JIPF (JURNAL ILMU PENDIDIKAN FISIKA)
p-ISSN: 2477-5959 | e-ISSN: 2477-8451 *Vol. 9 No. 1, January 2024, Page 65-73*

Global Warming E-Worksheet Integrated with PhET Interactive Simulations: It is Effective to Enhance Students' Critical Thinking Skills?

Nurul Wahdah [1*)], Trisonia Fitria [2], Muh Fajrin Arifa [3], Jumadi [4], Mutahharah Hasyim [5]
Universitas Negeri Yogyakarta, Indonesia[1,2,3,4], Universitas Negeri Makassar, Indonesia[5]
[*)]Corresponding E-mail: nurulwahdah.2022@student.uny.ac.id

Received: June 5th, 2023. Revised: November 2nd, 2023. Accepted: November 3rd, 2023

Keywords :
Crtitical Thinking Skills; an E-worksheet; Global Warming; PhET Interactive Simulations

ABSTRACT
The aims of this research is to determine the effectiveness of the global warming e-worksheet using Liveworksheet integrated with PhET interactive simulations to improve students' critical thinking skills. The independent variable is the use of a global warming e-worksheet integrated with PhET interactive simulations, while the dependent variable is the critical thinking skill (analyze the facts, formulate the main problem, interpreting, and summarizing). This research used a pre-experimental type, with a one-group pretest-posttest research design. At SMAN 4 Yogyakarta, 70 students in the 10th grade participated in the cluster random sampling technique. Criteria for measuring critical thinking skills were objective questions. Then, using SPSS, descriptive statistics, n-gain tests, and one-way ANOVA were used to examine the results. Results showed that the students' critical thinking skills were significantly enhanced by the global warming e-worksheet integrated with PhET interactive simulations. This points out that using electronic physics learning materials and integrating technology has a positive effect on improving cognitive skills. Students learn content during the learning process, but they also gain a deeper understanding of the material by using simulations that are based on real-world problems and scientific principles to complete e-worksheets.

INTRODUCTION

Education as a means of individual development is required to be able to produce quality and skilled students [1] [2]. These skill sets are 21st-century competencies that include critical thinking, creative thinking, teamwork, and communication [3] [4]. The 21st century learning paradigm places a strong emphasis on the requirement that students possess critical thinking skills and be able to grasp technology in line with the current advancement of technology [5]. One of the key competencies

required in 21st-century culture and academic curricula is critical thinking [6] [7]. In order to adapt and fulfill the needs of the 21st century, it may be assumed that critical thinking abilities and technological proficiency are two multiple abilities that are crucial.

Making predictions, analyzing probabilities, identifying relationships, and solving complicated issues are all high-level skills that are a part of critical thinking [8] [9]. To train critical thinking skills, it can be done by applying active learning and facilitating students' finding solutions to surrounding problems [10]. In the learning process, critical thinking assists students in handling social and scientific issues [11]. One of the subjects that requires learners to be able to think critically is physics. Students must be able to think critically, especially in physics. Physics concepts related to commonplace events, like global warming, must be examined and considered logically by the students [12].

Students who study global warming in school will be better equipped to evaluate its impacts, suggest remedies, and examine its symptoms [13]. Global warming necessitates a dynamic approach with student-centered learning and the inclusion of relevant, challenging, and significant circumstances. As a result, it must be included in a comprehensive learning system [14]. As a result, students must be taught how to solve difficult problems because global warming is a complex issue that needs to be addressed in education in order to help students contribute to finding solutions [14] [15] [16].

Additionally, a proper learning paradigm is needed to enhance critical thinking skills while learning. Problem-based learning (PBL), a type of instruction, can help students develop their critical thinking skills [17] [18]. The definition of PBL is a model of learning created so that students can learn from and solve issues [19]. PBL performs a variety of tasks, such as interdisciplinary emphasis, authentic investigation, generating and presenting work, cooperation, and using questions or issues as a stimulus.

In each lesson, including using PBL, teachers need to use learning tools. Worksheets are one of the teaching tools used [20]. Since most educational worksheets are paper-based, there are high costs involved, kids become bored easily, and technological advancement is underutilized [21]. In order to prevent students from getting bored easily, the worksheet must be interactive [22]. It is necessary to create an electronic worksheet (e-worksheet) for this reason. E-Worksheets will eventually be made accessible via laptops, PCs, smartphones, and tablets [23]. E-worksheets will be well-received by students because they are used to using computers and other technologies in lectures. It is intended that with this simple access, students will be more adaptable in their learning.

