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DEVELOPMENT OF DISCOVERY LEARNING-BASED E-LKPD FOR GRADE XI NERVOUS SYSTEM TO TRAIN CRITICAL THINKING, COMMUNICATION, AND COLLABORATION

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ABSTRACT

In the 21st century, 4C skills (creativity, communication, collaboration, and critical thinking) are essential for students to address various challenges through education. These skills can be developed through the use of electronic student worksheets (E-LKPD). This study aimed to develop a Discovery Learning-based E-LKPD on the Nervous System topic that is suitable for training critical reasoning, communication, and collaboration among Grade XI high school students. The E-LKPD was developed using the 4D development model and was tested in a limited trial involving 15 Grade XI students at SMA Islam Shafta Surabaya. The results showed that the E-LKPD was highly valid (96%), highly practical based on the learning implementation score (98%) and positive student responses (92%), and effective in improving critical reasoning with an average N-Gain score of 0.81. In addition, communication and collaboration skills achieved percentages of 95% and 97%, respectively. Based on these findings, the Discovery Learning-based E-LKPD on the Nervous System topic for Grade XI students was considered suitable for training critical reasoning, communication, and collaboration in terms of validity, practicality, and effectiveness.

Keywords: collaboration; communication; critical reasoning; discovery learning; E-LKPD

INTRODUCTION

In the 21st century, there are several essential skills that every individual should possess. These skills include Critical Thinking, Creativity, Communication, and Collaboration, commonly referred to as the 4C skills. The 4C skills are necessary for addressing challenges, solving problems, and adapting to the demands of life in the 21st century (Sugiharti & Gayatri, 2021). The Ministry of Primary and Secondary Education has developed a draft of a new approach, namely a curriculum based on a deep learning approach, as an effort to address the challenges of 21st-century learning (Kemendikdasmen, 2025). Through education, it is expected that competent human resources will be developed in accordance with the Graduate Competency Standards that have been established (Wijaya, 2023). The Graduate Competency Standards in the Regulation of the Minister of Primary and Secondary Education of the Republic of Indonesia No. 10 of 2025 require students to achieve graduate profile dimensions at the end of each educational level, including eight dimensions such as critical reasoning, communication, and collaboration (Permendikdasmen, 2025).

The graduate profile dimensions encompass competencies that emphasize cognitive development, character formation, and practical life skills, all of which are acquired by students upon the completion of their learning process

(Kemdikdasmen, 2025). Critical thinking is the ability to evaluate evidence and make informed judgments. Its indicators include interpretation, analysis, evaluation, inference, explanation, and self-regulation. Limited opportunities to develop these skills may lead to poor decision-making, lower academic performance, and increased vulnerability to misinformation (Facione, 2015). Critical thinking skills are closely aligned with the critical reasoning profile, as critical thinking involves reasoning processes, particularly when determining what actions should be taken (Syafitri *et al*., 2021). The critical reasoning profile refers to an individual's ability to think both logically and analytically, as well as to understand, evaluate, and process information through deep thinking (Kemdikdasmen, 2025).

The communication profile is a competency in which an individual is able to express ideas, thoughts, and information clearly and interact effectively in various situations (Kemdikdasmen, 2025). The communication profile includes several aspects, namely listening, reading, speaking, and writing (Permendikdasmen, 2025). Ineffective communication in learning can lead to misunderstandings and conflicts, as well as a decline in academic performance (Hidayat & Eliasa, 2024). The collaboration profile is a competency in which an individual is able to work effectively with others and cooperate through fair task distribution to achieve common goals (Kemdikdasmen, 2025). Collaboration is very important in biology learning, as students can work together to understand complex concepts through experiments, provide feedback to one another, and discuss the results (Yulinda *et al*., 2024). The aspects of the collaboration profile include the habit of caring and sharing, as well as building good cooperation with various groups in society (Permendikdasmen, 2025).

