

**EFFECTIVENESS OF GUIDED INQUIRY BASED WORKSHEET TO IMPROVE
STUDENTS' CRITICAL THINKING SKILLS ON
THE MATERIAL OF VIRUS REPLICATION**

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ABSTRACT

This study aims to examine the effectiveness of guided inquiry based worksheet on virus replication material to improve critical thinking skills of grade X high school students. The study used the method Research and Development (R&D) with a 4D development model (Define, Design, Develop, And Disseminate). A limited trial was conducted on 30 grade X high school students. The research instrument used was a critical thinking skills test based on Facione (2015) indicators, namely interpretation, analysis, inference, evaluation, explanation, and self-regulation. Data were analyzed using percentages and N-gain. The results showed that worksheet effectively improved critical thinking skills with an average pre-test score of 80.83 and a post-test score of 96.95, as well as an average N-gain of 0.84, categorized as high. Thus, the guided inquiry based student worksheet on virus replication was declared effective in improving students' critical thinking skills.

Keywords: biology instruction, deep learning, Merdeka Curriculum, critical thinking skills, teaching materials

ABSTRAK

Penelitian ini bertujuan untuk melihat keefektifan LKPD berbasis inkuiri terbimbing pada materi replikasi virus untuk meningkatkan keterampilan berpikir kritis peserta didik kelas X SMA. Penelitian menggunakan metode Research and Development (R&D) dengan model pengembangan 4D (Define, Design, Develop, dan Disseminate). Uji coba terbatas dilakukan pada 30 peserta didik kelas X SMA. Instrumen penelitian yang digunakan adalah tes keterampilan berpikir kritis berdasarkan indikator Facione (2015), yaitu interpretasi, analisis, inferensi, evaluasi, eksplanasi, dan regulasi diri. Data dianalisis menggunakan persentase dan N-gain. Hasil penelitian menunjukkan bahwa LKPD efektif meningkatkan keterampilan berpikir kritis dengan rata-rata nilai pre-test sebesar 80,83 dan post-test sebesar 96,95, serta rata-rata N-gain sebesar 0,84 berkategori tinggi. Dengan demikian, LKPD berbasis inkuiri terbimbing pada materi replikasi virus dinyatakan efektif untuk meningkatkan keterampilan berpikir kritis peserta didik.

Kata Kunci: pembelajaran biologi, pembelajaran mendalam, Kurikulum Merdeka, keterampilan berpikir kritis, bahan ajar

A. Introduction

21st century education demands that students possess critical thinking, communication, collaboration, and creativity (4C) skills to prepare them to face increasingly complex global challenges (Stanikzai, 2023). In line with these demands, the Independent Curriculum, through its in depth learning approach, emphasizes the development of various student competencies, including critical thinking skills, which play a crucial role in scientific analysis, evaluation, and decision-making (Mahardika & Jaya, 2025). Therefore, learning needs to be designed to facilitate students in actively and meaningfully constructing knowledge.

One learning model that can support the development of critical thinking skills is guided inquiry. This model engages students in a structured investigation process to discover concepts through observation, data collection, analysis, and drawing conclusions (Firdaus, 2018). Through this model, students develop the 4C competencies of the 21st century by involving them in problem solving, encouraging them to seek answers independently, and

providing learning freedom that remains within clear exploration boundaries (Fitriani *et al.*, 2023).

Virus replication is a biology topic that requires critical thinking skills because students are required to understand abstract processes and reason about the relationships between concepts comprehensively. An inadequate understanding of the concept of virus replication can hinder students' ability to analyze various problems related to viruses in everyday life (Amelia & Trimulyono, 2024). Furthermore, students often experience difficulty understanding the stages of virus replication, particularly the differences between the lytic and lysogenic cycles, because these processes cannot be directly observed (Setyaningrum *et al.*, 2019). Lack of critical thinking skills also makes it difficult for students to understand virus replication (Agustine & Nawawi, 2020).

To support the implementation of guided inquiry learning on virus replication, teaching materials are needed that can guide students throughout the investigation process. One such teaching material is the Student Worksheet (LKPD). Student

worksheet serves as a learning activity guide that helps students acquire and develop concepts through systematic and directed activities (Firdaus, 2018). Integrating worksheet with the guided inquiry model has the potential to increase student engagement in learning while simultaneously fostering critical thinking skills.

Various studies have shown that guided inquiry based worksheets are effective in improving students' critical thinking skills. Firdaus & Wilujeng (2018) revealed that the implementation of guided inquiry based worksheets can encourage an increase in students' critical thinking skills with an average N-gain score 0.43. Based on Hidayat's *et al.* (2023) also indicated that students' critical thinking skills increased from 76% to 87% after using student worksheets based on guided inquiry. Although the effectiveness of guided inquiry based student worksheets has been widely reported, there has been little research linking the use of guided inquiry based student worksheets with improved critical thinking skills in the context of virus replication material. Therefore, this study was conducted to fill this gap.