Through the E-Worksheet, students can run interactive simulations involving variables related to global warming, such as emmissions of carbon, temperature changes, and greenhouse effect [22]. Students can explore, observe, and analyze data obtained from such simulations, thus enabling them to understand the concept of global warming concretely and practice their critical thinking skills. Based on observations at SMAN 4 Makassar, learning using an e-worksheet is still rarely carried out, especially by using simulations directly with students. One tool that can be used is PhET interactive simulations, which is a series of interactive simulations that allow students to visually and exploratively understand physics concepts through virtual experiments. PhET interactive simulations can provide a more engaging and interactive learning experience for students [24]. Therefore, it is anticipated that combining e-worksheets with PhET interactive simulation on global warming content can enhance students' critical thinking skills. E-worksheets are integrated into PhET interactive simulations, where e-worksheets can be accessed online on the liveworksheets website.

Based on this description, it is important to conduct research on the implementation of integrated e-worksheet PhET simulation in physics subjects, in this case, global warming material. The purpose of this research study is to determine whether using an interactive simulation built within an e-worksheet on global warming helps students' critical thinking skills.

METHOD

This research type is a pre-experimental using a one group pretest-posttest research design [25]. This study used one modeling class and one implementation class. Table 1 shows the research design as follows.

Tabel 1. Research Design

Class	Pretest	Treatment	Posttest
Modeling	O_1	X	O_2
Implementation	O_1	X	O_2

Information:
O_1 : Pretest of students' critical thinking skills
X : The use of Physics Learning E-Worksheet Integrated with PhET Interactive Simulations on Global Warming
O_2 : Posttest of students' critical thinking skills

The study was conducted out throughout the 2022–2023 academic year at SMAN 4 Yogyakarta. Both modeling and implementation classes used the global warming e-worksheet integrated with PhET interactive simulations. The modeling class is taught by researchers, whereas the implementation class is taught by a physics teacher. Cluster random sampling was the sampling technique used in this research, and it involved 70 10th graders. Both the modeling class (35 students from X E6) and the experimental class (35 students from X E3) were plotted. Both independent and dependent factors are included in the research variables. The global warming e-worksheet integrated with PhET interactive simulations is the independent variable, and the students' critical thinking abilities are the dependent variable in this research.

The data collection techniques used were test techniques. Seven critical thinking objectives and questions served as the instruments used. The opening section explains that the critical thinking skill indicators used in this research are a combination of numerous expert viewpoints. Provide clear explanations, develop fundamental skills, make inferences, offer further explanations, and develop strategies and tactics are all signs of critical thinking skills.

The data was analyzed using both the results of the pretest and posttest, and the outcomes were then examined using the N-gain equation [26], that is shown in equation 1. A data analysis was done to compare the critical thinking skills of students before and after using a global warming e-worksheet integrated with PhET interactive simulations. According to Table 1, there are three distinct categories in the analysis.

$$g = \frac{S_{posttest} - S_{pretest}}{S_{ideal} - S_{pretest}} \quad (1)$$

Information:
g : n-gain score
$S_{pretest}$ = Pretest mean score
$S_{posttest}$ = Posttest mean score
S_{ideal} = Maximal Score

Table 2. Interpretation of n-gain score

Normalized Gain Score	Interpretation
$g > 0,7$	High
$0,3 < g \leq 0,7$	Medium
$g \leq 0,3$	Low

RESULTS AND DISCUSSIONS

Tests of critical thinking skills about global warming were tested for feasibility using expert judgment. The test results demonstrate that the instrument can be used. The results of this research have been divided into two sections: those from the modeling class taught by the researchers and those from the implementation class taught by physics teachers. Modeling is done in class X E6, while implementation is done in class X E3.

Normality Test

The data from the pretest and posttest on critical thinking skills in the modeling class and the implementation class were analyzed according to the Shapiro-Wilk normality test. Table 3 displays the results of the normality tests for the modeling class and the implementation class. The critical thinking skills pretest-posttest score in the modeling and implementation classes has a sig. value of more than 0.05. This shows that both classes' critical thinking skills pretest-posttest data have a normal distribution.

Table 3. Normality Test Results

Class	Test	Shapiro-Wilk		
		Statistic	df	Sig.
Modeling	Pretest	.987	35	.234
	Posttest	.991	35	.387
Implementation	Pretest	.979	35	.292
	Posttest	.980	35	.343

Homogeneity Test

Table 4 displays the results of the homogeneity test along with the sig values. The sig value are 0.383 and 0.313, which is higher than 0.05. This indicates that both the modeling class and the implementation class have homogeneous critical thinking skill variables.

Table 4. Homogeneity Test Results

Class	Levene Statistic	df1	df2	Sig.
Modeling	.771	1	68	.383
Implementation	1.035	1	68	.313

Improved Critical Thinking Skills

Pretest and posttest scores are calculated by the N-gain test to obtain a value for improving students' critical thinking skills. The result of students critical thinking skills test for modeling class is shown in the table 5 and the result of the n-gain analysis is shown in table 6.

Table 5. The modeling class test results

Result	Pretest	Posttest
The highest score	100	100
The lowest score	14	57
The average score	49	88
Increase of average score	39	

Table 6. The n-gain score analysis of the modeling class

The highest value	The lowest value	The average value
1.00	0.25	0.78

The average student n-gain score is 0.78, as seen in the table above. This indicates that the increase in students' critical thinking skills is in the high category. The use of PhET in learning and its application using PBL models can improve critical thinking skills ranging from medium to high categories [24]. In

line with research conducted by Mardhatil et al., E-Worksheet can be an alternative to physics learning activities because it is able to improve critical thinking skills efficiently [27].

Table 7 shows the results of the critical thinking skills of students test for the implementation class, and Table 8 shows the results of the n-gain analysis.

Table 7. The implementation class test results

Result	Pretest	Posttest
The highest score	100	100
The lowest score	43	71
The average score	71	91
Increase of average score	20	

Table 8. The n-gain score analysis of the modeling class

The highest value	The lowest value	The average value
1.00	0.00	0.70

The table above shows that the average student n-gain score is 0.70. This indicates that the increase in students' thinking skills is in the high category. The use of PhET systems is very practical and helps students improve their critical thinking skills.

The modeling and implementation classes had yet to achieve the standard value, according to the students' average critical thinking pre-test scores. There are numerous potential causes for this. One reason is that students don't comprehend the information on global warming since they simply make educated guesses about what happens in their local area. This lack may have an impact on students' critical thinking abilities. Additionally, the result shows an improvement in critical thinking skills. An e-worksheet-integrated PhET simulation that uses a PBL approach has been implemented, and this is what has caused the growth. Research shows that using online simulations and problem-based learning models to teach students about global warming improves their ability to think critically [28]. We will enhance student's skills in critical thinking through the use of PhET simulation. Increased skills in critical thinking will help students comprehend the information the teacher is teaching easier [29].

In both classes, the learning process is carried out by dividing the class into various study groups. E-worksheets are available online on the LiveWorksheets website for both modeling and implementation classes. Students will work on parallel investigations using PBL learning models with the guidance of an e-worksheet. Figure 1 shows the e-worksheet using the Liveworksheet used in this research. This e-worksheet can be accessed for free via www.liveworksheets.com.

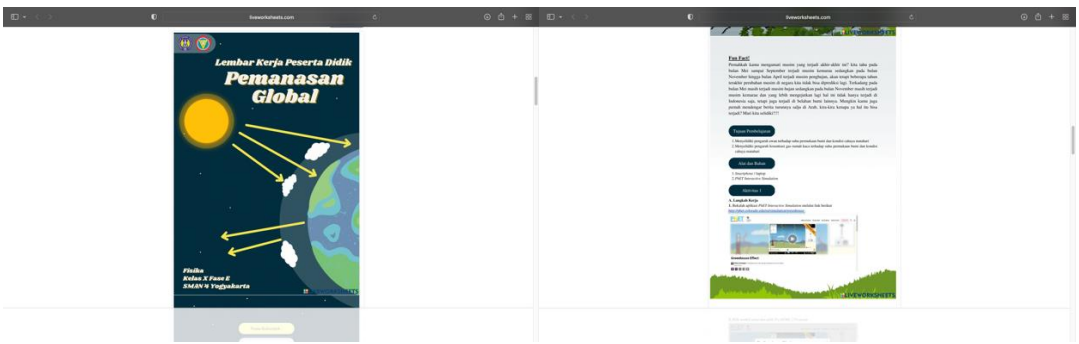

Fig 1. *e-worksheet using the Liveworksheet*

Students are given problems by researchers or lecturers using PowerPoint presentations, who then direct student research to make sense of the findings and find solutions to the problems. Figure 2 illustrates the PhET simulation used in this research.

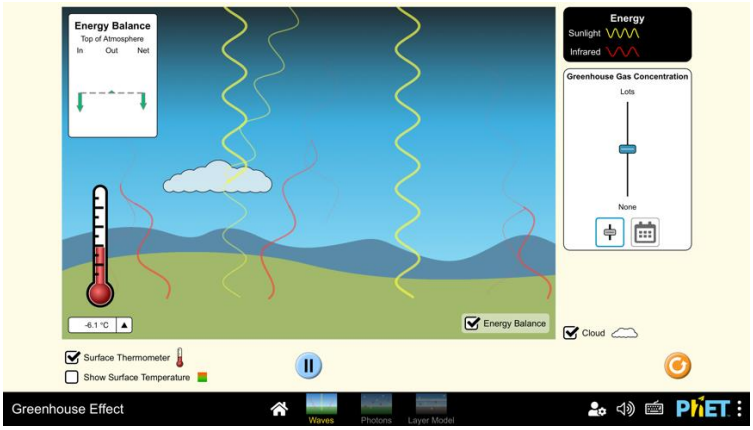

Fig 2. *PhET Interactive Simulation ilustration*

PhET simulations provide a depiction of the condition of sunlight reaching the surface of the earth. This depiction must be able to be written according to the results of student observations and an in-depth analysis that relates the causes, conditions, and impacts of global warming. This PhET simulation can help students to improve their thinking skills. In line with the research conducted by Ramadan et al., the use of teaching tools that integrate with PhET Interactive Simulation can improve students' critical thinking skills [30].

Both modeling and implementation classes also used the PBL model in the learning process. The result shows that both classes have an increasing ratio of pretests to posttests. This result is in line with the research that has been conducted by Sujatmika et al. to improve the quality of learning through the use of PBL-based e-worksheets [20]. This electronic worksheet has the benefit of being multimedia and interactive, which is not possible with a worksheet that is printed on paper. PBL is applied in seven steps, with a stimulus or activity geared toward enhancing critical thinking provided for each step [20].

The Effective Treatments Contibutions

The data has met the normal and homogeneous requirements to be tested using a one-way ANOVA or f test to determine the comparison of the average pre-test and post-test scores in modeling and implementation classes. The following results of the one-way ANOVA test are presented in Table 9 that also known as the effective contribution amounts for each class.

Table 9. The Effective Treatments Contribution

Class	df	Mean Square	F	Sig	Eta-squared
Modeling	1	3223.214	65.594	.000	.491
Implementation	1	822.857	39.857	.000	.369

Based on the table, it is found that the outcomes of the experiments have a substantial difference between modeling and implementation class tests, as indicated by the significance value in the significance column being smaller than 0.05.

From Table 9, also known the partial eta value as a result of the ANOVA effect size analysis. Partial eta squared values can be used to determine the treatment's actual contribution to modeling class and implementation class. In modeling class, using a global warming e-worksheet integrated with PhET interactive simulations substantially improved critical thinking skills by 49.1%. Although the implementation class improved students' critical thinking skills by 36.9%, Based on these findings, it

is known that using a global warming e-worksheet integrated with PhET interactive simulations in modeling class rather than implementation class can improve students' critical thinking skills.

The results discussed above show how the e-worksheet that used Liveworksheet helps students in improving their abilities. In line with Novikova's research found that students were enthusiastic, confident in learning and independent, critical, and diligent when doing e-worksheet with Liveworksheet [31]. E-worksheet with Liveworksheet enables effective interaction between students and educators, as well as improves learning achievement.

The results also show that e-worksheet combined with interactive PhET simulation can help students improve their scientific skill, which help students' critical thinking skills. Research by Ariyansah et al., which supports this assertion, proves that applying an electronic worksheet increases the value of students' learning outcomes [23]. In line with what was done by Putri et al., the E-Worksheet, which has been validated based on expert assessment, is practically used in learning because it is able to increase student understanding based on test comparisons before and after learning [32].

CONCLUSION AND SUGGESTION

The purpose of this research was to demonstrate how using an online worksheet on global warming that was integrated with interactive simulations by PhET improved students' critical thinking skills. The use of an e-worksheet combined with interactive PhET simulations can enhance students' critical thinking skills, as shown by their high scores in the implementation and modeling of the physics material related to global warming. The recommendations made based on this research include that observation sheets be added to future research in order to better observe the students as they engage in each learning activity.

ACKNOWLEDGMENTS

Thank you to the Journal of Physics Education Science has provided a platform for sharing and exchanging knowledge. Thank you to Prof. Dr. Jumadi, M.Pd., who helped me to complete my research by guiding and directing me.

REFERENCES

[1] Mardhiyah, R. H., Aldriani, S. N. F., Chitta, F., & Zulfikar, M. R. (2021). Pentingnya keterampilan belajar di abad 21 sebagai tuntutan dalam pengembangan sumber daya manusia. *Lectura: Jurnal Pendidikan*, *12*(1), 29-40.

[2] Sole, F. B., & Anggraeni, D. M. (2018). Inovasi pembelajaran elektronik dan tantangan guru abad 21. *Jurnal Penelitian Dan Pengkajian Ilmu Pendidikan: E-Saintika*, *2*(1), 10-18.

[3] Valtonen, T., Hoang, N., Sointu, E., Näykki, P., Virtanen, A., Pöysä-Tarhonen, J., ... & Kukkonen, J. (2021). How pre-service teachers perceive their 21st-century skills and dispositions: A longitudinal perspective. *Computers in Human Behavior*, *116*, 106643.

[4] Idawati, I., Muhardjito, M., & Yuliati, L. (2019). Authentic learning berbasis inquiry dalam program STEM terhadap literasi saintifik siswa berdasarkan tingkatan kemampuan pemecahan masalah siswa. *Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan*, *4*(8), 1024-1029.

[5] Maskur, R., Rahmawati, Y., Pradana, K., Syazali, M., Septian, A., & Kinarya Palupi, E. (2020). The Effectiveness of Problem Based Learning and Aptitude Treatment Interaction in Improving Mathematical Creative Thinking Skills on Curriculum 2013. *European Journal of Educational Research*, *9*(1), 375-383.

[6] Nygren, T., Haglund, J., Samuelsson, C. R., Af Geijerstam, Å., & Prytz, J. (2019). Critical thinking in national tests across four subjects in Swedish compulsory school. *Education Inquiry*,

10(1), 56-75.
[7] Damayanti, A. E., & Kuswanto, H. (2021). The Effect of the Use of Indigenous Knowledge-Based Physics Comics of Android-Based Marbles Games on Verbal Representation and Critical Thinking Abilities in Physics Teaching. *Journal of Technology and Science Education*, *11*(2), 581-593.
[8] Sumarni, W., & Kadarwati, S. (2020). Ethno-stem project-based learning: Its impact to critical and creative thinking skills. *Jurnal Pendidikan IPA Indonesia*, *9*(1), 11-21.
[9] Tanti, T., Kurniawan, D. A., Kuswanto, K., Utami, W., & Wardhana, I. (2020). Science process skills and critical thinking in science: Urban and rural disparity. *Jurnal Pendidikan IPA Indonesia*, *9*(4), 489-498.
[10] Puspita, I., Kaniawati, I., & Suwarma, I. R. (2017, September). Analysis of critical thinking skills on the topic of static fluid. In *Journal of Physics: Conference Series* (Vol. 895, No. 1, p. 012100). IOP Publishing.
[11] Mahanal, S., Zubaidah, S., Sumiati, I. D., Sari, T. M., & Ismirawati, N. (2019). RICOSRE: A Learning Model to Develop Critical Thinking Skills for Students with Different Academic Abilities. *International Journal of Instruction*, *12*(2), 417-434.
[12] Himawan, N. A., & Ariswan, A. (2023). Physics Learning E-Module Integrated with Practicing Pancasila Values on Momentum and Impulse: Is it Effective to Improve Students' Critical Thinking Skill and Hard Work Character?. *JIPF (Jurnal Ilmu Pendidikan Fisika)*, *8*(1), 30-41.
[13] Alatas, F., & Fauziah, L. (2020). Model problem based learning untuk meningkatkan kemampuan literasi sains pada konsep pemanasan global. *JIPVA (Jurnal Pendidikan IPA Veteran)*, *4*(2), 102-113.
[14] Fauziah, L., Herlina, K., Andra, D., & Abdurrahman, A. (2023). The Effectiveness of Nature of Science-Based Learning Programs to Stimulate Complex Problem-Solving in Global Warming. *JIPF (Jurnal Ilmu Pendidikan Fisika)*, *8*(2), 240-247.
[15] Bouman, T., Verschoor, M., Albers, C. J., Böhm, G., Fisher, S. D., Poortinga, W., ... & Steg, L. (2020). When worry about climate change leads to climate action: How values, worry and personal responsibility relate to various climate actions. *Global Environmental Change*, *62*, 102061.
[16] Nukusheva, A., Ilyassova, G., Rustembekova, D., Zhamiyeva, R., & Arenova, L. (2021). Global warming problem faced by the international community: international legal aspect. *International Environmental Agreements: Politics, Law and Economics*, *21*, 219-233.
[17] Widodo, S. A., Turmudi, T., Dahlan, J. A., Istiqomah, I., & Saputro, H. (2018, July). Mathematical comic media for problem solving skills. In *Joint Workshop KO2PI and The 1st International Conference on Advance & Scientific Innovation* (pp. 101-108).
[18] Hudha, M. N., Aji, S., & Rismawati, A. (2017). Pengembangan modul pembelajaran fisika berbasis problem based learning untuk meningkatkan kemampuan pemecahan masalah fisika. *SEJ (Science Education Journal)*, *1*(1), 36-51.
[19] Yuan, K., Aftoni, A., & Çobanoğlu, Ö. (2020). The effect of problem-based learning model and blended learning model to metacognitive awareness as a reflection towards a new normal era. *Jurnal Pendidikan Teknologi Dan Kejuruan*, *26*(2), 183-188.
[20] Sujatmika, S., Irfan, M., Ernawati, T., Wijayanti, A., Widodo, S., Nurdiyanto, H., & Rahim, R. (2019, April). Designing e-worksheet based on problem-based learning to improve critical thinking. In *Proceedings of the 1st International Conference on Science and Technology for an Internet of Things, 20 October 2018, Yogyakarta, Indonesia*.
[21] Purnawati, W., Maison, M., & Haryanto, H. (2020). E-LKPD Berbasis Technological Pedagogical Content Knowledge (TPACK): Sebuah Pengembangan Sumber Belajar Pembelajaran Fisika. *Tarbawi: Jurnal Ilmu Pendidikan*, *16*(2), 126-133.
[22] Rini, T. A., & Cholifah, P. S. (2020). Electronic module with project based learning: Innovation of digital learning product on 4.0 era. *Teknologi Pendidikan*, *5*(2), 155-161.
[23] Ariyansah, D., Hakim, L., & Sulistyowati, R. (2021). Pengembangan e-LKPD praktikum fisika pada materi gerak harmonik sederhana berbantuan aplikasi phyphox untuk meningkatkan pemahaman konsep peserta didik. *Jurnal Penelitian Pembelajaran Fisika*, *12*(2), 173-181.
[24] Putranta, H., & Wilujeng, I. (2019, August). Physics learning by PhET simulation-assisted using

problem based learning (PBL) model to improve students' critical thinking skills in work and energy chapters in MAN 3 Sleman. In *Asia-Pacific Forum on Science Learning and Teaching* (Vol. 20, No. 1, pp. 1-44). The Education University of Hong Kong, Department of Science and Environmental Studies.

[25] Sugiyono. (2013). *Metode Penelitian Kuantitatif, Kualitatif, dan Tindakan*. Alfabeta.

[26] Hake, R. R. (1999). Analyzing Change/Gain Scores. Dept. of Physics Indiana University. *Unpublished.[Online] URL: http://www. Physics. Indiana. Edu/~ Sdi/AnalyzingChange-Gain. pdf*.

[27] Mardhatilah, R., Zaini, M., & Kaspul, K. (2022). Pengaruh LKPD-Elektronik sistem gerak terhadap hasil belajar dan keterampilan berpikir kritis peserta didik: Effect of movement system LKPD-Electronic on learning outcomes and critical thinking skills of students. *Practice of The Science of Teaching Journal: Jurnal Praktisi Pendidikan*, *1*(2), 53-64.

[28] Sari, R., Perdana, R., Wilujeng, I., & Kuswanto, H. (2019, June). The implementation of problem-based learning model with online simulation to enhance the student's analytical thinking skill in learning physics. In *Journal of Physics: Conference Series* (Vol. 1233, No. 1, p. 012030). IOP Publishing.

[29] Putranta, H., & Kuswanto, H. (2018). Improving students' critical thinking ability using problem based learning (PBL) learning model based on PhET simulation. *SAR Journal*, *1*(3), 77-87.

[30] Ramadan, E. M., & Astuti, D. P. (2020). Application of e-handout based on PhET simulation to improve critical thinking skills and learning independence of high school students. In *Journal of Physics: Conference Series* (Vol. 1440, No. 1, p. 012025). IOP Publishing.

[31] Novikova, Y. (2020). Using liveworksheets to diversify language lessons. *Вісник Харківського національного автомобільно-дорожнього університету*, (91), 221-221.

[32] Putri, W. A. S., Hakim, L., & Sulistyowati, R. (2022). