione’s framework, which conceptualises critical thinking as the ability to formulate judgments through processes such as interpretation, analysis, evaluation, and inference using evidence-based reasoning (Arini & Rahayu, 2023). The observed increase in posttest scores reflects students' improved capacity to define problems, analyse relationships, and draw logical conclusions, thereby demonstrating alignment with core critical thinking constructs.

In addition, the results corroborate the claim that integrating critical thinking into physics learning facilitates deeper conceptual understanding and enhances problem-solving abilities in authentic contexts (Sefriani, 2023). This is further supported by recent studies indicating that student-centred learning environments significantly promote higher-order thinking skills, particularly when learners are actively engaged in knowledge construction processes (Hwang et al., 2020).

Moreover, the findings are consistent with the perspective that critical thinking in physics encompasses analytical, logical, and reflective dimensions (Pradana et al., 2020). The high N-Gain scores suggest that the instructional design successfully fostered these competencies. This aligns with contemporary educational theories emphasising that active learning strategies enhance metacognitive awareness and cognitive flexibility, which are essential components of critical thinking (Saavedra, A. R., & Opfer, 2012). The results of this study are consistent with a growing body of empirical research demonstrating the effectiveness of discovery learning in enhancing students’ critical thinking skills. The significant improvement observed in both experimental and control groups supports prior findings that inquiry-based and constructivist learning approaches facilitate deeper cognitive engagement and promote higher-order thinking.

Specifically, the superior performance of the experimental class suggests that integrating discovery learning with the flipped classroom model yields additional pedagogical benefits. This finding is in agreement with previous studies indicating that flipped learning environments provide opportunities for pre-class content acquisition and in-class active problem-solving, thereby optimising cognitive processing and critical engagement (Alten et al., 2019). Furthermore, recent research has shown that flipped classroom approaches significantly enhance students’ autonomy, engagement, and critical thinking skills, particularly in STEM education contexts (Zainuddin & Perera, 2017). The present study reinforces these findings by demonstrating higher learning gains in the experimental group exposed to the flipped discovery learning model. On the other hand, the high N-Gain achieved by the control class indicates that discovery learning alone remains an effective instructional strategy. This aligns with prior studies suggesting that discovery-based approaches encourage active exploration, hypothesis testing, and knowledge construction, all of which contribute to improved analytical and problem-solving skills (Furtak et al., 2012).

Importantly, no contradictions were identified between the present findings and previous research. Instead, this study extends existing literature by providing empirical evidence that both discovery learning and its integration with flipped classroom models are highly effective in fostering critical thinking skills in physics education. The results, therefore, strengthen the argument for implementing student-centred pedagogical approaches to meet the demands of 21st-century learning.

4. CONCLUSION

This study yielded several conclusions, including: a) The N-Gain value for students' critical thinking abilities was 0.76, or an average percentage of critical thinking abilities of 85.21% with a high interpretation, and the average percentage of implementation in the experimental class was 85.3% in the highly effective category. b) The N-Gain value for students' critical thinking abilities was 0.69, or an average percentage of 79.31% with a moderate interpretation, and the control class's average implementation percentage was 83.66% in the effective category. On a learning scale that assesses critical thinking skills, the flipped classroom model, supported by the discovery learning model, has not optimally improved students' critical thinking, particularly in online media. However, it is effective in overcoming learning challenges in high schools. It is easier for teachers and students to carry out learning activities when teachers are more adept at using the internet media. Therefore, the study's implications highlight the importance of increasing teachers' proficiency with learning technology and school facility support to maximise the development of students' critical thinking abilities through the flipped classroom model, which is based on discovery learning. To produce more thorough findings with greater generalizability, future research should examine the efficacy of different types of online media in greater detail, broaden the sample to include a wider range of educational levels, and take into account additional factors such as learning motivation, digital literacy, and technological preparedness.