Based on these conditions, this study aims to analyze the effectiveness of guided inquiry based student worksheets in improving students' critical thinking skills on virus replication. The results are expected to provide an effective alternative teaching materials to support biology learning and enhance students' critical thinking skills.

B. Method

This research is a development research which refers to the 4D model (Define, Design, Develop, And Disseminate) from Thiagarajan *et al.* (1974) to produce worksheet based on guided inquiry on the material of virus replication. The research was conducted in the 2025/2026 academic year. The define to develop stages were conducted in the Biology Department, Faculty of Mathematics and Natural Sciences, Surabaya State University, while the implementation stage was carried out on 30 students of Class X of SMAN 1 Srengat for 2 meetings. The effectiveness of worksheet was measured using one-group pretest-posttest design. Data were obtained through a critical thinking skills test consisting of 12 multiple choice questions given before

and after the use of the worksheet. Students were considered to have completed the test if they obtained a score of ≥ 76 . The collected data were then analyzed using the formula N-Gain (Sari & Suryanti, 2024).

$$g = \frac{(S_{posttest} - S_{pretest})}{(S_{max} - S_{pretest})}$$

The results of the normalized N-gain calculation are interpreted with N-gain $-1.00 < g < 0.00$ in the category there is a decrease, $g = 0$ in the category there is no increase, $0.00 < g < 0.30$ in the low category, $0.30 < g < 0.70$ in the medium category, and $0.70 < g < 1.00$ in the high category (Sari & Suryanti, 2024).

C. Results and Discussion

The product developed is a guided inquiry based student worksheet (LKPD) on the topic of virus replication, designed to train students' critical thinking skills. The worksheet consists of an introduction, content, and conclusion. All learning activities are structured according to the syntax of guided inquiry and critical thinking indicators of Facione (2015) which include interpretation, analysis, inference, evaluation, explanation, and self regulation.

The first feature is the *Kick Start*, which trains interpretation skills through activities to identify important information from news about the spread of HIV. The *Big Question* feature trains analytical skills by guiding students to formulate scientific problems based on the news. Next, the *My Guess* feature facilitates inference skills by developing hypotheses regarding the problem formulation that has been made. The *Fact Hunt* feature trains interpretation, analysis, and explanation skills through activities to put together a virus replication puzzle, compare the lytic and lysogenic cycles, and analyze the differences in the replication of bacteriophages and HIV viruses. Evaluation skills are trained through the *Reality Check* feature, which is an activity to verify the conformity of hypotheses with data from observations and discussions. The *Wrap Up* feature trains inference and self regulation skills through activities to draw conclusions and reflect on the understanding gained during learning. The *Ding-Dong* feature functions as assistance in the form of additional directions and barcodes linked to supporting learning resources that

support students in completing each learning activity.

The effectiveness of the guided inquiry based virus replication worksheet is assessed based on students' achievement of critical thinking indicators. This achievement is measured through a test consisting of pre-test and post-test. The question are aligned to the learning objective and critical thinking's indicators. The following are the result presented at **Table 1.**

Table 1. The result of pre-test and post-test

Reference	Pre-test	Post-test
Average	80,83	96,95
Student who have passed	17	30
Percentage of completion	56,70%	100%

Based on **Table 1**, the student have increased the score before and after using the worksheet. Of the 30 students, in the activity pre-test, only 56.7% (17 students) received scores above the minimum score (≥ 76). Meanwhile, in the activity post-test, 100% of students met the minimum and were declared complete. The N-gain values were then calculated based on pre-test and post-test result to find out the improvement in

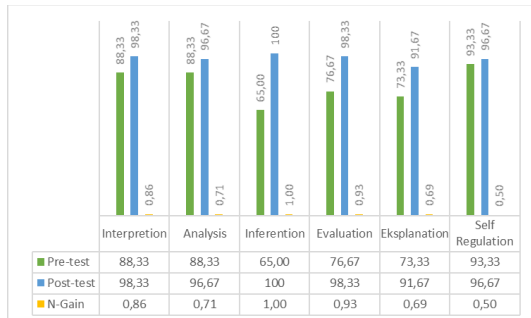
students' abilities. The N-gain values are shown in **Table 2.**

Table 2. Recapitulation of N-gain values

No	Critical Thinking Indicators	Question Number	Average		N-Gain	Category
			Pre-test	Post-test		
1	Interpretation	1, 2	88,33	98,33	0,86	High
2	Analyses	3, 7	88,33	96,67	0,71	High
3	Inference	4, 5	65,00	100	1,00	High
4	Evaluation	8, 10	76,67	98,33	0,93	High
5	Eksplan ation	6, 11	73,33	91,67	0,69	Medium
6	Self Regulation	9, 12	93,33	96,67	0,50	Medium
Average			80,83	96,95	0,84	High

