EFFECTIVENESS OF ELECTRONIC STUDENT WORKSHEET BASED ON THE CASE-BASED LEARNING MODEL TO TRAIN PROBLEM-SOLVING SKILLS ON RESPIRATORY SYSTEM MATERIAL

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ABSTRACT

Electronic Student Worksheets is an interactive digital learning resources integrating images and videos to facilitate independent, flexible, and contextual learning. This study aimed to determine the effectiveness of CBL-based Electronic Student Worksheet in training students' problem-solving skills on the respiratory system topic. The study employed the 4D development model, consisting of define, design, develop, and disseminate stages. A limited trial was conducted involving 20 eleventh grade students. The effectiveness of the Electronic Student Worksheet was evaluated using pre-test and post-test scores analyzed through the Shapiro–Wilk normality test, paired-samples t-test, and N-gain analysis. The paired-samples t-test results showed a significance value of < 0.001, indicating a significant difference between pre-test and post-test scores. The average student score increased from 61.4 to 90.5, with an N-gain score of 0.74, categorized as high. Improvements were also observed across all problem-solving skill indicators based on Polya (1973), namely understanding the problem (0.93), devising a solution strategy (0.86), Implementation (0.71), and looking back (0.49). Referring to the effectiveness results, the Case-Based Learning-based Electronic Student Worksheet was demonstrated to be effective in training students' problem-solving skills in the respiratory system topic.

Keywords: Case-Based Learning, E-LKPD, problem-solving skills, respiratory system

ABSTRAK

Lembar Kerja Peserta Didik Elektronik (E-LKPD) sebagai sumber belajar interaktif berbasis digital dengan integrasi gambar dan video, sehingga peserta didik dapat belajar mandiri, fleksibel, serta sesuai dengan konteks pembelajaran. Penelitian ini bertujuan untuk mengetahui efektivitas E-LKPD berbasis Case-Based Learning dalam melatihkan kemampuan pemecahan masalah peserta didik pada materi sistem pernapasan. Penelitian menggunakan model pengembangan 4D (define, design, develop, dan disseminate). Uji coba terbatas dilakukan pada 20 peserta didik kelas XI SMAN 1 Waru. Efektivitas E-LKPD dianalisis berdasarkan hasil pre-test dan post-test menggunakan uji normalitas Shapiro-Wilk, uji t berpasangan, dan uji N-gain. Hasil uji t berpasangan menunjukkan nilai signifikansi < 0,001 yang

menunjukkan nilai < 0,005 menunjukkan bahwa terdapat perbedaan signifikan antara skor pre-test dan post-test. Rata-rata nilai peserta didik meningkat dari 61,4 menjadi 90,5 dengan nilai N-gain sebesar 0,74 yang termasuk kategori tinggi. Peningkatan juga terjadi pada seluruh indikator kemampuan pemecahan masalah sesuai Polya (1973), yaitu memahami masalah (0,93), merancang strategi penyelesaian (0,86), pelaksanaan (0,71), dan melakukan pengecekan kembali (0,49). Mengacu pada hasil efektivitas E-LKPD, dinyatakan E-LKPD berbasis Case-Based Learning efektif untuk melatihkan kemampuan pemecahan masalah peserta didik pada materi sistem pernapasan.

Kata kunci: E-LKPD, Case-Based Learning, kemampuan pemecahan masalah, sistem pernapasan

A. Introduction

Advances in technology and globalization have required educational systems to become more adaptive to the demands of a rapidly changing world. Twenty-first-century education is no longer solely oriented toward the acquisition of knowledge but also emphasizes the development of critical thinking and problem-solving skills, creativity, collaboration, communication, and the effective use of technology in learning (Rismana & Hernawati, 2025). In line with these demands, twenty-first-century learning should be student-centered, collaborative, contextual, and closely connected to learners' social environments (Asri et al., 2023). The implementation of the Merdeka Curriculum further reinforces these expectations by promoting competency-based learning that prioritizes 21st-century skills, particularly the 4Cs: critical thinking and problem-solving, creativity and innovation, collaboration, and communication (Hasanuddin et al., 2022; Nurhayati et al., 2024).