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REFERENCES

Abraham, I., & Supriyati, Y. (2022). Desain Kuasi Eksperimen Dalam Pendidikan : Literatur. *Jurnal Ilmiah Mandala Education*, 8(3), 2476–2482. https://doi.org/10.36312/jime.v8i3.3800/http

Agusta, F., Zuniari, N. I., Kuswanto, H., Siswanto, P., Husna, N., & Nurohman, S. (2025). Bibliometric analysis of flipped classroom trends in physics education : Insights from the Scopus database *Momentum: Physics Education Journal*, 9(1). https://doi.org/10.21067/mpej.v9i1.10261

Van Alten, D. C., Phielix, C., Janssen, J., & Kester, L. (2019). Effects of flipping the classroom on learning outcomes and satisfaction: A meta-analysis. *Educational Research Review*, 28, 100281. https://doi.org/10.1016/j.edurev.2019.05.003

Anaperta, M., & Helendra, H. (2021). Pengembangan modul pembelajaran fisika berbasis model pembelajaran guided discovery learning pada kelas XI IPA SMA Negeri 1 Ulakan Tapakis. *Natural Science*, 7(2), 89–95. https://doi.org/10.15548/nsc.v8i2.3840

Ardhini, R. A., Asikin, M., & Zaenuri, Z. (2021). Systematic Literature Review: Model Pembelajaran Discovery Learning Untuk Meningkatkan Kemampuan Berpikir Kritis. *IJoIS: Indonesian Journal of Islamic Studies*, 2(2), 201–215. https://dx.doi.org/10.59525/ijois.v2i2.41

Arini, R., & Rahayu, Y. S. (2023). Profile of Critical Thinking Results Analysed Based on Facione Indicators and Learner Gender. *IJORER: International Journal of Recent Educational Research*, 4(4), 434–446. https://doi.org/10.46245/ijorer.v4i4.328

Arsyad, S. N., Tangkin, W. P., Astuti, B., Studi, P., Pendidikan, D., Malang, K., & Sleman, K. (2024). Implications Of Bruner's Cognitive Theory On Elementary School Education In The 21st Century. *Klasikal: Journal of Education, Language Teaching and Science*, 6(3), 697–704. https://doi.org/10.52208/klasikal.v6i3.1225

Elkhalladi, J., Sefrioui, A., & Amsdar, L. (2025). The Effect Of The Flipped Classroom On Students ' Soft Skill Development : Quasi-Experimental Study. *Open Education Studies*, 7(1), 20250063. https://doi.org/10.1515/edu-2025-0063

Ennis, R. H. (1984). The Nature of Critical Thinking: An Outline of Critical Thinking Dispositions and Abilities. Informal Logic, 6(2), 1-8. https://doi.org/10.22329/il.v6i2.2729

Frima, F. K., Gumilar, G. G., & Supriyanti, F. T. (2020). Pengaruh metode discovery-inquiry terhadap profil keterampilan berpikir kritis siswa pada pembelajaran topik kelarutan. *Jurnal Pendidikan Sains Universitas Muhammadiyah Semarang*, 219, 220.

https://doi.org/10.26714/jps.8.1.2020.41-49

Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D. C. (2012). Experimental and quasi-experimental studies of inquiry-based science teaching: A meta-analysis. *Review of educational research*, 82(3), 300–329. https://doi.org/10.3102/0034654312457206

Haryadi, R., & Pujiastuti, H. (2019). Discovery Learning Based On Natural Phenomena To Improve Students' Science Process Skills. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, 5(2), 183–192. https://doi.org/10.21009/1.05214

Hasanah, M., Zulmaidar, S., Silangit, P., Jamil, R. P., Amanda, W. N., Pendidikan, P., Indonesia, B., & Medan, U. A. (2023). Analisis Tingkat Kemampuan Berpikir Kritis Siswa Sma Nurul Iman Tanjung Morawa. *Pedagogi: Jurnal Ilmiah Pendidikan*, 9(1), 16–22. https://dx.doi.org/10.47662/pedagogi.v9i1.540

Hwang, G. J., Xie, H., Wah, B. W., & Gašević, D. (2020). Vision, challenges, roles and research issues of Artificial Intelligence in Education. *Computers and Education: Artificial Intelligence*, 1, 100001. https://doi.org/10.1016/j.caeai.2020.100001

Jamallika, S. A. N., Handziko, R. C., & Krisnawati, T. (2024). The effect of discovery learning model assisted by evolution video on concept mastery and science literacy in high school students. *Jurnal Pendidikan Sains Universitas Muhammadiyah Semarang*, *12*(2), 1-8. https://doi.org/10.26714/jps.12.2.2024.1-8

Lailiah, I., Wardani, S., Sudarmin, S., & Sutanto, E. (2021). Implementasi guided inquiry berbantuan e-LKPD terhadap hasil belajar kognitif siswa pada materi redoks dan tata nama senyawa kimia. *Jurnal Inovasi Pendidikan Kimia*, *15*(1), 2792–2801. https://doi.org/10.15294/jipk.v15i1.26204