According to the 2022 PISA results, Indonesia ranked 69th with a score of 369, placing students at proficiency Level 1a, below the expected baseline Level 2. This indicates that many students have not yet achieved fundamental competencies in interpreting data, identifying scientific questions, conducting scientific inquiry, making inferences, and connecting textual information with prior knowledge (OECD, 2023). Although the PISA data target 15-year-old or junior high school students, it can still serve as a reference for senior high school education, as underdeveloped critical thinking skills at the junior high school level may affect students' learning outcomes at higher educational levels. Solikah & Susantini (2022) stated that senior high school students may be influenced by habits developed at previous educational levels, particularly reliance on memorization and limited application of knowledge in problem-solving. Therefore, these data remain relevant because their impacts can be observed at higher educational levels.

Critical thinking skills in several schools in Surabaya are still relatively low, as evidenced by Sugiharti & Gayatri (2021) with research findings showing that students' critical thinking skills at SMA Muhammadiyah 1, SMA Muhammadiyah 2, and SMA Muhammadiyah 9 are in the low category. In addition, observations at SMA Islam Shafta Surabaya in January 2026 showed that students had difficulty analyzing problems and tended to respond spontaneously without deep thinking. Moreover, lecture-based and predominantly individual learning limited opportunities for interactive communication and

collaboration. Therefore, efforts are needed to develop critical reasoning, communication, and collaboration as essential competencies to be achieved by the end of learning.

Critical reasoning, communication, and collaboration need to be trained during the learning process through the selection of appropriate learning materials. In this study, the topic of the Nervous System in biology was chosen because interviews with a biology teacher at SMA Islam Shafta Surabaya on 23 January 2026 indicated that one of the most difficult biology topics to teach is the Nervous System. In addition, the Nervous System is considered a complex topic, in line with Zendrato *et al*. (2024), who state that it is difficult because the material is abstract and cannot be sufficiently understood through visualization alone. The Nervous System topic is also included in the deep learning-based curriculum, particularly in the Phase F biology learning outcomes, where students are required to study organ systems, including the Nervous System (BSKAP, 2025). In teaching the Nervous System topic, an appropriate learning model is required, namely one that is interactive, student-centered, and supported by relevant learning tools (Raharjo *et al*., 2022). There are several learning models that can develop critical reasoning, communication, and collaboration skills, such as Problem-Based Learning, Project-Based Learning, Discovery Learning, and others. However, the learning model chosen in this study is Discovery Learning.

Discovery Learning is a student-centered approach in which students discover new knowledge by using their prior experience and knowledge. This process refers to acquiring knowledge independently rather than finding something previously unknown to humankind (Kennedy & Akpan, 2025). The stages (syntax) of Discovery Learning include stimulus presentation, problem statement, data collection, data analysis, data verification, and drawing conclusions (Kharismawati *et al*., 2020). These stages are closely related to the scientific approach, which aligns with the process skills component in teaching biology. These skills include observing, formulating questions and making predictions, planning and conducting investigations, processing and analyzing data/information, evaluating and reflecting, and communicating results (BSKAP, 2025). Therefore, the Discovery Learning model can be used in teaching the Nervous System topic.

Through the Discovery Learning model, the learning process still requires supporting teaching materials in the form of electronic student worksheets (E-LKPD). E-LKPD was selected because it can enhance student engagement in the learning process (Kemdikdasmen, 2025). One of the advantages of E-LKPD is that teachers can add learning materials by including relevant images and videos (Amthari *et al*., 2021). E-LKPD can also contain activity guidelines or procedural steps (Istiqomah, 2021). In addition, E-LKPD is easily accessible anytime and anywhere and can create a more interactive learning environment (Masruroh & Raharjo, 2024). The E-LKPD developed in this study is designed using Canva and accessed through the Liveworksheet platform, integrated with the Discovery Learning model, and includes features that support the development of critical reasoning, communication, and collaboration skills.