Based on **Table 2**, the average pre-test score is 80.83 and the average post-test score is 96.95. The average N-gain is 0.84 in the high category. The critical thinking indicators measured consist of interpretation, analysis, inference, evaluation, explanation, and self regulation, each of which has a category. N-gains sequentially are 0.86; 0.71; 1.00; 0.93; 0.69; and 0.50. The N-gain values of interpretation, analysis, inference, and evaluation are

included in the high category. Meanwhile, the N-gain values of explanation and self regulation are in the medium category. The scores can be seen in the **Graph 1**.



Graph 1 N-gain values per critical thinking indicators

Based on graph 1, the average score of pre test the highest is in self regulation indicator at 93,33 and the lowest is in inference indicator at 65.00. Meanwhile in the post-test average score, the highest is in inference indicator at 100 and the lowest is in explanation indicator at 91,67. The highest N-gain value is inference at 1,00 and the lowest is in the self regulation at 0,50.

The effectiveness of worksheet is shown through an increase in the average score of students from 80.83 in the pre-test to 96.95 in the post-test with an average N-gain score 0.84 is categorized as high. Learning completion also increased from 56.7% to 100%. According to Plomp & Nieveen (2010), learning tools are

considered effective if they produce outcomes that align with development objectives. Therefore, these results indicate that guided inquiry based student worksheets are effective in strengthening students' conceptual mastery and critical thinking skills in the virus replication material.

This increase is thought to be influenced by the application of a guided inquiry model which provides opportunities for students to be actively involved in the learning process through activities of identifying problems, formulating hypotheses, collecting information, analyzing data, and drawing conclusions (Sonia *et al.*, 2023). This activity aligns with the characteristics of inquiry learning, which emphasizes student involvement in constructing knowledge through investigation and problem solving (Firdaus & Wilujeng, 2018). Through this process, students not only passively receive information but also gain learning experiences that encourage the development of critical thinking skills, as indicated by Facione (2015).

Reviewed based on critical thinking indicators, interpretation gets a pre-test score at 88,33%, post-test at 98.33%, and N-gain 0.86, in the

high category. This increase reflects the growing ability of students to understand information, identify meaning, and interpret the phenomena being studied. According to Facione (2015), interpretation includes the ability to categorize, clarify, and understand the meaning of information or experiences. The high achievement of this indicator may be related to activities in the learning feature *Kick Start* and *Fact Hunt*. This features guided students to observe illustrations, analyze HIV news, and identify important information before conducting further investigation. This process supported students in gradually building initial understanding, making the information easier to interpret. These results align with Agustine & Nawawi's (2020) statement that learning about viruses requires providing opportunities for students to connect information to context to develop critical thinking skills.

Analysis indicators obtain values pre-test 88,33%, post-test 96.67%, and N-gain 0.71 is categorized as high. This achievement illustrates the improvement in students' ability to identify relationships between concepts, differentiate relevant

information, and analyze virus replication mechanisms. According to Facione (2015), analysis is the ability to identify inferential relationships between concepts, statements, and available evidence. The high achievement of this indicator can be related to the activities of determining problem formulation and filling out the difference table of viruses replication mechanism. Through these activities, students not only receive information but also compare, connect, and organize concepts independently. This condition is in accordance with the characteristics of inquiry learning, which places students at the center of the investigation process (Ali *et al.*, 2024).

The inference indicator shows a highest increase with the value pre-test 65,00%, post-test 100%, and N-gain 1.00. The relatively low score in pre-test indicates that students' ability to formulate hypotheses and draw conclusions still requires reinforcement before learning. After the implementation of the Student Worksheet, there was a significant increase, indicating that students were increasingly able to formulate hypotheses and draw conclusions based on the evidence obtained.

Facione (2015) explains that inference includes the ability to identify relevant information, construct conjectures, and produce logical conclusions based on available data. The high increase in this indicator may be related to the features *My Guess* and *Wrap Up* which encourages students to make initial predictions and then compare them with the results of the investigation. These findings are in line with Sonia *et al.* (2023) stated that the guided inquiry model has a positive effect on critical thinking skills because students are trained to construct reasoning based on the results of investigations.

The evaluation indicator achieved a value pre-test 76,67%, post-test 98.33%, and N-gain 0.93. According to Facione (2015), evaluation is the ability to assess the credibility of information and the quality of arguments before making a decision. This significant improvement reflects students' growing ability to compare information, assess the accuracy of answers, and consider available evidence. This high achievement may be related to the activity *Reality Check* when students present the results of their discussions and compare them with those of other

groups. This activity requires students to evaluate arguments before delivering a final decision. Puling *et al.* (2024) also stated that critical thinking is related to the ability to analyze and evaluate information objectively, so that students do not just absorb information, but also assess the quality of the information before drawing conclusions.

In contrast to the previous indicators, explanations obtained a value pre-test 73,33%, post-test 91.67%, and N-gain 0.69, thus categorized as medium. According to Facione (2015), explanation is the ability to state the results of reasoning and provide justification based on the evidence, concepts, methods, and context used. In this study, the explanation indicator was measured through students' ability to explain the impact of reverse transcription of HIV viral RNA and its integration into host cell DNA, as well as the differences in the replication mechanisms of HIV and bacteriophages based on their genetic material. Despite the improvement, explanation achievement was still lower than several other indicators because students were not only required to understand each stage of virus replication separately but also to

connect various interrelated biological concepts into a coherent and logical explanation. The complexity of these concepts means that explanation skills require more intensive practice than other critical thinking indicators (Agustine & Nawawi, 2020). In addition, Oktatinari & Fauziah (2026) stated that explanation skills require consistent practice through analysis, discussion, and presentation of scientific reasons to develop optimally. This increase in value is in line with Amelia & Trimulyono (2024) and Elcane *et al.* (2021) stated that guided inquiry based student worksheets are effective in supporting students in explaining biological concepts more systematically through investigative activities, analysis, and drawing conclusions.

Self regulation indicators score pre-test 93,33%, post-test 96.67%, and N-gain 0.50 so that it is in the medium category. However, this achievement needs to be reviewed from the value pre-test students who were already high before the implementation of the learning process. This phenomenon may be related to ceiling effect, namely a condition where students already have high initial scores so that the

opportunity to increase their scores is limited. According to Hake (1998) in Azmi *et al.* (2026), students with high initial scores tend to achieve improvements gain smaller because the upgrade space is getting narrower.

According to Rositawati, (2018), self regulation is the ability to monitor, assess, and improve thought processes through reflection on decisions or beliefs. In this study, self regulation was measured through questions that asked students to reflect on their initial misconceptions about HIV transmission and then determine appropriate actions based on the scientific information they had learned. This activity required students to recognize misconceptions, evaluate their initial beliefs, and replace them with more accurate understandings. This process is a form of metacognition, which is a high-level critical thinking skill because it involves awareness of one's own thought processes (Facione, 2015). Therefore, the development of self-regulation generally occurs more slowly than other indicators of critical thinking and requires ongoing practice.

Overall, the achievement of the six indicators shows that the guided

inquiry based student worksheet not only improves learning outcomes but also facilitates the development of critical thinking skills, as indicated by Facione (2015). The high achievement in interpretation, analysis, inference, and evaluation indicates that the activities in the student worksheet have been effective. Although the explanation and self regulation indicators received medium scores, the factors influencing the achievement of these two indicators differed. In the explanation indicator, student improvement was still influenced by the complexity of the virus replication material, which requires an understanding of the relationships between concepts and the ability to explain biological processes coherently and logically. Meanwhile, in the self regulation indicator, the improvement tended to be lower because students already had high initial scores and still needed to reflect to correct some of their previous misconceptions.

The findings of this study also indicate that guided inquiry-based student worksheets support the implementation of deep learning within the Merdeka Curriculum. Through investigative activities, information

analysis, discussion, reflection, and conclusion drawing, students not only memorize the stages of virus replication but also meaningfully understand the relationships between concepts and apply their knowledge in different contexts. This aligns with the objectives of deep learning, which emphasize conceptual understanding, critical thinking, and constructing meaning from learning experiences (Sera *et al.*, 2025).

Despite showing positive results, this study still has limitations. It used a one-group pretest-posttest design without a comparison group. Therefore, the effectiveness of the Student Worksheet cannot be directly compared with other teaching materials or learning models. Furthermore, the product trial was conducted on a limited scale, so generalization of the research results requires caution. Future research could use an experimental design with a control group and a larger sample size to obtain stronger evidence of effectiveness.

D. Conclusion

The guided inquiry based student worksheet on the virus replication material has been proven

effective in improving students' critical thinking skills, as indicated by an increase in the average score from 80.83 in the pre-test to 96.95 in the post-test with an average N-Gain of 0.84 in the high category. Based on the critical thinking skill indicators, interpretation, analysis, inference, and evaluation have increased to the high category, while explanation and self regulation are in the medium category. These results indicate that the developed worksheet is able to facilitate students in understanding information, analyzing concepts, drawing conclusions, and evaluating information based on evidence on the virus replication material.

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