Latifah, N., & Utama, A. H. (2024). Optimalisasi Kemampuan Berpikir Kritis Melalui Metode Flipped Classroom : Systematic Literature Review. *JIIP-Jurnal Ilmiah Ilmu Pendidikan*, 7(8), 8174-8184. https://doi.org/10.54371/jiip.v7i8.4970

Mandar, Y. (2025). Implementasi Teori Konstruktivisme Dalam Pai: Kajian Teori Jean Piaget Dan Jerome Bruner. *Raudhah Proud To Be Professionals: Jurnal Tarbiyah Islamiyah*, 10(1), 223-237. https://doi.org/10.48094/raudhah.v10i1.829

Nababan, L. U. A., Zulmi, M. A., Sihombing, M. J., & Harahap, S. P. R. (2023). Meta Analisis Pengaruh Model Discovery Learning Pada Mata Pelajaran Fisika Terhadap Berpikir Kritis Siswa. *Jurnal Inovasi Pendidikan Sains dan Terapan (INTERN)*, 2, 1–8. https://doi.org/10.58466/intern.v2i1.1157

Nazara, I. A., Ariadi, P., Dinata, C., & Budi, G. S. (2025). Penerapan Model Discovery Learning Pada Materi Suhu Dan Kalor Di Kelas XI Semester II SMA Negeri Di Palangka Raya. *Bahana Pendidikan: Jurnal Pendidikan Sains*, 6(2), 41–51. https://doi.org/10.37304/bpjps.v6i2.15113

Ndoa, P. K., Lay, S., & Waruwu, F. (2024). Implementasi Teori Belajar Discovery Learning Jerome Bruner Dalam Proses Pembelajaran. *Pedagogik: Jurnal Ilmiah Pendidikan dan Pembelajaran Fakultas Tarbiyah Universitas Muhammadiyah Aceh*, 11(1), 28-38. https://doi.org/10.37598/pjpp.v11i1,%20April.2045

Nugraheni, B. I., Surjono, H. D., & Aji, G. P. (2022). How Can a Flipped Classroom Develop Critical Thinking Skills? A Literature Review. *International Journal of Information and Education Technology*, 12(1), 82–90. https://doi.org/10.18178/ijiet.2022.12.1.1590

Nurfadillah, L., Anwar, C., & Firdos, H. (2020). Pengaruh Model Pembelajaran Flipped Classroom Terhadap Kemampuan Berpikir Kritis Matematis Siswa. *Wilangan: Jurnal Inovasi Dan Riset Pendidikan Matematika*, 1(2), 215-225. https://dx.doi.org/10.26737/jpdi.v6i2.2574

Trihartini, T., Nurohman, S., & Buhera, R. (2025). The Impact Of Integrating Discovery Learning And Differentiated Instruction On Students' Critical Thinking Skills In Heat And Temperature Topics. *Jurnal Pendidikan Fisika dan Teknologi*, 11(1), 272-281. https://doi.org/10.29303/jpft.v11i1.8940

Oudbier, J., Spaai, G., Timmermans, K., & Boerboom, T. (2022). Enhancing The Effectiveness Of Flipped Classroom In Health Science Education: A State-Of-The-Art Review. *BMC Medical Education*, 22(1), 34. https://doi.org/10.1186/s12909-021-03052-5

Pradana, D., Nur, M., & Suprapto, N. (2020). Improving Critical Thinking Skills of Junior High School Students Through Science Process Skills-Based Learning. *Jurnal Penelitian Pendidikan IPA*, 6(2), 166-172. https://doi.org/10.29303/jppipa.v6i2.428

Eka, P., & Puspita, D. (2020). Implementasi pembelajaran daring dan luring saat Pandemi Covid 19.

Edugama, 6(1), 111-120. https://doi.org/10.32923/edugama.v6i1.1326

Putri, A. A., Gimin, G., Hariyanti, H., & Erlinda, S. (2023). Pengaruh Model Pembelajaran Discovery Learning Berbantuan Flipped Classroom Terhadap Hasil Belajar Di SMAN 1 Perhentian Raja. *Journal on Education*, 5(3), 9390–9402. https://doi.org/10.31004/joe.v5i3.1746

Ramadoni, R., & Mustofa, M. (2022). Enhancing Flipped Classroom With Peer Teaching To Promote Students' Conceptual Understanding And Self-Efficacy In Calculus Courses. *Pegem Journal of Education and Instruction*, 12(3), 154–168. https://doi.org/10.47750/pegegog.12.03.17

Rochman, C., Cahya, E., Mahen, S., & Nasrudin, D. (2018). Authentic Assessment Based On Teaching And Learning Trajectory With Student Activity Sheet (SAS) On Basic Physics Courses. *WAPFI (Wahana Pendidikan Fisika)*, 3(1), 1-8. https://doi.org/10.5220/0007094901740177.