A previous relevant study was conducted at SMAN 15 Surabaya, which implemented Discovery Learning-based

LKPD on the Nervous System topic. However, the study only focused on training the indicators of interpretation, analysis, and inference (Rahmadhia & Qomariyah, 2024). Therefore, the findings of the present study may support and extend the previous findings by incorporating additional graduate profile competencies, namely critical reasoning, communication, and collaboration. Another study conducted by Utari *et al.* (2025) developed an E-LKPD based on Discovery Learning to train science communication skills on the Biotic and Abiotic materials. The results showed that the Discovery Learning-based E-LKPD teaching material was highly valid in training students' science communication skills. In addition, the study by Lutfiadi & Zawawi (2021) also used LKPD with the Discovery Learning model, which successfully improved 21st-century skills, including critical thinking, communication, and collaboration skills. Although E-LKPD based on Discovery Learning in biology has been previously studied, research on Discovery Learning-based E-LKPD for the Nervous System topic to train critical reasoning, communication, and collaboration skills is still very limited.

Based on the description above, the objective of this development research is to produce a Discovery Learning-based E-LKPD with the expectation that it can train students' graduate profiles in critical reasoning, communication, and collaboration on the Nervous System topic. The product is considered feasible when viewed from three aspects, namely validity, practicality, and effectiveness (Nieveen *et al*., 1999). These three aspects remain relevant for use in this study because, according to recent research conducted by Masruroh & Raharjo (2024), validity, practicality, and effectiveness can determine the feasibility of an E-LKPD.

METHOD

This study is a development research using the 4D model, which consists of the Define, Design, Develop, and Disseminate stages (Thiagarajan & Semmel, 1976). In the Define stage, a front-end analysis is conducted to identify initial problems and possible alternative solutions, followed by learner analysis, which involves documenting students' initial conditions, including their academic abilities, learning experiences, and learning motivation. The next step is task analysis combined with curriculum analysis to formulate appropriate learning objectives and tasks. This is followed by concept analysis, which involves identifying the subject matter and organizing it into a structured hierarchy, and finally, specifying learning objectives. In the Design stage, criterion-referenced tests (pre-test and post-test) are developed, learning media in the form of E-LKPD designed using Canva is selected, appropriate formats such as titles and features within the E-LKPD are determined, and an initial design is produced.

During the develop stage, the E-LKPD was comprehensively developed based on the initial design. The E-LKPD draft was validated by expert lecturers using a validation sheet. In addition, the pre-test and post-test items, as well as the observation instruments for communication and collaboration skills, were also validated. If the instruments met the validity criteria (score > 70%), the limited trial stage was conducted.

The limited trial involved 15 Grade XI students from SMA Islam Shafta Surabaya. This sample size was considered

adequate because the study employed a limited trial in a development research design aimed at evaluating the validity, practicality, and effectiveness of the E-LKPD rather than generalizing the findings. The participants were selected because they represented the target users, namely Grade XI students studying the Nervous System topic. The inclusion criteria were Grade XI students who participated in all learning activities and completed the pre-test and post-test, while students who did not complete all activities or research instruments were excluded from the study.

During the disseminate stage, the E-LKPD was disseminated through the publication of the research findings in a journal article and by providing access links to E-LKPD I and E-LKPD II to SMA Islam Shafta Surabaya for use in subsequent Nervous System learning activities. The study was conducted over a period of ten months, from July 2025 to April 2026.

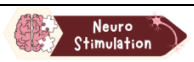
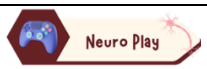
The feasibility of the E-LKPD was determined through validity, practicality, and effectiveness tests. The validity test was conducted by two expert lecturers using a validation sheet with a 4-point Likert scale. The practicality test consisted of observations of the implementation of learning activities by observers using an observation sheet, as well as student responses collected through a questionnaire employing a Guttman Yes/No scale. The effectiveness test included observations of students' communication and collaboration profiles using an observation sheet with a Guttman Yes/No scale, while students' critical reasoning skills were assessed based on the average N-Gain score obtained from pre-test and post-test instruments.

