RESEARCH ARTICLE

Development of PhET-assisted simulation e-worksheet using flipped laboratory approach for science communication skills

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Abstract: Communication skills are one of the 21st century skills. Specific communication in biology learning includes science communication. The purpose of the study was to analyze the improvement of science communication skills using E-Worksheet assisted by PhET on nervous system material. This research and development consist of three stages: the preliminary study stage, the product development stage and the product testing stage. Static-Group Pretest-Posttest research design. This study involved 35 students in the experimental class and 35 students in the control class selected using Purposive Sampling. The research instrument consisted of a validation questionnaire and limited description with indicators of science communication. Data analysis informs that e-worksheet is very feasible with an average score of 83.83%. The improvement of science communication skills on the nervous system material in the classroom using e-worksheet assisted by PhET simulation with an overall N-Gain value of 0.56 with moderate criteria. E-Worksheet assisted by PhET simulation helps the learning process. The guide to using E-Worksheet assisted by PhET simulation should be clearer and more detailed and provide training for teachers to be more familiar with electronics.

Keywords: E-worksheet; flipped laboratory; nervous system; PhET-assisted simulation; science communication skills

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Introduction

Communication skills are one of the aspects of 21st-century skills. Science communication is a fundamental skill students must possess to face the 21st century (Odell et al., 2023; van Dam et al., 2020). This communication skill involves a person's ability to transform complex scientific concepts into interesting and understandable content (Feletto, 2024). Improving science communication skills is an important effort to bridge the gap between the scientific community and the public (Moemeke, 2023). These skills are also important for academics with a science background to combat the spread of misinformation (Osterhage & Rogers-Carpenter, 2022).

A survey found that 90% of scientists stated that one of the main challenges in science communication is the perception that non-scientists or non-researchers do not need science communication skills (Joubert & Falade, 2019). The low level of science communication skills among the general public, particularly in developing countries, results in important scientific information for societal progress being overlooked, hindering knowledge development (Heyl, 2018). This condition also greatly influences education in schools. As science communication is not considered important for non-scientists, many schools in developing countries do not pay sufficient attention to developing 21st-century skills. This causes students to be untrained in conveying or understanding scientific concepts, especially when dealing with complex materials (Weingart & Joubert, 2019).

In the 21st century, technology has become an inseparable component of education. The integration of technology in education not only modernizes the learning process but is also in line with the current educational framework (Farisi, 2016). Several studies have also reported the impact of technology integration on other 21st century competencies (Blake, 2016; Fu & Hwang, 2018; Gökçearslan et al., 2017). Therefore, many other publications emphasize the urgency of optimizing technology in the learning process (Ahmadi, 2023; Kirkwood & Price, 2014).

One of the uses of technological developments in learning is through the use of electronic worksheets (e-worksheets). Previous studies have shown that the use of e-worksheets supports learning that is oriented towards improving critical thinking skills, collaboration, and creativity (Kusno & Setyaningsih, 2021; Ratih & Rohaeti, 2024). The use of e-worksheets can also significantly improve students' problem-solving skills (Harini et al., 2023) and science process skills (Febriansyah et al., 2021). Furthermore, by integrating interactive elements into e-worksheets, learning will increase students' motivation and confidence (Teresa & Febria, 2023) and their interest in the learning process (Pulungan et al., 2022).

Furthermore, the implementation of virtual simulations such as PhET simulations has also proven to be an effective method that improves students' science skills. With virtual laboratories, students can conduct experiments that are difficult to do in school laboratories and facilitate them to understand scientific concepts more deeply (de Jong et al., 2013). This kind of simulation accommodates students to study observable and unobservable phenomena, thus enriching their learning experience (Rohim, 2020). The combination of e-worksheets and virtual simulations will create a dynamic learning environment that can improve various important skills in science learning.

Flipped Laboratory is an innovative learning approach that reverses the traditional roles between the classroom and the laboratory. Flipped Laboratory is an innovative learning approach that reverses the traditional roles between classroom and laboratory. Theoretical learning is done independently outside the classroom/laboratory, usually through instructional videos, readings, or other online sources. In-class/laboratory time is used for conducting experiments, practical, or discussion activities. The main focus in the laboratory is on the practical application of previously learned theory (Mshayisa & Basitere, 2021). The Flipped Laboratory approach often involves group work. Students collaborate to design experiments, discuss, answer questions. This approach enhances communication and collaboration skills in the context of science, which is important in modern work environments (Candaş & Altun, 2023).

The research results of Nurason et al. (2022) show that *PhET*-Assisted Simulation E-Worksheets can improve students' science communication skills by providing an interactive and visual learning environment. These simulations help students understand complex scientific concepts and train them to communicate this understanding effectively, both orally and in writing (Costello et al., 2022). This aligns with Lafiani et al. (2022) research, which found that through discussions, students not only confirm their understanding of the material but also practice science communication skills essential for problem-solving in the modern era.

The results of the preliminary study based on an open interview with a biology teacher that biology grades for nervous system material are considered difficult. The factor that students have difficulty understanding nervous system material is due to several factors, namely the lack of learning media and time. Based on interviews with three students, information was obtained that students tend to prefer learning by using technology and feel bored if they only rely on discussions and assignments without using technology. Nervous system material is one of the complex materials in the school curriculum (Byukusenge et al., 2023). The nervous system is one of the topics that is difficult to learn by students, both high school students (Fauzi et al., 2021) as well as college students (Montrezor, 2014) and prospective teacher students (Laelasari & Wakhidah, 2023). In addition, concepts such as information processing and neurobiological mechanisms also add to the difficulty level (Bei et al., 2024).

Several previous studies have developed worksheets with PhET simulations in various subjects. The development of PhET-assisted inquiry-based electronic worksheets was reported to improve the communication and collaboration skills of junior high school students in Depok (Rahayu & Wibowo, 2023). Guided inquiry-based worksheets using PhET simulations that were tested in junior high schools in Sukoharjo were also developed to improve students' conceptual understanding (Amini et al., 2022). In addition, digital worksheets with PhET simulations developed by a team from the State University of Jakarta are also useful for improving students' high-level thinking skills (Susila et al., 2021). Students' retention of the material they have learned also increases when they participate in learning involving PhET simulations. In this study, e-worksheets with PhET simulations will be developed for biology subjects, especially the nervous system material. This topic has not been used as a worksheet context in the previous studies mentioned. Therefore, the purpose of this study is to develop a PhET-assisted simulation e-worksheet to improve science communication skills in the topic of the nervous system using a filled laboratory approach.

Method

This research was conducted in one of the public high schools in Bandung City. This research uses a Research and Development (R&D) design consist of three main steps, namely the preliminary study stage, the product development stage and the product testing stage (Sukmadinata, 2017). The framework describing the flow of interactive e-worksheet development can be seen in Figure 1.

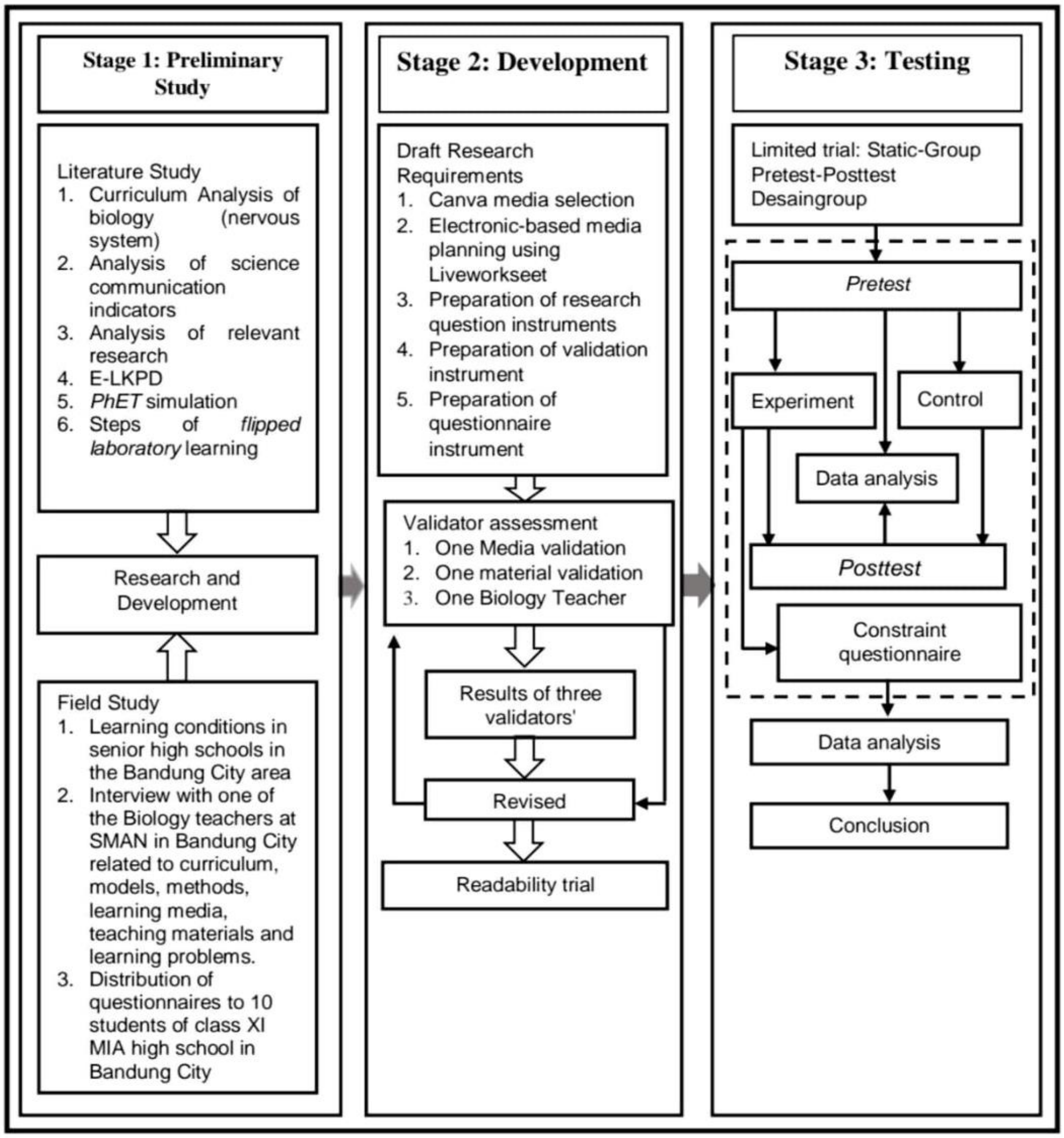


Figure 1. Research flow scheme

Stage one of the preliminary study consists of two stages, namely field studies and literature studies. The preliminary study stage is a crucial first step in Sukmadinata's R&D model. This stage involves two main activities, namely field studies and literature studies. Field studies aim to collect primary data directly from sources in the field through observation, interviews, questionnaires, and documentation. The data obtained from the field study provides a clear and specific picture of the problems or needs that will be addressed by the developed product. The literature study focuses on gathering information from various literature sources to build a theoretical framework, identify research gaps, and gain inspiration.
The second stage, namely the product development stage, consists of selecting teaching media. This includes using Canva and Liveworksheet to design the E-Worksheet. The initial design of the product is in the form of an E-Worksheet draft. The initial design of research tools includes E-Worksheet supported by PhET simulation with Flipped Laboratory approach on Nervous System material. The data collection

tools used consist of validation sheets, pretest questions, posttest questions, and questionnaire sheets. Validation test to determine the feasibility of a product. Validation by three experts, including: one media expert (lecturer who teaches learning media courses), one material expert (lecturer who teaches courses on biological content), and a biology teacher as a practitioner validator. Initial products that still have misconceptions or receive suggestions and comments from validators will be revised and then revalidated. E-worksheet assisted by PhET simulation using the Flipped Laboratory approach that has gone through the validation and improvement process is then tested for readability to 15 students. The results of the readability questionnaire in the form of comments and suggestions are used as a basis for making further improvements to the E-Worksheet at the development stage.

The third stage is the product testing stage. Stage three consists of a limited trial involving two classes, namely experimental and control classes. The experimental class has a written question test in the form of pretests and posttests and a questionnaire of constraints, while the control class only has a written question test in the form of pretests and posttests.

The study involved two classes, namely the experimental class totaling 35 students and the control class totaling 35 students. The technique used was purposive sampling. The test technique used a written question instrument covering science communication indicator, namely; changing the form of image presentation, changing the form of table presentation, changing the form of graphical presentation, explaining the results of data analysis and discussing the results of activities of a problem or event (Rustaman, 2008; Suryani, et al, 2022). The data collection technique used a static-group pretest-posttest design (Sugiono, 2021) (Tabel 1). In Tabel 1, O1 is pre-test score of the experimental class, O2 is post-test score of the experimental class, O3 is pre-test score of the control class, O4 is post-test score of the control class, and X is treatment given to the experimental class.

Table 1. Static-group pretest-posttest research design

Pre-Test	**Treatment**	***Post-Test***
O_1	X	O_2
O_3		O_4

The feasibility of the PhET-assisted simulation e-worksheet design using the flipped laboratory approach on nervous system material is analyzed through data validated by subject matter experts, media experts, and biology teachers. The scores from experts and students are then averaged and interpreted according to the product feasibility and practicality assessment criteria, referring to Arikunto (2010), which can be seen in Table 2.

Table 2. Validation criteria

No	**Percentage**	**Feasibility**
1.	0.00 – 49.99	Very poor/not valid/not feasible
2.	50.00 – 59.99	Poor/less valid/less feasible
3.	60.00 – 79.99	Good/valid/feasible
4.	80.00 – 100.00	Very good/very valid/very feasible

The study aims to measure the improvement of science communication skills consisting of five indicators, namely changing the form of image presentation, changing the form of table presentation, changing the form of graphical presentation, explaining the results of data analysis and discussing the results of activities of a problem or event (Rustaman, 2008; Suryani et al., 2022). The improvement of this treatment will be measured through the comparison of students' pretest and posttest scores. The improvement of science communication skills is expected to be measured through the calculation of normalized gain using formula (1). The obtained n-gain value is then interpreted into criteria, referring to Hake (1999) which can be seen in Table 3.

$$\text{N-Gain} = \frac{\text{Final Test Score} - \text{Initial Test Score}}{\text{Maximum Score} - \text{Initial Test Score}} \quad (1)$$

Table 3. N-Gain index

Interval	**Criteria**
G > 0.70	High
0.30< G < 0.70	Medium
G < 0.30	Low

Results and Discussion

This research produced an interactive e-worksheet that utilizes PhET simulation and applies the Flipped Laboratory approach for learning nervous system materials. This e-worksheet is designed to provide

learning flexibility for students, allowing them to study the material independently at home before conducting activities in class. Thus, class time can be optimally utilized for discussions, experiments and concept deepening. The Flipped Laboratory approach allows students to access learning materials anytime and anywhere through electronic devices (Mshayisa & Basitere, 2021). The *PhET* simulation integrated in the e-worksheet provides interesting and interactive visualizations so that students can more easily understand complex concepts (Sarwoto et al., 2020).
The results of the validation of PhET-assisted e-worksheet with a Flipped Laboratory approach on nervous system material show that this e-worksheet has met the eligibility criteria in terms of media, material, and suitability for student learning needs. can be seen in Table 4.

Table 4. Validation result scores

No	Aspects	Score (%)	Category/Decision
1.	Media	80.00	feasible, no revision needed
2.	Material	87.00	feasible, no revision needed
3.	Practicality	90.00	Very feasible, no revision needed
Average		**83.83%**	
Interpretation		**Very Valid**	
Category		**Very Feasible**	

E-worksheet assisted by PhET simulation with Flipped Laboratory approach that has been validated is declared very feasible to use with an average value of 83.83%. After being declared valid, this E-Worksheet then continued to the readability test stage. This trial aims to assess the readability and effectiveness of e-worksheet in supporting the learning process. The aspects assessed include media, material, and language. The results of the learning media readability test are presented in Table 5.

Table 5. Readability result scores

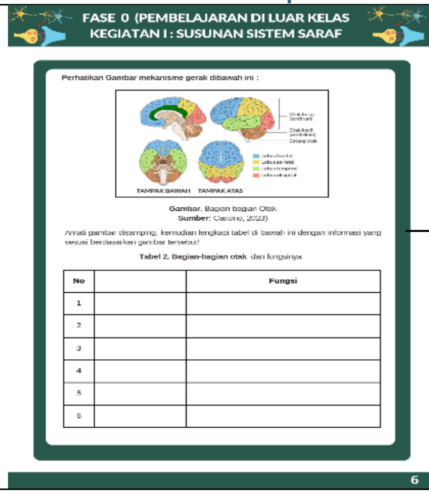
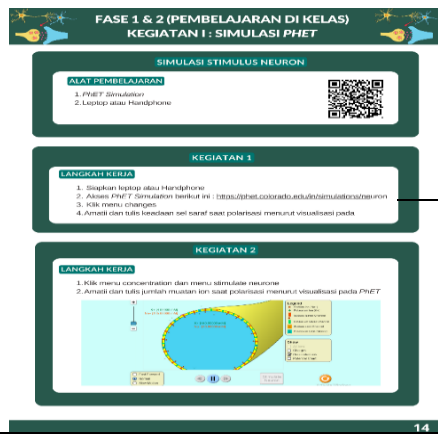
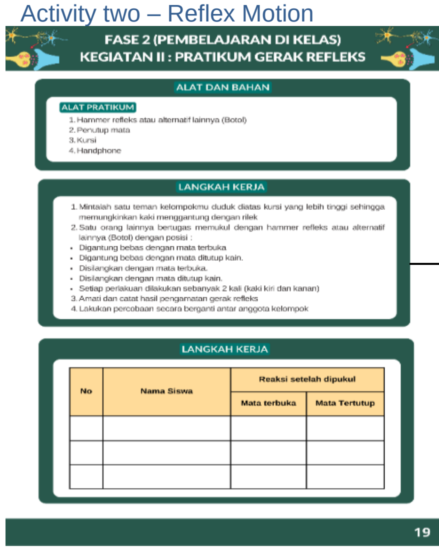
No	Aspect	Score (%)	Score (%)
1.	Media	80.00	80,00
2.	Material	85.11	85,11
3.	Language	86.66	86,66
Total Score		**253.99**	**253.99**
Average		**84.66**	**84.66**

Based on the results of the readability test using the Guttman scale, it shows a very high level of feasibility, which is 84.66%. This shows that students find this e-worksheet easy to understand and interesting. This is in line with research conducted by Pratiwi et al. (2022). The study found that quality e-worksheet can facilitate active learning, increase students' learning motivation, and enrich students' learning experience. The e-worksheet design with the *Flipped Laboratory* approach can be seen in Table 6.

Table 6. E-worksheet design assisted by PhET-Assisted Simulation with a flipped laboratory approach

No	Electronic Module Aspects	Description
	Media	
1.	Ease of access https://www.liveworksheets.com/c?a=s&t=Ae4SNMmzUn&sr=n&l=uq&i=sxcuxdc&r=hr&f=dzdczfuc&ms=uz&cd=p-r9---vg-llxtpmkxmnkwsngnkgexkxg&mw=hs	This E-Worksheet can be accessed online through the Liveworksheets website, accessible from various devices such as computers and phones connected to the internet
2.	Attractive display design	The attractive design in the worksheet includes the use of image illustrations and the *PhET* logo to present learning materials about the nervous system visually and interactively. Images in the E-Worksheet are clear and colored

No	Electronic Module Aspects	Description
		
3.	Automatic assessment 	Features to submit answers directly and to assess participants' answers automatically in several types of questions, helping to provide immediate feedback to students
	Readability	
4.	Instructions 	Instructions on the first page consist of technical instructions for using the media. The language and terms used are easy to understand 1. Pray before studying 2. Read each command given carefully 3. Do the activities in the E-LKPD in a structured and group manner 4. Read every command given carefully 5. Ask and ask the teacher for help if you have difficulty in doing the work 6. Complete the group identity 7. Read the instructions for each activity 8. Answer the questions in each activity 9. Click finish if you have finished working on the activities in the LKPD 10. Read the table of contents to find out the order of learning activities
	Content / Material	
5.	Pre-Class Learning Phase	The Pre-Class Learning Phase is available on pages four, five, and six, and consists of the theory of nervous system structure, functions, conscious movement, reflex movement, and impulse transfer along with its tasks.

No	Electronic Module Aspects	Description
		Observe the picture below, then complete the table below with the appropriate information based on the picture!
6.	In-Class Learning Phase: Activity one *PhET* simulation 	The In-Class Learning Phase on pages seven to ten consists of web link features connected to *PhET* simulations related to impulse transfer material Activity instructions Prepare a laptop or mobile phone Access the following *PhET Simulation*:https://PhET.colorado.edu/in/simulations/neuron Click the Changes menu Observe and write down the state of the nerve cell during polarisation according to the visualization in
7.	Activity two – Reflex Motion 	Pages eleven to fourteen consist of practical activities in class 1. Have one of your group mates sit on a taller chair that allows the legs to hang freely. 2. One other person is in charge of hitting with a reflex hammer or alternative (Bottle) in the position 3. Hanging freely with eyes open 4. Hanging freely with eyes covered with cloth. 5. Crossed with eyes open. 6. Crossed with eyes covered with cloth. 7. Each treatment is done twice (left and right leg). 8. Observe and record the results of reflex motion observations. 9. Experiment by alternating between group members

The learning media used in this study is an e-worksheet that contains material about the nervous system in digital form. The purpose of using this PhET-Assisted Simulation e-worksheet is to determine the improvement of students' science communication skills in nervous system material after using the E-Worksheet that has been designed, validated, and tested for readability. The research instrument is in the form of questions in a written test given to students before and after learning using the E-Worksheet. The improvement in students' science communication skills can be measured by the n-gain value through test result analysis. The following are the n-gain values obtained by students through pretest and posttest results. The N-gain value of students in nervous system material is calculated based on the difference between post-test and pretest scores. This measurement is used to assess the improvement in understanding and science communication skills of students. The overall N-gain value data can be seen in Table 7.

Table 7. Overall N-Gain score

Class	*Pretest*	*Posttest*	*N-gain*	Interpretation
Control	34.92	46.60	0.19	low
Experiment	30.54	69.27	0.56	medium

The results showed that the use of PhET-assisted simulation e-worksheet with flipped laboratory approach on Nervous System material can improve students' science communication skills compared to conventional learning. This is indicated by the higher N-gain score in the experimental group. The Flipped Laboratory approach that combines independent learning with collaborative activities in class, as well as interactive visualization through PhET simulation, has created an effective learning environment for students to explore concepts, discuss and present their understanding. In other words, the E-Worksheet and PhET simulation have facilitated active student-centered learning, thus improving their ability to communicate science knowledge (Nurafriani & Mulyawati, 2023). PhET simulations provide an interactive tool that helps students understand science concepts in a visual and practical way (Muzana et al., 2021). This significant improvement can be seen in the higher N-gain value in the experimental class. With independent learning outside the classroom, students can study the material independently at home, while time in class can be utilized for practical activities and group discussions (Kolgatin et al., 2023; Mykytyn et al., 2024; Singh et al., 2023).

The improvement of communication skills in the experimental class shows the effectiveness of the Flipped Laboratory approach in facilitating learning. Through the use of PhET-assisted simulation E-Worksheet with the Flipped Laboratory approach, students have the opportunity to learn the material independently before class learning begins. When the class session took place, the available time was optimally used for group discussions, presentations, and experiments (Mshayisa & Basitere, 2021). The PhET simulation in the E-Worksheet allows visualizations of abstract and difficult-to-understand concepts, making the material more accessible and understandable to students (Muzana et al., 2021).

Based on the results of the N-gain analysis (Figure 2), it can be seen that the average increase in students' science communication skills in the experimental class is higher than the control class. The experimental class showed an increase in the medium category, with a percentage reaching 71.43%. This indicates that the use of e-worksheet based on PhET simulation with the Flipped Laboratory approach is effective in improving students' ability to communicate concepts related to the nervous system.

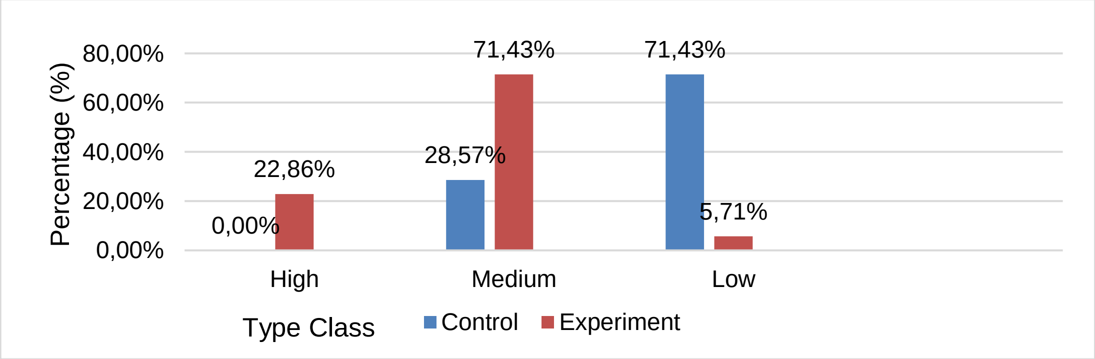


Figure 2. N-Gain score diagram

The significant improvement in the experimental class can be attributed to several factors. Firstly, e-worksheet provides flexibility for students to learn independently anytime and anywhere (Harini et al., 2023; Sa'adah & Ikhsan, 2024; Sari et al., 2024). Secondly, PhET simulations provide interactive visualizations that make it easier for students to understand abstract concepts. The PhET simulation is an activity part of the Electronic Worksheet that provides a learning experience for students. PhET simulations help students visualize abstract concepts and apply theory in a more real-world context

(Khofifah et al., 2024; Meliniasari & Setyarini, 2024; Sopari et al., 2024). Thirdly, the Flipped Laboratory approach allows students to directly practice what they have learnt through discussions and group activities in class (Candaş & Altun, 2023).
The science communication skills indicators in e-worksheet include five sub-indicators from three main indicators. The scores from the pretest and posttest questions were analyzed using normalized gain calculations because there was a difference in value between the initial test score (pretest) and the final test score (posttest) (Hake, 1999). The results of the increase per indicator calculated using the N-gain score are presented in Table 8.

Table 8. N-Gain score each indicator

Indicators	N-Gain in Experiment Class	Note	N-Gain in Control Class	Note
Changing the form of image presentation	0.64	High	0.01	Low
Change the presentation form of the table	0.43	Medium	0.13	Low
Changing the graphic presentation	0.51	Medium	0.03	Low
Explaining the Results of Data Analysis	0.51	Medium	0.22	Low
Discuss the results of a problem or event	0.70	High	0.36	Medium

Based on Table 8, the data shows that the highest increase in the experimental class is in the indicator of discussing the results of a problem or event with a score of 0.70 with high criteria, while the lowest increase is in the indicator of converting graphical presentations into descriptions or tables with a score of 0.43 with moderate criteria. In the regular class, the highest increase was in the indicator of discussing the results of a problem or event with a score of 0.36 with moderate criteria. The lowest increase was in the indicator of changing the presentation of the graph with a score of 0.01 with low criteria.
Based on these data, it shows that the strongest indicator is discussing the results of a problem or event. Based on the data, it can be seen that the experimental class using e-worksheet assisted by PhET simulation using the Flipped Laboratory approach is higher than the regular class. The Flipped Laboratory concept reverses the teaching and learning process in the laboratory/classroom. Theoretical material is delivered first at home through e-worksheet media. Time in the laboratory/classroom is optimally used for simulation, practicum, discussing results, analyzing data, and drawing conclusions. This is relevant to the research Costello et al. (2022) that the implementation of pre-laboratory activities (PLAs), students are prepared before the practical session, allowing learners to focus more on laboratory activities. Good preparation, time in the laboratory can be used to explore the material, perform simulations, and discuss the results obtained, thus increasing students' understanding and involvement in the learning process. This is in line with research Lafiani et al. (2022) It is recognized that through discussion, students not only confirm their understanding of the material but also practice science communication skills that are essential for solving problems in the modern era. This is in line with the pilot test questions, the indicator of discussing the results of an activity on a problem or event on the nervous system disorders sub-material is in the low category.
The weak category indicator is changing the form of graphical presentation in experimental and control classes. In the experimental class there was an increase of 0.43 with moderate criteria while the regular class experienced an increase of 0.01 with low criteria. Based on this data, it can be seen that the experimental class using e-worksheet assisted by PhET simulation using Flipped Laboratory approach is higher in increasing the indicator of changing the form of graph presentation than the regular class. PhET simulation activities presented in the E-Worksheet help students in understanding impulse transmission material. PhET simulation presents graphs, symbols, stimuli, and interactivity. This is relevant to the research Taibu et al. (2021) that the PhET simulation presents graphics to help students understand science concepts interactively. The use of PhET simulations in learning has been shown to enhance students' learning experience. Students who do not have sufficient experience in converting graphical presentation forms may experience difficulties. This is in line with previous study which states that the ability to read graphs of high school students is still low (Amin et al., 2020). Presentation of graphs that are converted into tables must pay attention to the components of the table, namely the table title, information on the table, table contents, and accuracy in making columns and rows. Present the description of the graph or table by identifying the data structure and composing the appropriate sentence (Rustaman, 2008).

Conclusion

E-Worksheet assisted by PhET simulation with Flipped Laboratory approach is considered feasible based on the assessment of material experts and media experts. The use of e-worksheet assisted by

PhET simulation with the Flipped Laboratory approach can improve students' science communication skills on nervous system material with an average N-gain of 0.56 with moderate criteria, based on the n-gain value per indicator, the highest n-gain value lies in the indicator of discussing the results of activities of a problem or event with an average N-gain of 0.70 with moderate criteria, while the lowest n-gain value is in the sub-indicator reading the graph which is 0.43 with moderate criteria.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contributions

T. W. Agustina: developing e-worksheet, preparing the initial draft of e-worksheet, conducting research, analysing data, writing manuscripts, and revising; **L. Lestari:** developing e-worksheet, preparing the initial draft of e-worksheet, conducting research, analysing data, writing manuscripts, and revising; **E. Paujiah:** analysing the materials of nervous system; **A. Y. Nuryantini:** analysing the flipped laboratory and conducting reviews; **Y. Sukmawardani:** analysed science communication questions and data analysis; and **R. L. Flara:** analysing data related to PhET simulations.

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