Ruhana, B. A., Meiliyadi, L. A. D., & Zaini, M. (2023). Pengaruh model discovery learning terhadap keterampilan berpikir kritis siswa pada materi suhu dan kalor. *Relativitas: Jurnal Riset Inovasi Pembelajaran Fisika*, 6(1), 1–10. https://doi.org/10.29103/relativitas.v6i1.10375

Saavedra, A. R., & Opfer, V. D. (2012). Teaching and learning 21st century skills: Lessons from the learning sciences. *A Global Cities Education Network Report. New York, Asia Society*, 10, 2012. https://doi.org/10.1177/003172171209400203

Sania, N. R., Sayono, J., & Khakim, M. (2022). Pengaruh Model Flipped Classroom Terhadap Kemampuan Berpikir Kritis Peserta Didik SMAI Almaarif Singosari. *Jurnal Pemikiran Pendidikan Dan Penelitian Kesejarahan*, 9(2), 130-138. https://doi.org/10.26858/jp.v9i2.35703.

Sefriani, R., Rahmadani, A. F., Jalinus, N., Refdinal, R., Novrita, S. Z., & Widyastuti, R. (2023). Critical Thinking Skills In Learning Physics: A Bibliometric Analysis Using Vosviewer. *At-Tajdid: Jurnal Pendidikan dan Pemikiran Islam*, 7(2), 355-362. http://dx.doi.org/10.24127/att.v7i2.3028

Septarini, R. A., & Kholiq, A. (2021). Pengembangan Media Prest Untuk Meningkatkan Keterampilan Berpikir Kritis Peserta Didik Sma Pada Materi Momentum Dan Impuls. *Inovasi Pendidikan Fisika*, 10(1), 32-38. https://doi.org/10.26740/ipf.v10n1.p32-38.

Siburian, J., Sinaga, E., & Murni, P. (2023). Kemampuan berpikir kritis melalui implementasi flipped classroom pada siswa SMA. *Inkuiri: Jurnal Pendidikan IPA*, 12(1), 71-80. https://doi.org/10.20961/inkuiri.v12i1.68213

Syahrizal, H., & Jailani, M. S. (2023). Jenis-Jenis Penelitian Dalam Penelitian Kuantitatif Dan Kualitatif. *QOSIM: Jurnal Pendidikan Sosial & Humaniora*, 1(1), 13-23. https://dx.doi.org/10.61104/jq.v1i1.49.

Surur, M., Alifudin, M., & Syafitri, L. H. N. (2023). Relevansi Teori Kognitif Menurut Jerome Seymour Bruner Terhadap Strategi Pembelajaran Bermakna Di Era Digital. *Asas Wa Tandhim: Jurnal Hukum, Pendidikan Dan Sosial Keagamaan*, 2(2), 223-234. https://doi.org/10.47200/awtjhpsa.v2i2.3219.

Viskaali, H., Helmi, H., & Arafah, K. (2025). Development Of Discovery-Based Physics Teaching Modules To Improve Critical Thinking Skills. *Indonesian Journal on Learning and Advanced Education (IJOLAE)*, 411–426. https://doi.org/10.23917/ijolae.v7i2.8050

Wayudi, M., Suwatno, S., & Santoso, B. (2020). Kajian Analisis Keterampilan Berpikir Kritis Siswa Sekolah Menengah Atas. *Jurnal pendidikan manajemen perkantoran*, 5(1), 67-82. https://doi.org/10.17509/jpm.v5i1.25853.

Widiyana, A., Situmorang, R. P., & Tapilouw, M. C. (2021). Development of animated media-based discovery learning to improve scientific literacy content for senior high school students in human circulatory system material. *Jurnal Pendidikan Sains (Jps)*, *9*(1), 69. https://doi.org/10.26714/jps.9.1.2021.69-80

Zainuddin, Z., & Perera, C. J. (2017). Exploring students' competence, autonomy and relatedness in the flipped classroom pedagogical model. *Journal of further and higher education*, 43(1), 115-126.