The data obtained from the validity test were analyzed by calculating the average percentage score of the E-LKPD validity. The E-LKPD was considered valid if it achieved a score of ≥71% (adapted from Riduwan, 2016). The practicality test data, including both the implementation of learning activities and students' responses, were analyzed by calculating the average percentage scores of implementation and positive student responses. The E-LKPD was considered practical if the obtained score was ≥71% (adapted from Riduwan, 2016). The effectiveness test data related to the development of communication and collaboration profiles were analyzed by calculating the average percentage effectiveness score. The E-LKPD was considered effective if it achieved a score of ≥71% (adapted from Riduwan, 2016). In addition, the pre-test and post-test results were analyzed by calculating the average N-Gain score. The N-Gain scores were categorized as follows: $g \leq 0.3$ (low), $0.3 < g \leq 0.7$ (moderate), and $g > 0.7$ (high) (Hake, 1998). The E-LKPD was considered effective in fostering students' critical reasoning skills if the obtained N-Gain score fell within the moderate to high category.

RESULTS AND DISCUSSION

This study produced an E-LKPD based on the Discovery Learning model, designed to foster the graduate profile competencies of critical reasoning, communication, and collaboration in the Nervous System topic for eleventh-grade students. The E-LKPD was designed using Canva and accessed through the Liveworksheets. The developed E-LKPD consists of several features. The description of each feature are presented in Table 1.

Table 1. Features of the E-LKPD

Appearance and Features	Description
	*Neuro Stimulation* This feature contains activities aligned with the Stimulation phase and is designed to foster students' interpretation skills and communication profile.
	*Neuro Problem* Contains activities aligned with the Problem Statement phase and is designed to foster students' analysis skills, communication and collaboration competencies.
	*Neuro Collection* Contains activities aligned with the Data Collection phase and is designed to foster students' self-regulation skills and collaboration competencies.
	*Neuro Analyze* Contains activities aligned with the Data Processing phase and is designed to foster students' analysis and explanation skills, as well as their communication and collaboration competencies.
	*Neuro Verification* Contains activities aligned with the Verification phase and is designed to foster students' evaluation skills, communication and collaboration competencies.
	*Neuro Generalization* Contains activities aligned with the Generalization phase and is designed to foster students' inference skills, communication and collaboration competencies
	*Neuro Talk* Provides open discussion activities through the Padlet platform and is designed to foster the written communication dimension.
	*Neuro Play* Contains mini-games related to the Nervous System topic.

The strength of the developed E-LKPD lies in the Neuro Problem feature, which guides students in formulating problems and hypotheses through a brief Nervous System case. This feature trains students to develop problems and hypotheses based on the provided stimulus. This is in line with the view of *(Amalia et al.* (2022), who state that instructions in E-LKPD should be designed in a detailed and clear manner to facilitate students in achieving specific skills. In addition, another advantage of the E-LKPD is its focus on three graduate profile competencies: critical reasoning, communication, and collaboration. Through this E-LKPD, students are expected to develop these essential skills to face 21st-century challenges (Sugiharti & Gayatri, 2021).

The validation of the E-LKPD was conducted by assessing several aspects. A summary of the validation results is presented in Table 2..

Table 2. Summary of E-LKPD Validation Result

No	Validated Criteria	Mean
1.	Presentation Component	3,8
2.	Content Component	3,9
3.	Language Component	3,8
Overall mean score		3,8
Overall score percentage		96%
Criteria		**Very Valid**

Description: 25%–47% (Not valid); 48%–70% (Less valid); 71%–85% (Valid); 86%–100% (Highly valid)

Overall, the validation results indicate that the E-LKPD is highly valid for training students' critical reasoning,

communication, and collaboration skills. However, the validators still provided suggestions and feedback during the validation process. In addition, an illustration of the patellar ligament location needs to be added in the E-LKPD I experimental procedure to help students more easily identify the reflex hammer tapping point. In the presentation component, the average validity score obtained was 3.75. This is because the E-LKPD was designed in accordance with the material, with readable font type and size and appropriate color composition. Each design feature includes activities that support the development of critical reasoning, communication, and collaboration skills. This is in line with the opinion of Kurniawati *et al*. (2024), who stated that teaching materials presented in an attractive, innovative, and detailed format can make the learning process easier and more engaging for students

In the content component, the average validity score was 3.9 with a percentage of 97%. This is because the material selected in the E-LKPD is in accordance with the scope of the Nervous System topic being taught. In addition, the selected simple experiment is considered to support the achievement of learning objectives. Furthermore, the developed E-LKPD is aligned with the discovery learning syntax and contains activities that train critical reasoning, communication, and collaboration skills.

In the language component, the average score was 3.8. This indicates that the Indonesian language used is good and correct, communicative, and informative. However, there are still several words that need to be revised by the researcher so that the E-LKPD becomes more suitable for use in learning, as the use of appropriate language aims to avoid misinterpretation by students (Masruroh & Raharjo, 2024).

The practicality of the discovery learning-based E-LKPD in training students' critical reasoning, communication, and collaboration profiles was assessed based on the results of the observation of E-LKPD implementation during the learning process, as well as the results of the student response questionnaire. The results of the observation of the learning implementation using the E-LKPD are presented in Table 3 below.

Table 3. Recapitulation of E-LKPD Implementation Observation Results

Observed aspects	Implementation (%)		Mean (%)
	P1	P2	
Opening	100	92,5	96,25
Main	100	95.3	97,7
Closing	100	100	100
Overall implementation	**100**	**95,5**	**98**
Criteria	**Very practical**		

Description: 0%–35% (Not practical); 36%–70% (Less practical); 71%–85% (Practical); 86%–100% (Highly practical) P1: Meeting 1, P2: Meeting 2

The average implementation percentage was 98%, indicating that nearly all aspects were carried out in accordance with the Discovery Learning syntax. However, in the data collection and verification stages, some activities were not fully optimal, such as several students not reading the experimental instructions and limited participation in hypothesis discussions in Group 2. During the limited trial, each learning stage was generally implemented well. This high level of implementation also contributed to the improvement of several skill indicators, as each activity in the Discovery Learning-

based E-LKPD facilitated different learning processes. In particular, data collection and analysis activities helped students develop their analysis and inference skills through the Neuro Collection and Neuro Analyze features. A detailed distribution of the improvement in each indicator is presented in Figure 1. These findings indicate that the proper implementation of the Discovery Learning syntax supports the achievement of the targeted competencies. This finding is consistent with Rahmadhia & Qomariyah (2024), who reported that Discovery Learning-based biology instruction on the nervous system is highly practical. The practicality of the E-LKPD was also supported by the student response questionnaire results, as presented in Table 4.

Table 4. Recapitulation of Students' Responses to the Discovery Learning-Based E-LKPD

No	Assessed aspects	Positive responses (%)
1.	Presentation	95
2.	Language	64
3.	Suitability of the E-LKPD with the Discovery Learning model	99
4.	Suitability with critical thinking skills	98
5.	Suitability with the graduate profile of communication and collaboration	100
Average percentage of all aspects		**92**
Criteria		**Very Practical**

Description: 0%–35% (Not practical); 36%–70% (Less practical); 71%–85% (Practical); 86%–100% (Very practical)

Based on the recapitulation of student response results, a positive student response percentage of 92% was obtained. This indicates that the E-LKPD is practical and easy to use by students during learning. A relevant study was also conducted by Rahmadhia & Qomariyah (2024), where learning using Discovery Learning-based worksheets obtained a positive response of 97%. In addition to being identified from the students' checkmarks in the agreed column, positive responses were also seen from the reasons written by students in the explanation column. One of the reasons was that students felt the E-LKPD had clear instructions, both in the usage guidelines and the experimental procedures.

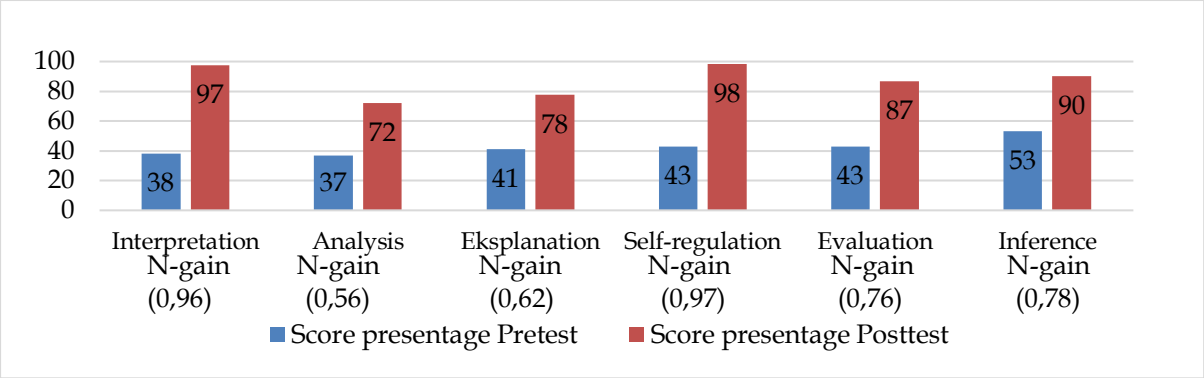
The E-LKPD did not only receive positive responses; some students disagreed with several statements, particularly in the language aspect, which obtained the lowest positive response (64%). A total of 12 students reported difficulty understanding foreign or scientific terms used in the E-LKPD, such as ligamen patella, interneuron, and neuron. Limited understanding of biological terminology can affect the learning process (Dachi *et al.*, 2025). Therefore, teachers should introduce scientific terms gradually during learning (Aprillia *et al.*, 2023).

The effectiveness of the Discovery Learning-based E-LKPD in training critical reasoning skills was measured using N-Gain from pre-test and post-test scores. Overall results are presented in Table 5, while N-Gain for each critical thinking indicator is shown in Figure 1.

Table 5. Recapitulation of Pre-test and Post-test Results and N-Gain Scores

Student	*Pre-Test*		*Post-Test*		N-Gain (g)	Criteria
	Score	KKTP	Score	KKTP		
1	34	NA	82	A	0,73	High

Student	*Pre-Test*		*Post-Test*		N-Gain (g)	Criteria
	Score	KKTP	Score	KKTP		
2	40	NA	78	A	0,63	Medium
3	58	NA	94	A	0,86	High
4	49	NA	95	A	0,90	High
5	46	NA	77	A	0,57	Medium
6	23	NA	85	A	0,81	High
7	28	NA	92	A	0,89	High
8	27	NA	95	A	0,93	High
9	51	NA	97	A	0,94	High
10	36	NA	76	A	0,63	Medium
11	41	NA	97	A	0,95	High
12	33	NA	87	A	0,81	High
13	37	NA	92	A	0,87	High
14	52	NA	95	A	0,90	High
15	34	NA	80	A	0,70	Medium
Mean	**39**	**NA**	**88**	**A**	**0,81**	**High**



Description: g ≤ 0,3 : Low, 0,3 < g ≤ 0,7: Medium, g > 0,7: High

Figure 1. *N-Gain for Each Critical Thinking Indicator*

Based on the recapitulation above, all 15 students did not meet the Learning Objective Achievement Criteria (KKTP). This indicates that the Nervous System material previously taught using the lecture method was not optimal in training students' critical thinking skills. This finding is in line with Siregar & Adlini (2022), who stated that the lecture method in biology learning can cause student boredom. In addition to external factors, low pre-test scores were also influenced by internal factors such as students' motivation and engagement. Since the pre-test was conducted in the first lesson period, several students appeared less motivated and had difficulty maintaining focus. Observer notes indicated that 3 out of 15 students arrived late, while others showed signs of sleepiness, such as reduced responsiveness to initial instructions and delayed engagement in the pre-test. These observations help explain the low initial performance before the implementation of the E-LKPD. This is consistent with Faiq & Indana (2025), who found that learning styles, psychological conditions, and

student motivation significantly affect learning outcomes.

Based on the overall post-test results in Table 5, all 15 students met the Learning Objective Achievement Criteria (KKTP). The N-Gain scores ranged from moderate to high, with an average of 0.81, which is categorized as high. This indicates that the developed E-LKPD is effective in training students' critical reasoning skills on the Nervous System topic. In addition to the E-LKPD as learning material, the choice of learning model also influences the success of developing critical thinking skills. The Discovery Learning model is considered effective because it encourages students to be more active, engage in inquiry, and gather information to solve problems (Siregar & Adlini, 2022).

Based on Figure 1, the interpretation indicator in item number 1 obtained an N-Gain score of 0.96, indicating a high improvement. Facione (2015) states that interpretation is the ability to understand or express the meaning of something. In line with the learning objectives, students were able to interpret information or stimuli to identify relevant problems, as this skill was trained during the E-LKPD activities in the stimulation stage through reflex and body balance videos. Therefore, the E-LKPD contributed positively to improving students' interpretation skills.

The analysis indicator in question number 2 obtained an N-Gain score of 0.56, indicating a moderate improvement. This item assessed students' analytical skills in identifying problems to formulate research questions and hypotheses. The Neuro Problem and Neuro Analyze features were used to train students in analyzing problems and experimental data. Although the improvement in analytical skills is categorized as moderate, the E-LKPD still contributed positively to its development. This is in line with Masruroh & Raharjo (2024), who stated that moderate improvement in students' critical thinking skills is a positive progress, although additional practice is needed to achieve higher improvement.

The explanation indicator in question number 3 obtained an N-Gain score of 0.62, which is categorized as a moderate improvement. Although the improvement is moderate, the developed E-LKPD facilitated activities that train explanation skills through the Neuro Analyze feature, where students practice answering questions by providing explanations based on experimental data and learned concepts. This is in line with Santoso & Susantini (2026), who found that moderate improvement in the explanation indicator is influenced by the use of E-LKPD as teaching material equipped with features that train such skills.

The self-regulation indicator in question number 4 obtained an N-Gain score of 0.97, which is categorized as high improvement. In the developed E-LKPD, self-regulation skills are trained through the Neuro Collection feature, which contains simple experimental activities related to reflex movements and the role of the nervous system in maintaining body balance. According to Facione (2015), self-regulation is the conscious ability to monitor and correct one's own thinking process, including self-checking and self-correction. During the experiments, students were trained to regulate their thinking based on the results of their observations and experiments. Santoso & Susantini (2026) stated that self-regulation plays an important role in students' critical thinking skills, as it enables students to

review both their own work and their peers' work during learning.

The evaluation indicator in question number 5 obtained an N-Gain score of 0.72, which is categorized as high improvement. According to Facione (2015), evaluation is the ability to judge the credibility of statements and assess the strength of arguments. The high improvement is attributed to the E-LKPD, which facilitates activities that train evaluation skills through the Neuro Verification feature, where students are asked to evaluate previously formulated hypotheses along with logical reasoning. This enables students to perform well on items requiring evaluative thinking. This finding is supported by Ramadhani & Rahayu (2024), who stated that high improvement in evaluation skills occurs because students are accustomed to practicing tasks that require evaluating both prior and new knowledge.

The inference indicator in question number 6 obtained an N-Gain score of 0.78, which is categorized as high improvement. According to Facione (2015), inference is the ability to draw reasonable conclusions by considering relevant information. This skill was trained through questions that required students to formulate conclusions based on learning activities. The high improvement indicates that students were able to draw conclusions based on the provided information. In addition, students' initial ability in the inference indicator was already relatively high, indicating that they possessed good initial skills in drawing conclusions. This is in line with Masruroh & Raharjo (2024), who stated that high improvement in inference indicates that students are able to construct conclusions based on information rather than personal opinion alone.