One of the key competencies emphasized in twenty-first-century learning is problem-solving ability. Problem-solving ability refers to the process of identifying and implementing appropriate solutions to a given problem (Lede et al., 2025). Problem-solving ability plays a crucial role in biology education because it enables students to understand problems, analyze alternative solutions, and make informed decisions in daily life. As biology is closely related to real-life phenomena, students should be able to connect scientific concepts with environmental problems (Astuti & Izzah, 2022). Biology learning therefore requires students not only to understand

concepts but also to apply them in authentic contexts (Choerunnisa & Indri, 2024). Problem-solving also promotes analytical, logical, and systematic thinking (Marsel & Fadilah, 2025). According to Polya (1973), problem solving consists of understanding the problem, devising a solution strategy, implementation, and looking back. Therefore, learning should actively engage students in evidence-based problem-solving processes (Maulidya et al., 2021).

One learning model that is well suited to fostering problem-solving ability is the Case-Based Learning (CBL) model. CBL emphasizes the use of authentic and contextual cases as learning media through which students identify problems, analyze information, evaluate alternative solutions, and make evidence-based decisions (Fa'izah & Wulandari, 2023). According to Williams (2004), the Case-Based Learning model consists of seven stages: (1) identifying the case, (2) analyzing the case, (3) independently gathering information, data, and relevant literature, (4) determining appropriate solution strategies, (5) drawing conclusions, (6) presenting the findings, and (7) revising or improving the proposed solutions. Through its implementation, students are encouraged not only to understand concepts theoretically but also to apply their knowledge in solving authentic problems through discussion, investigation, and reflection (Khoiriyah & Wijaya, 2022).

Electronic Student Worksheet (E-Worksheet) provide flexible access to learning materials regardless of time and place, thereby enhancing learning effectiveness (Ayuni et al., 2025). However, their integration with digital platforms such as Liveworksheet has not yet been widely implemented in classroom instruction. Supported by interactive features, images, and videos, E-Worksheet can increase students' engagement and create more meaningful learning experiences (Amthari et al., 2021). Integrating E-Worksheet with the Case-Based Learning (CBL) model offers opportunities for students to actively analyze, investigate, and scientifically solve authentic problems (Sugiansyah et al., 2025). Previous studies have demonstrated the effectiveness of Problem-Based Learning (PBL)-based E-Worksheet in improving students' problem-solving ability in the respiratory system topic (Rizqiyah &

Hariani, 2025; Nurhalisa et al., 2024). However, the development of CBL-based E-Worksheets for this topic remains limited.

This gap highlights the need to develop and evaluate CBL-based E-Worksheets as innovative digital learning resources to support students' problem-solving ability in biology learning. Their effectiveness should be assessed based on students' achievement of the four problem-solving indicators: understanding the problem, devising a solution strategy, implementation, and looking back. Accordingly, students' performance across these indicators can be used to determine the effectiveness of the developed E-Worksheet in facilitating the problem-solving process within the respiratory system topic.

Based on the foregoing discussion, there is a need to develop effective digital learning resources that not only facilitate problem solving but also present authentic contexts closely related to students' everyday experiences. The Case-Based Learning (CBL) model is particularly relevant because it encourages students to analyze real-world cases, evaluate evidence, and formulate scientifically grounded solutions. Integrating this instructional model with electronic student worksheets has the potential to create a more interactive, flexible, and student-centered learning environment. Therefore, the development of CBL-based electronic student worksheets is well aligned with the demands of twenty-first-century education, particularly in promoting students' problem-solving ability. Accordingly, this study aims to evaluate the effectiveness of CBL-based electronic student worksheets in fostering students' problem-solving ability on the topic of the respiratory system.

