
Pedevlopment of Problem-Based Learning (PBL) Based E-LKPD on Respiratory System Materials to Improve Students' Critical Thinking Skills

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Abstract

Critical thinking skills are higher-order thinking skills that are essential to be developed in biology learning. This development research aimed to produce a Problem-Based Learning (PBL)-based electronic student worksheet (E-LKPD) on the respiratory system topic to improve students' critical thinking skills, which is feasible in terms of validity, practicality, and effectiveness. The development of the E-LKPD employed the 4D model consisting of define, design, develop, and disseminate stages. The product trial was conducted on 36 eleventh-grade students of SMAN 14 Surabaya. The parameters measured in this study included validity assessed by experts, practicality based on the implementation of learning activities and students' responses, and effectiveness based on the improvement of students' critical thinking skills from pretest and post-test results. The data were analyzed using descriptive quantitative methods. The results showed that the developed E-LKPD obtained a validity score of 98.75%, categorized as very valid. The practicality of the E-LKPD based on the implementation of learning activities reached 98.5%, while students' responses reached 97.8%, both categorized as very practical. The effectiveness of the E-LKPD was indicated by the improvement of students' critical thinking skills with an N-Gain score of 0.74 which falls into the moderate category.

Keywords

E-LKPD, Problem-Based Learning, Respiratory System, Critical Thinking Skills



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INTRODUCTION

The development of 21st century education requires learning that focuses not only on the mastery of knowledge, but also on the development of higher-order *thinking skills* (HOTS) (OECD, 2018). In cognitive taxonomy, HOTS includes the ability to analyze, evaluate, and create (Anderson and Krathwohl, 2001). One of the skills that is at the core of HOTS is critical thinking skills. In the Deep Learning Curriculum, critical thinking is an

important part of the dimension of the graduate profile that is needed in the problem-solving and decision-making process (Ministry of Education and Education, 2025). Facione (2011) explained that critical thinking is an assessment process that involves the ability to interpret, analyze, evaluate, infer, explain, and *self-regulation*. Therefore, critical thinking skills play an important role in helping students understand concepts in depth and apply knowledge in various real-world situations (Ariadila *et al.*, 2023).

In biology learning, critical thinking skills are very necessary because students are required to analyze scientific phenomena, evaluate information, and solve problems logically and systematically (Zubaidah, 2016). However, various studies show that the critical thinking skills of students in Indonesia are still not optimally developed. Sugiharti & Gayatri (2021) reported that the critical thinking skills of high school students in biology materials in Surabaya were in the low category with a percentage of 51.85%. Another study by Novitasari & Ambarwati (2024) shows that students' critical thinking skills are in the medium category with an average of 76.57%, with the highest achievement in the interpretation indicator and the lowest in the inference indicator. This condition shows that the development of critical thinking skills in biology learning still requires more optimal efforts.

One of the factors that affect the low critical thinking skills is the use of learning strategies that have not fully encouraged active involvement of students. *Teacher-centered learning* tends to limit students' opportunities to develop analytical and reflective thinking processes (Aisyah *et al.*, 2025). The results of observation of biology learning in high school show that most students still have low critical thinking skills, shown by limitations in asking analytical questions, conveying logical arguments, and evaluating the problems given. In addition, the learning resources used are still limited to conventional LKS which contain material summaries and practice questions so that they have not optimally trained students' critical thinking skills. This condition shows the need for innovation in the use of learning models and learning resources that are able to encourage students' thinking activities in more depth.