The level of N-Gain is not only determined by the difference between pre-test and post-test scores, but also by the effectiveness of the improvement. In the interpretation indicator, the N-Gain score is higher than that of the analysis indicator. This is because the interpretation indicator achieved a higher percentage score, close to the maximum possible score. In addition, although the difference between pre-test and post-test scores for the analysis and inference indicators was only 2%, the inference indicator showed a higher N-Gain score. This indicates that students utilized 78% of their learning potential in inference, compared to 56% in analysis, suggesting greater room for improvement in the analysis indicator. Overall, all critical thinking indicators showed improvement ranging from moderate to high levels.

The effectiveness of the E-LKPD is not only seen from its success in improving critical reasoning skills, but also from its effectiveness in training communication and collaboration skills. The recapitulation of the observation results on communication and collaboration skills is presented in Table 6 below.

Table 6. Recapitulation of Observation Results of Communication and Collaboration Profile

No	Profile Dimension Indicator	Effectiveness (%)	
		P1	**P2**
Communication Profile		94,5	96,7
Collaboration Profile		96	96,5
Average percentage score of trained communication and collaboration profiles		95	97
Criteria		**Very Effective**	

Description: 0%–35% (Not effective); 36%–70% (Less effective); 71%–85% (Effective); 86%–100% (Very effective)

Based on Table 6, in the communication profile, all students were able to carefully listen to the stimulus video at the beginning of the lesson. For the reading indicator, students read the instructions and learning materials provided, although 1–2 students did not do so carefully. The researcher then refocused students by creating a more engaging learning environment. This is in line with Pasapan *et al*. (2025), who stated that a pleasant learning environment can motivate students to be more active and maintain a conducive classroom atmosphere.

For the speaking indicator, almost all students actively interacted within and between groups. For the writing indicator, 13 out of 15 students participated in written discussions through the Neuro Talk feature, and all students completed the experimental tables and E-LKPD questions. Overall, the observer assessments showed that the developed E-LKPD effectively trained students' oral and written communication skills. This finding supports the study by Anisah & Wisanti (2022), which stated that LKPD-based teaching materials are highly suitable for training students' communication skills in biology learning.

The collaboration skills trained included three indicators, namely respect/caring, cooperation, and idea sharing. In the respect/caring indicator, students practiced and demonstrated mutual respect when their peers expressed opinions without showing any blaming attitudes. In the cooperation indicator, students worked together to complete the experiments more efficiently, while in the idea-sharing indicator, students showed openness to ideas presented during discussions and actively contributed responses to their peers' ideas. However, 1–3 students still showed negative responses by not showing respect during discussions and demonstrating indifference toward their peers.

Based on the overall observer assessment results, the percentage of communication and collaboration profiles trained in Meeting 1 was 95%, while in Meeting 2 it was 97%. This indicates that the developed E-LKPD is highly effective in training students' communication and collaboration skills on the Nervous System topic through features that facilitate interaction and teamwork. This finding is in line with Yulinda *et al*. (2024), who stated that LKPD-based teaching materials are effective in training students' collaboration skills in biology learning.

This study has several limitations, as the limited trial was conducted in only one school and involved a relatively small sample of 15 Grade XI students. Therefore, the findings cannot be generalized to the broader high school student population. However, this is consistent with the purpose of development research, which focuses on evaluating the validity, practicality, and effectiveness of a product through a limited trial. For future implementation, the E-LKPD is recommended to be applied in schools with diverse characteristics and larger sample sizes, supported by teacher training and technical readiness.

CONCLUSION

This study concluded that the Discovery Learning-based E-LKPD on the Nervous System topic is feasible for training students' critical reasoning, communication, and collaboration skills.

Feasibility was indicated by a 96% validation score (very valid), a 98% implementation score, and a 92% positive student response (highly practical). The E-LKPD was also effective, as shown by an N-Gain score of 0.81 for critical reasoning and communication and collaboration scores of 95% and 97%, respectively. For broader implementation, teacher training and technical support, including stable internet access and familiarity with the Liveworksheets platform, are recommended.

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