B. Methodology

This study employed the 4D development model, consisting of the define, design, develop, and disseminate stages (Thiagarajan et al., 1974). The research was conducted at the Undergraduate Biology Education Study Program, Faculty of Mathematics and Natural Sciences, State University of Surabaya, from July 2025 to June 2026. A limited trial was conducted at SMAN 1 Waru, involving 20 eleventh-grade students. The obtained scores were calculated using the following formula:

$$\text{Score} = \frac{\sum Obtained\ score}{\sum Maximum\ score} \times 100$$

The resulting data were analyzed using a parametric statistical test, namely the paired-samples *t*-test, to determine whether there was a significant difference between students' pre-test and post-test scores before and after using the developed electronic student worksheet (E-Worksheet). All statistical analyses were performed using SPSS version 27.

Prior to hypothesis testing, the data were examined for normality using the Shapiro–Wilk test. This test was conducted to determine whether the data satisfied the assumptions required for parametric statistical analysis (Nurjihan & Bunawan, 2025). The Shapiro–Wilk test was selected because the sample size was relatively small (n < 50). The decision criterion was based on the significance level (α = 0.05), with data considered normally distributed when the significance value (Sig.) was greater than 0.05 (Azizah et al., 2026).

If the data were normally distributed, further analysis was conducted using the paired-samples *t*-test. This statistical test was considered appropriate because the study involved two related sets of observations, namely the pre-test and post-test scores obtained from the same group of students, indicating dependent (paired) data (Fitri et al., 2023). The research hypotheses were formulated as follows: H_0: There was no significant difference between students' pre-test and post-test scores after learning using the Case-Based Learning-based electronic student worksheet.; H_a: There was a significant difference between students' pre-test and post-test scores after learning using the Case-Based Learning-based electronic student worksheet. (Pratiwi & Setyaningtyas, 2020). The hypotheses were tested using a significance level of α = 0.05. H_0 was rejected when the two-tailed significance value ($p < 0.05$), whereas H_0 was accepted when the two-tailed significance value ($p \geq 0.05$).

After determining the significance of the difference between the pre-test and post-test scores, the normalized gain (N-Gain) test was performed to measure the improvement in students' scores. The N-Gain technique was used to evaluate the effectiveness of the developed electronic student worksheet in improving students' problem-solving skills. The N-Gain

score was calculated using the following formula:

$$N\text{-}gain\ (g) = \frac{Post - Pre}{Max - Pre}$$

Based on the N-Gain calculation, the developed electronic student worksheet was considered effective if it achieved an N-Gain score greater than 0.30, indicating a moderate to high level of effectiveness (Sari et al., 2022)

C.Result and Discussion

The effectiveness of the Case-Based Learning (CBL)-based electronic student worksheet was evaluated using students' pre-test and post-test scores, which reflected the problem-solving skills developed through the learning activities. These skills included understanding the problem, devision a solution strategy, implementation, and looking back. The minimum mastery criterion (MMC) at SMAN 1 Waru was 79. The pre-test and post-test data were analyzed using SPSS version 27. The significance of the differences before and after the implementation of the electronic student worksheet was determined through the Shapiro–Wilk normality test, the paired-samples *t*-test, and the *N*-Gain analysis.

The Shapiro–Wilk normality test was conducted before the paired-samples *t*-test to determine whether the data met the normality assumption. The results showed significance values of 0.152 for the pre-test and 0.090 for the post-test. Since both values exceeded 0.05, the pre-test and post-test scores were considered normally distributed. Data are regarded as normally distributed when the significance value is greater than 0.05, whereas values below 0.05 indicate a non-normal distribution. Because the normality assumption was satisfied, parametric statistical analysis using the paired-samples *t*-test was considered appropriate to obtain more accurate results (Sodikin et al., 2025).

The paired-samples *t*-test was conducted to determine whether a significant difference existed between students' scores before and after the intervention (Khasanah & Setiawan, 2022). The analysis yielded a significance value of $p < 0.001$, indicating that the probability value was below the significance level of 0.05. Therefore, the null hypothesis (H_0) was rejected, and the alternative hypothesis (H_a) was accepted. These findings demonstrate a statistically

significant difference between the pre-test and post-test scores, indicating an improvement in students' problem-solving skills following the implementation of the developed electronic student worksheet. According to Novianti et al. (2023), a two-tailed significance value below 0.05 indicates that the developed electronic student worksheet is effective for use in the learning process. Since a significant difference was identified, the effectiveness of the intervention was further evaluated using the *N*-Gain analysis. The *N*-Gain results are presented in **Table 1.**

Table 1. Summary of students' pre-test and post-test scores before and after learning using CBL-based E-LKPD

No.	Score		N-gain	Category
	Pre-test	Post-test		
1.	54 (NC)	94 (C)	0.87	High
2.	68 (NC)	100 (C)	1.00	High
3.	80 (C)	89 (C)	0.45	Moderate
4.	68 (NC)	92 (C)	0.75	High
5.	42 (NC)	86 (C)	0.76	High
6.	50 (NC)	100 (C)	1.00	High
7.	80 (C)	95 (C)	0.75	High
8.	70 (NC)	100 (C)	1.00	High
9.	60 (NC)	86 (C)	0.65	Moderate
10.	50 (NC)	89 (C)	0.78	High
11.	62 (NC)	100 (C)	1.00	High
12.	72 (NC)	88 (C)	0.57	Moderate
13.	60 (NC)	86 (C)	0.65	Moderate
14.	50 (NC)	80 (C)	0.60	Moderate
15.	68 (NC)	83 (C)	0.47	Moderate
16.	60 (NC)	86 (C)	0.65	Moderate
17.	54 (NC)	92 (C)	0.83	High
18.	70 (NC)	86 (C)	0.53	Moderate
19.	60 (NC)	95 (C)	0.88	High
20.	50 (NC)	84 (C)	0.68	Moderate
Mean	61,4	90,55	0,74	High
ΣTotal number of students achieving mastery	2	20		
Mastery (%)	10%		100%	

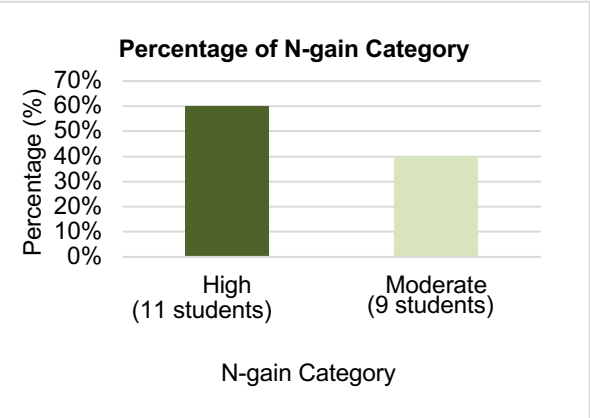
Notes:
Complete (C)
Not Complete (NC)

Category:
High: $g > 0.70$
Moderate: $0.30 < g \leq 0.70$
Low: $g \leq 0.30$

As presented in **Table 1**, the mean pre-test score was 61.4, while the mean post-test score increased to 90.5. This improvement resulted in an *N*-Gain score of 0.74, which falls within the high category. These findings are consistent with those of Lukman et al. (2025), who reported that the Case-Based Learning model effectively supports the development

of students' problem-solving skills. Through Case-Based Learning, students are encouraged to apply relevant theoretical knowledge to solve authentic problems while actively participating in identifying appropriate solutions (Saragih et al., 2025).

Furthermore, 55% of the students achieved a high *N*-Gain category, whereas the remaining 45% attained a moderate category. These results indicate that the Case-Based Learning-based electronic student worksheet effectively enhanced students' problem-solving skills, as evidenced by the predominance of students in the high *N*-Gain category. The distribution of students across the *N*-Gain categories is illustrated in **Graph 1**.



Graph 1 Distribution of Students Across *N*-Gain Categories

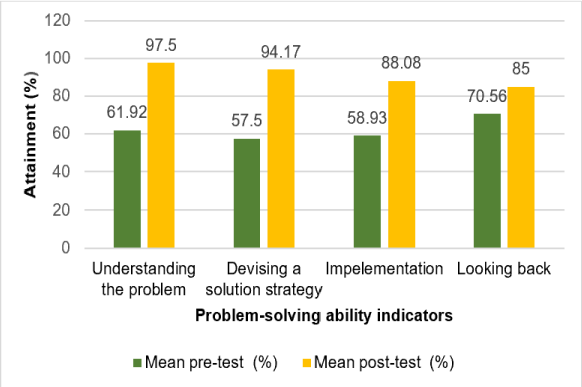
The implementation of the Case-Based Learning (CBL)-based electronic student worksheet facilitated the development of students' problem-solving skills. The mean scores for each problem-solving skill indicator are presented in **Table 2**.