One of the efforts that can be made to overcome these problems is to implement a learning model that encourages active student involvement, such as *Problem-Based Learning* (PBL). The PBL model places authentic problems as the starting point for learning so that students are encouraged to analyze information, evaluate evidence, and formulate solutions

based on logical reasoning (Barrows, 1996). In addition, this model also emphasizes high-level thinking processes in problem solving (Hmelo-Silver, 2004). The implementation of the PBL model will be more effective if it is supported by innovative learning resources, one of which is the Electronic Student Worksheet (E-LKPD). E-LKPD allows the integration of various multimedia features such as images, videos, and digital links so that it can increase student engagement (Rahayu *et al.*, 2021). In addition, E-LKPD also facilitates analysis and problem-solving activities more optimally (Mahmudah & Bahtiar, 2022). Previous research has shown that PBL-based E-LKPD is able to improve students' critical thinking skills (Fina *et al.*, 2023). This is supported by contextual problem-solving activities in learning (Arya & Rahmadina, 2024).

Based on this description, there is still a need to develop learning resources that are able to facilitate active learning and train students' critical thinking skills. Therefore, this study aims to develop Problem-Based Learning-based E-LKPD on respiratory system materials in grade XI of high school. The development of E-LKPD is expected to produce valid, practical, and effective learning resources in improving students' critical thinking skills, as well as contributing to digital technology-based biology learning innovations.

METHODS

The research on the development of PBL-based E-LKPD on the Respiratory System material uses a quantitative descriptive method, by applying a 4D mold covering four main stages, namely Define (definition), Design (design), Develop (development), and Disseminate (disseminate). The definition stage includes initial analysis, student analysis, task analysis, and concept analysis, carried out in the Biology Education Department of Unesa. The design stage includes the preparation of instruments, media selection, format selection, and the preparation of the initial design of E-LKPD. The development stage was carried out through validation by experts and limited trials, this stage was carried out at the Department of Biology Education Unesa and SMAN 14 Surabaya in October 2020-February 2021. The disseminate stage is carried out on a limited basis through the publication of scientific articles.

Validation is carried out to assess the feasibility of the product based on aspects of presentation, content, and language. Furthermore, a trial was carried out limited to one class XI at SMA Negeri 14 Surabaya which was selected based on the consideration of the biology

teacher, with 36 students to find out the practicality and effectiveness of E-LKPD in learning. The research instruments used include validation sheets, observation sheets on learning implementation, student response questionnaires, and tests (pretest and post-test). Data collection techniques are carried out through validation, observation, questionnaire, and test methods. Validity data was obtained from validation sheets by subject matter experts and media experts using the Likert scale (1–4). The average score obtained is percentaged using the formula:

$$P = \frac{\sum \text{Skor total yang diperoleh}}{\sum \text{Skor Maksimal}} \times 100\% \dots \dots (1)$$

Practicality was obtained from the questionnaire of student responses and observation of the implementation of learning using *the Guttman scale*. The percentage of practicality is calculated by the formula:

$$P = \frac{\sum \text{Jumlah jawaban YA}}{\sum \text{Jumlah Responden}} \times 100\% \dots \dots (2)$$

Effectiveness is determined based on *the results of the pretest and post-test* to determine the improvement of students' critical thinking skills. E-LKPD is declared effective if students' learning outcomes reach a minimum of $\geq 71\%$ completion.

$$\text{Completeness\%} = \frac{\text{Jumlah Peserta Didik Tuntas}}{\text{Jumlah Total Peserta Didik}} \times 100\% \dots \dots (3)$$

To measure the improvement of students' critical thinking skills, the *N-Gain Score calculation* is used with the following formula (Hake, 1998):

$$N\text{-Gain} = \frac{\text{Skor Pretest} - \text{Skor Posttest}}{100 - \text{Skor Pretest}} \dots \dots (4)$$

RESULTS AND DISCUSSION






Development of PBL-based E-LKPD

The development of PBL-based E-LKPD is carried out by applying a 4D development model (*define, design, develop, and disseminate*), with gradual improvements based on suggestions and input from supervisors and examiners as validators. This E-LKPD has two main activity topics. The first activity with the topic "Exploration of Respiratory System Organs" focuses on the observation of the anatomical structure and function of the organs of the respiratory system as well as the mechanism of gas exchange, while the second activity with the topic "The Impact of Cigarette Smoke Exposure on the Health of the Respiratory System" this topic focuses on discussing the impact of smoking habits and exposure to

cigarette smoke on the health of the respiratory system.

This E-LKPD is developed in electronic format and implemented through the *Liveworksheets platform*, so that it can be accessed online through various devices, such as smartphones, tablets, laptops, and computers, as long as it is connected to the internet network. Digital e-LKPD is considered more attractive, responsive, and able to increase the interactivity and effectiveness of biology learning (Prasetyo *et al.*, 2022). The E-LKPD that has been designed includes a number of learning features that function to support teachers in developing students' critical thinking skills.

Table 1. Features on E-LKPD

Logo Fitur	Deskripsi
	<i>BioNews</i> presents contextual issues related to respiratory system disorders through articles or illustrations to encourage curiosity and help learners interpret relevant information. (Indicator: interpretation)
	<i>BioQuest</i> contains guiding questions to facilitate learners in identifying, understanding, analyzing problems and formulating initial problem solving ideas. (Indicators: analysis and explanation)
	<i>BioExplore</i> facilitates students in searching, processing, and analyzing information independently or in groups with the guidance of teachers. (Indicators: analysis and evaluation)
	<i>BioPresent</i> supports students in compiling and presenting solutions based on the results of the investigation in a systematic and logical manner. (Indicators: inference and explanation)
	<i>BioReflect</i> directs students to evaluate the learning process and reflect on the understanding gained in the context of maintaining a healthy respiratory system. (Indicators: evaluation and <i>self-regulation</i>)

The design of E-LKPD is systematically prepared by paying attention to readability, visual clarity, and ease of navigation to help students follow the learning flow gradually. Digital design clarity is known to be able to increase the focus and effectiveness of student interaction in learning (Hidar & Indana, 2024). In addition, the integration of illustrated

images and learning videos helps students understand the mechanisms of the respiratory system which are abstract and dynamic, thereby supporting the improvement of the quality of reasoning and learning engagement (Lestari *et al.*, 2025). E-LKPD is also equipped with *BioNews*, *BioQuest*, *BioExplore*, *BioPresent*, and *BioReflect* features that are adjusted to PBL syntax and critical thinking indicators to support students in the process of interpretation, analysis, evaluation, inference, explanation, and self-regulation. The development of these features is in line with the theory of constructivism which emphasizes that knowledge is actively built through learning experiences and interaction with the environment (Piaget, 1950), and has been proven to be able to increase students' activeness in problem solving (Sari *et al.*, 2020).

Results of E-LKPD Study and Validation

During the seminar, *the first draft* proposal was reviewed by the examiner lecturer so as to get suggestions and input. The suggestions and inputs obtained are then used as the basis for revising the *draft II*.

Table 2. Review and Revision Results E-LKPD

Ye s	Suggestions and Feedback (Draft I)	After Revision (Draft II)
1.	The E-LKPD Feature Explanation is too long and lacks aesthetics, just a table.	Explanation of E-LKPD Features is fewer, easier to understand and more elegant.
2.	The summary of the material presented is too little, still too general and not interesting.	The summary of the material has been determined and given pictures of the respiratory system organs to make it interesting.
3.	The E-LKPD does not include the topic of learning activities and time allocation.	E-LKPD has been listed as a time allocation and learning topics.
4.	E-LKPD of the respiratory system feels less attractive if it is not given practicum activities.	In the BioExplore Activity, 1 practicum has been given on every 1 discussion topic.
5.	Just list the contents, it is suggested to add a	A glossary has been listed before the E-

Ye s	Suggestions and Feedback (Draft I)	After Revision (Draft II)
	glossary.	LKPD bibliography.
6.	The video included in the E-LKPD has a duration of 19 minutes that is too long. It will take time to learn	The researcher revised it by changing the video to a shorter 6-minute length, to save time
7.	In the E-LKPD feature, there is no need to include the PBL Stage	The PBL stage on the E-LKPD feature is moved into the E-LKPD Characteristic
8.	The Finish button is still not facilitated in the E-LKPD	The finish button used by E-LKPD uses the <i>Liveworksheet Platform</i>

The validation stage is carried out by two validators consisting of material experts and learning media experts. The results of PBL-based E-LKPD validation on respiratory system materials are presented in Table 3.

Table 3. Recapitulation of Validation Results E-LKPD

No	Assessment Aspects	Shoes		Percentage
		V1	V2	(%)
A. Presentation Components				
1.	Cover Design	4	4	100
2.	Title E-LKPD	4	4	100
3.	Time Allocation	4	4	100
4.	Learning Objectives	4	4	100
5.	Instructions for Use of E-Lkpd	4	4	100
6.	Systematics of E-Lkpd Presentation	4	4	100
7.	E-LKPD Layout	4	4	100
8.	Image and Media Quality	4	4	100
9.	Features of E-LKPD	3	3	80
10.	E-LKPD Accessibility	4	4	100
Overall Average				98

No	Assessment Aspects	Shoes		Percentage (%)
		V1	V2	
B. Contents Components				
11.	Suitability of the material with the concept	4	4	100
12.	Compatibility of E-LKPD with <i>Problem-Based Learning</i> (PBL)	4	4	100
13.	E-LKPD Compatibility With Learning Experience	4	4	100
14.	E-LKPD Compatibility with Critical Thinking Skills	4	4	100
Overall Average				100
C. Language Component				
15.	Language Use	4	4	100
16.	Compatibility with PUEBI	4	4	100
Overall Average				100
Component Wholeness Assessment				98,75
Criteria				Highly Valid

Based on the validation results in Table 3, all aspects obtained an average of 98.75%, including the very valid category. The assessment of the validity of the E-LKPD is based on three main aspects, namely the feasibility of presentation, the feasibility of the content, and the feasibility of language. The details of the results of the percentage of presentation components that received an average of 98% were categorized as very valid. In the content aspect, a 100% assessment was obtained that was categorized as very valid. The language component also received a 100% assessment and was categorized as very valid.

E-LKPD validation is carried out to ensure the feasibility of the product before being used in learning, so as to meet the set quality standards (Sagita & Putra, 2023). Based on the validation results, E-LKPD obtained an average percentage of 98.75% with a very valid category in terms of presentation, content, and language. The presentation aspect obtained

an average of 98% which included the cover design, learning objectives, layout, features, media quality, and accessibility of E-LKPD. Attractive and relevant visual designs are known to increase attention and facilitate students' understanding (Junardi, 2025), while structured presentation systematics support independent learning and strengthen inter-material linkages (Ersalina *et al.*, 2023). Although the answer delivery feature scored lower than other components because it still utilizes the built-in facilities of *the Liveworksheet platform*, the overall aspect of presentation still shows excellent quality in supporting learning effectiveness.

The content and language aspects each obtained an average of 100% with a very valid category. The feasibility of the content was assessed based on the suitability of the material with the concept, PBL syntax, learning experience, and critical thinking indicators. The presentation of contextual and gradual material is considered to be able to help students build understanding independently according to the perspective of constructivism (Vygotsky, 1978). In addition, the compatibility of E-LKPD with PBL has been proven to support students' critical thinking skills and learning outcomes (Sinurat *et al.*, 2025). In the linguistic aspect, the use of straightforward, communicative, and PUEBI-compliant language is an important indicator in increasing students' understanding and active involvement during learning (Rahmawati *et al.*, 2024).

Practicality of E-LKPD

After being declared feasible through a validation process by material experts and media experts, the E-LKPD was then implemented to 36 students at SMAN 14 Surabaya. Practicality assessments were carried out through observation of learning implementation and questionnaires of student responses after the use of E-LKPD. The results of the two instruments are presented as follows.

Implementation Observation Sheet

Tabel 4 Results of the Learning Implementation Observation Sheet

No	Learning Activities	Implementation of E-LKPD	
		P1	P2
Early Activities			
1.	Students work on Pretest questions	100%	0%

No	Learning Activities	Implementation of E-LKPD	
		P1	P2
2.	Students read learning outcomes and objectives	100%	100%
3.	Students read the steps to use E-LKPD and the E-LKPD feature	100%	100%
4.	Students read a summary of the material	100%	100%
5.	Students observe the video that has been provided on the Qr code	67%	100%

Syntax 1. Student Orientation to Problems

1.	Students read discourse on problems that disturb the respiratory system	100%	100%
2.	Students make a formulation of problems related to existing readings	100%	100%

Syntax 2. Organizing Students to Learn

1.	Students work on BioQuest activities contained in E-LKPD	100%	100%
2.	Students discuss in groups	100%	100%
3.	Students seek information from trusted sources	67%	100%

Syntax 4. Guiding Research

1.	Students read instructions for working on the BioExplore stage	100%	100%
2.	Students work on BioExplore activities until BioReflect	100%	100%
3.	Students ask the teacher as a facilitator	33%	100%

Syntax 4. Developing Results

1.	Students presented the results of the E-LKPD that had been done with the group	100%	100%
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Syntax 5. Analysis and Evaluation

1.	Students and teachers analyze and conclude the results of the E-LKPD	100%	100%
2.	Students concluded the activities that had been carried out	100%	100%
3.	Students reflect on the problems that have been given and	100%	100%

No	Learning Activities	Implementation of E-LKPD	
		P1	P2
	their anticipations		
4.	Students Work on <i>Post-test questions</i>	0%	100%
Average		87%	94%
Criteria		Very Practical	Very Practical
Overall Average		90,5%	
Criteria		Very Practical	

The practicality of PBL-based E-LKPD on respiratory system materials was assessed through observation of learning implementation and student response questionnaires. The results of the observation showed an average learning implementation of 90.4% with the category of very practical. Implementation in E-LKPD 1 obtained a percentage of 87% and increased to 94% in E-LKPD 2. This increase shows that students are starting to get used to using E-LKPD and understand technology-based learning activities so that the adaptation process also affects the effectiveness of learning (Yolanda *et al.*, 2023). Good learning implementation is known to be able to influence student activities during the learning process (Pratiwi & Hidayati, 2022), while student activity and involvement during learning are important indicators in determining the practicality of E-LKPD (Hidar & Indana, 2024).

However, some activities in the first meeting did not take place optimally, such as observing learning videos and looking for relevant information on *the BioNews* feature , each of which obtained 67% implementation. This is because students are still less active and tend to use general sources of information compared to reliable scientific sources. The excessive use of AI is known to reduce students' ability to evaluate information sources and think critically (Winanda & Ardi Prasetyo, 2025), so digital literacy skills are needed to help students verify information critically (Lathifah *et al.*, 2026). In addition, the activity of asking teachers obtained the lowest percentage of 33% because students still lacked confidence and felt awkward when asking questions. This condition is in accordance with the view of humanism which emphasizes the importance of emotional comfort in the learning process

(Rogers, 1969), so teachers need to provide stimulus and motivation so that students are more active during learning (Franitya *et al.*, 2023).

Results of Student Response Questionnaire

Tabel 5. Results of the Student Response Questionnaire

No	Kegiatan Pembelajaran	Jawaban (n=36)		Persentase (%)
		Ya	Tidak	
1.	E-LKPD berbasis <i>Problem based learning</i> mudah diakses dan digunakan.	36	0	100
2.	Tampilan E-LKPD <i>Problem based learning</i> menarik dan membuat saya semangat belajar.	35	1	97
3.	Bahasa yang digunakan dalam E-LKPD <i>Problem based learning</i> mudah dipahami.	36	0	100
4.	Petunjuk pengerjaan dalam E-LKPD <i>Problem based learning</i> jelas dan mudah diikuti.	36	0	100
5.	Soal dan aktivitas dalam E-LKPD <i>Problem based learning</i> sesuai dengan materi yang diajarkan.	36	0	100
6.	E-LKPD <i>Problem based learning</i> membantu saya memahami konsep dengan lebih baik.	36	0	100
7.	E-LKPD <i>Problem based learning</i> membuat saya lebih aktif dalam proses pembelajaran.	32	4	89
8.	Gambar, ilustrasi, atau media yang ada di E-LKPD <i>Problem based learning</i> membantu saya belajar.	35	1	97
9.	E-LKPD <i>Problem based learning</i> membantu saya memahami cara menyatakan informasi dalam soal permasalahan yang diberikan.	35	1	97
10	E-LKPD <i>Problem based learning</i> membantu saya mengidentifikasi informasi yang penting dalam soal permasalahan dan mengabaikan informasi yang	36	0	100

No	Kegiatan Pembelajaran	Jawaban (n=36)		Persentase (%)
		Ya	Tidak	
	tidak relevan.			
11	E-LKPD <i>Problem based learning</i> membantu saya memberikan alasan logis untuk menjawab soal atau kasus.	34	2	94
12.	E-LKPD <i>Problem based learning</i> membantu saya dalam menemukan kesimpulan terhadap soal permasalahan yang diberikan.	36	0	100
13	E-LKPD <i>Problem based learning</i> membantu saya menguji dan mengevaluasi solusi yang dihasilkan untuk memastikan kebenarannya.	36	0	100
Rata-Rata Keseluruhan		97,8%		
Kriteria		Sangat Praktis		

Based on the data of the student response questionnaire to PBL-based E-LKPD in Table 5, the percentage of "Yes" answers on all statements is in the range of 87% to 100%. Most indicators obtained a percentage of 100%, while other indicators were at 97%, 94%, and 87%. Overall, the average percentage of "Yes" answers reached 97.8% and was included in the "Very Practical" category. This percentage shows that students respond positively to the use of PBL-based E-LKPD that has been developed. The positive response from students shows that E-LKPD is easy to use, attractive, and able to support the learning process effectively. According to Irawan & Hakim (2021), a learning resource is said to be practical if the majority of students give a positive response to the product developed, while Nieveen (1999) emphasizes that the practicality of learning tools is determined by the level of ease of use and positive acceptance from users.

Effectiveness of E-LKPD

The effectiveness of Problem-Based Learning-based E-LKPD in improving students' critical thinking skills on respiratory system materials was evaluated through test

instruments in the form of *pre-test* and *post-test*. The two instruments consist of 16 questions arranged based on critical thinking indicators, namely interpretation, analysis, evaluation, inference, explanation, and self-regulation.

Tabel 6. Recapitulation of *Pretest* and *Post-Test* Results

Students-	Pretest		Post-Test		N-Gain	Criteria
	Value	Ket	Value	Ket		
1	87	T	94	T	0,54	Medium
2	50	TT	81	T	0,62	Medium
3	56	TT	75	T	0,43	Medium
4	75	T	75	T	0,00	Low
5	75	T	94	T	0,76	Height
6	69	TT	94	T	0,81	Height
7	50	TT	81	T	0,62	Medium
8	75	T	87	T	0,48	Medium
9	94	T	100	T	1,00	Height
10	69	TT	81	T	0,39	Medium
11	56	TT	81	T	0,57	Medium
12	75	T	81	T	0,24	Low
13	69	TT	87	T	0,58	Medium
14	69	TT	87	T	0,58	Medium
15	87	T	94	T	0,54	Medium
16	62	TT	94	T	0,84	Height
17	81	T	87	T	0,32	Medium
18	50	TT	56	TT	0,12	Low
19	69	TT	100	T	1,00	Height
20	62	TT	75	T	0,34	Medium
21	69	TT	94	T	0,81	Height
22	69	TT	94	T	0,81	Height
23	69	TT	75	T	0,19	Low
24	50	TT	87	T	0,74	Height

Students-	Pretest		Post-Test		N-Gain	Criteria
	Value	Ket	Value	Ket		
25	56	TT	75	T	0,43	Medium
26	75	T	87	T	0,48	Medium
27	75	T	87	T	0,48	Medium
28	69	TT	75	T	0,19	Low
29	75	T	81	T	0,24	Low
30	50	TT	81	T	0,62	Medium
31	50	TT	81	T	0,62	Medium
32	69	TT	75	T	0,19	Low
33	44	TT	81	T	0,66	Medium
34	62	TT	81	T	0,50	Medium
35	75	T	87	T	0,48	Medium
36	69	TT	94	T	0,81	Height
Average	66,8%		84,4%			
Percentage	33,3%		97,2%			
Category	Not Good		Excellent			

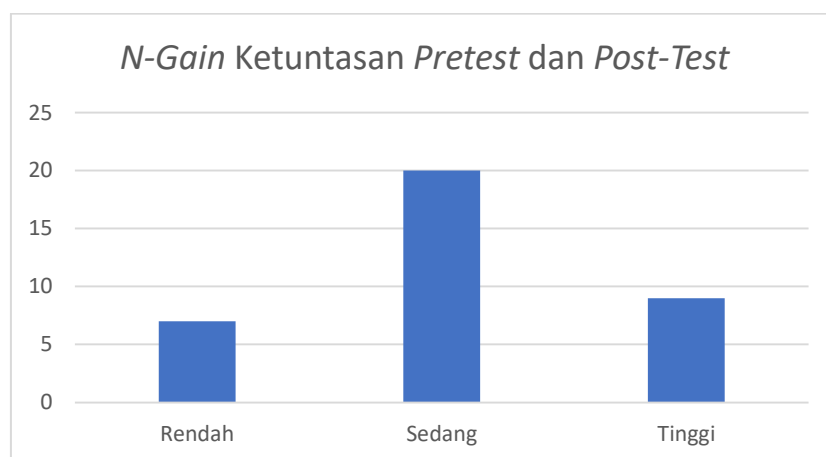


Figure 1. N-Gain *Pretest* and *Post-Test* Results for Each Category.

The effectiveness of PBL-based E-LKPD on respiratory system materials is assessed based on the improvement of students' critical thinking skills through pretest and post-test results prepared according to indicators of interpretation, analysis, evaluation, inference,

explanation, and self-regulation. The results showed that the average pretest score was 66.8% with 33.3% completeness, while the average post-test increased to 84.4% with 97.2% completeness. This increase shows that the implementation of PBL is able to encourage students to be more active in discussing, asking questions, and expressing opinions so as to support the development of higher-level thinking skills (Wardani & Fiorintina, 2023). The N-Gain results showed that there were 7 students in the low, 20 medium, and 9 high categories. The use of N-Gain in this study was chosen because it was able to show a proportional level of improvement in critical thinking skills through a comparison of pretest and post-test scores, so it is more appropriate to assess the effectiveness of learning compared to the T-test which only focuses on the significance of data differences (Abdul Wahab & Azhar, 2021). The achievement of each indicator of critical thinking skills is obtained through the results of working on *pretest* and *post-test* questions. The results of the achievement of these indicators are presented in table 7 and figure 2.

Tabel 7. Results of the Achievement of Each Critical Thinking Indicator

Indicator	Average (%)		N-Gain	Category
	Pretest	Post-test		
Interpretasi	62	85	0,61	Medium
Analysis	59	70	0,27	Low
Evaluation	45	88	0,78	Height
Inference	85	97	0,80	Height
Explanation	88	100	1,00	Height
Self-Regulation	92	100	1,00	Height
Overall average	71,8	90	0,74	Height

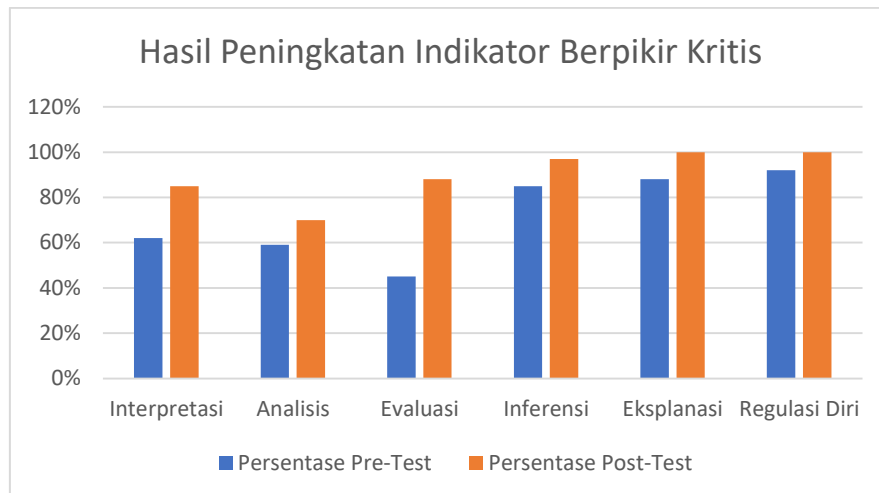


Figure 2. Percentage of Critical Thinking Indicator Skills

Based on the results of each critical thinking indicator, all indicators increased after the use of PBL-based E-LKPD. The interpretation indicator increased from 62% to 85% with an N-Gain of 0.61 through the *BioNews feature* which presents contextual problems related to air pollution and the dangers of cigarette smoke, thereby helping students understand and interpret scientific phenomena (Jannah, 2024). The analysis indicator increased from 59% to 70% with an N-Gain of 0.27 through activities on *the BioQuest* and *BioExplore* features that trained students to find and verify information independently (Putri et al., 2020). The evaluation indicator increased from 65% to 88% with an N-Gain of 0.78 because students were trained to compare and assess the accuracy of information before determining a solution (Sari et al., 2020). The inference indicator also increased from 68% to 97% with an N-Gain of 0.80 through the activity of drawing conclusions on *the BioPresent* feature that helps students connect information logically (Aliyah et al., 2024). In addition, the indicators of explanatory and self-regulation obtained the highest increase with an N-Gain of 1.00 through presentation and reflection learning activities that encouraged students to explain the results of thinking and evaluate the learning process independently (Fitriani et al., 2021). Overall, the results of the study show that the PBL-based E-LKPD developed has met the criteria of valid, practical, and effective so that it is feasible to be used to improve students' critical thinking skills in biology learning.

CONCLUSION

Based on the results of development and testing, Problem-Based Learning-based E-LKPD on respiratory system materials has been proven to play a role in improving students'

critical thinking skills. The validation results showed a very high level of validity (98.75%) so that it was suitable for use as a learning resource. From the practical aspect, E-LKPD is classified as very practical with 98.5% implementation and 97.8% student response. In addition, the results of the analysis showed an increase in critical thinking skills in all indicators, with an average N-Gain value of 0.74 which was in the medium category.

Referring to the research findings, several aspects can be the focus of further development. Research needs to be conducted on a broader scale by involving a more diverse group of students to test the effectiveness of E-LKPD in various contexts. In addition, development can be extended not only to critical thinking skills, but also to other abilities such as problem-solving, creativity, and science literacy. Furthermore, E-LKPD can be developed with more innovative features, such as interactive media integration, simulations, or learning videos to increase student engagement.

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