Table 2. Results of Students' Problem-Solving Ability

Problem-Solving Ability Indicators	Mean		*N-gain*	Category
	Pre-test (%)	Post-test (%)		
Understanding the problem	56,15	97,5	0,94	High
Devising a solution strategy	52,14	94,17	0,88	High
Implementation	57,50	88,08	0,72	High
Looking back	75,56	85,00	0,39	Moderate
Overall Mean	**60,34**	**91,19**	**0,73**	**High**

As presented in **Table 2**, students' problem-solving skills improved overall by 29.15%, with an N-Gain score of 0.74 (high). The greatest improvement occurred in understanding the problem (35.58%; N-Gain = 0.93, high), followed by devising a solution strategy (36.67%; 0.86, high), implementation (29.15%; 0.71, high), and looking back (14.44%; 0.49, moderate). These findings indicate that the CBL-based electronic student worksheet effectively developed students' problem-solving skills on the respiratory system topic. This result aligns with Purnamayanti et al. (2023), who reported that prior learning experiences enhanced students' problem analysis and solution identification. The improvement across the problem-

solving skill indicators is illustrated in **Graph 2.**



Graph 2 Attainment of Students' Problem-Solving Ability

Based on **Graph 2,** students' problem-solving skills improved, with the overall mean score increasing from 61.40% on the pre-test to 90.55% on the post-test, representing a 29.15% improvement. The greatest improvement occurred in understanding the problem, with scores increasing from 61.92% to 97.50%, resulting in a high N-Gain category. Students adapted quickly to the initial stages of the electronic student worksheet and effectively identified problems through authentic cases on sleep apnea and respiratory responses during aerobic exercise. These contextual cases facilitated problem identification and understanding (Aliza & Roshayanti, 2025).

For the devising a solution strategy indicator, the mean score increased from 57.50% on the pre-test to 94.17% on the post-test, yielding a high N-Gain category. Initially, many students struggled to formulate solution strategies independently because they were accustomed to teacher-directed laboratory activities. They experienced difficulties in determining data collection methods, formulating hypotheses, identifying variables, and designing experimental procedures. However, the electronic student worksheet gradually encouraged students to plan investigations before conducting experiments, enabling them to organize procedures, select appropriate strategies, and justify their decisions logically. These findings support Maulidah et al. (2024), who reported that authentic learning experiences enhance students' strategic planning skills and their ability to apply scientific knowledge to real-life situations.

For the implementation indicator, the mean score improved from 58.93% to 88.08%, corresponding to a high N-Gain category. Although some students initially required additional time to understand procedures, apply demonstration videos, and record

observations accurately, they gradually became more proficient in implementing experimental procedures systematically. The implementation activities, including respiratory air composition and respiratory rate experiments, strengthened students' ability to connect scientific investigations with real-world contexts and generate appropriate solutions. This finding is consistent with Marsel & Fadilah (2025) and Maspupah et al. (2020), who emphasized that implementation skills develop through systematic and sequential problem-solving procedures.

For the looking back indicator, the mean score increased from 70.56% on the pre-test to 85.00% on the post-test, resulting in a moderate N-Gain category and representing the smallest improvement among the four indicators. Many students tended to overlook the reviewing process because they assumed their initial answers were correct. In addition, the reflection activities were conducted at the end of the lesson, when students' attention had begun to decline. Similar findings were reported by Maulidah et al. (2024), who found that the looking back indicator often shows lower achievement because students rarely evaluate their responses carefully. In the electronic student worksheet, this stage required students to re-examine information, verify answer accuracy, and ensure consistency with biological concepts after completing conclusions and revising discussion results (Meidina & Dewi, 2026). Through this process, students became more accustomed to reviewing their understanding, planning, and implementation before drawing final conclusions (Sapitri et al., 2024). However, compared with the other stages, the looking back activities consisted of relatively brief reflection tasks, providing limited opportunities for thorough evaluation. This finding is consistent with Sholeh et al. (2024), who reported that the use of self-assessment checklists helps students recognize and monitor weaknesses in their own work, thereby promoting greater independence in evaluating the accuracy of their solutions without relying solely on external feedback. Therefore, incorporating reflective questions or a self-assessment checklist at the final stage may further optimize students' ability to evaluate the accuracy of the solutions they have developed.

The Case-Based Learning (CBL) model was implemented through seven instructional phases. Phases 1 and 2, namely identifying and analyzing the case, developed students' understanding of the problem through contextual cases and supporting information in the electronic student worksheet. Consequently, the understanding of the problem indicator improved from 61.92% on the pre-test to 97.50% on the post-test (high N-Gain). Students also demonstrated better performance in solving problems related to gas exchange, respiration, environmental adaptations, and respiratory disorders. These findings are consistent with Kurino et al. (2023), who reported that authentic real-life problems facilitate meaningful understanding of biological concepts.

Phases 3 and 4, involving identifying relevant information and determining case solutions, were designed to develop the devising a solution strategy and implementation indicators. The devising a solution strategy score increased from 57.50% to 94.17%, while the implementation score improved from 58.93% to 88.08%, both within the high N-Gain category. Through designing experiments, collecting and analyzing data, and applying evidence to solve respiratory system problems, students strengthened both strategic planning and implementation skills, consistent with Isnaini et al. (2021).

Phases 5, 6, and 7, namely drawing conclusions, presenting findings, and revising solutions, were intended to develop the looking back indicator. Students' looking back ability increased from 70.56% on the pre-test to 85.00% on the post-test, corresponding to a moderate N-Gain category. Students formulated conclusions, presented findings, and revised their work based on peer and teacher feedback, enabling them to evaluate the accuracy of their discussion results and ensure consistency with scientific concepts.

Overall, the CBL phases effectively facilitated students' problem-solving skills through authentic cases, scientific investigations, and evidence-based reasoning. Although the looking back indicator improved, its gain remained moderate because some students were still not accustomed to reviewing their work and tended to assume that their initial answers were correct. Nevertheless, this stage is essential for verifying the accuracy

and validity of problem-solving outcomes (Berutu & Juliani, 2024).

Overall, these findings indicate that the developed electronic student worksheet was effective in developing students' problem-solving skills. This result is consistent with constructivist learning theory, in which students actively analyzed authentic cases, developed arguments, and generated solutions to real-world problems (Romdhon et al., 2024). According to Piaget, knowledge is actively constructed through learners' own experiences rather than transmitted directly from the social environment (Nurjamilah et al., 2025). Similarly, John Dewey emphasized learning by doing through meaningful learning experiences (Kartika et al., 2023). Consistent with these perspectives, the Case-Based Learning-based electronic student worksheet encouraged students to independently design experiments, analyze data, and determine appropriate solutions to authentic cases (Sistermans, 2020).

The learning process also aligns with Atkinson and Shiffrin's Information Processing Theory, which explains learning as the process of receiving, processing, storing, and retrieving information. These cognitive processes were facilitated through case analysis and collaborative discussions in the electronic student worksheet (Nugroho, 2024). Furthermore, the findings support Ausubel's Meaningful Learning Theory, which emphasizes integrating new knowledge with prior knowledge. By presenting contextual cases, the electronic student worksheet enabled students to connect newly acquired concepts with their existing understanding, thereby promoting a more meaningful and comprehensive understanding of the respiratory system (Schunk, 2012).

D. Conclusion

The development of an Electronic Student Worksheet (E-Worksheet) based on the Case-Based Learning model for respiratory system material was found to be effective in training students' problem-solving abilities. The effectiveness was determined based on the achievement of problem-solving ability indicators, which increased by 30.85%, with an N-gain score of 0.74 in the high category.

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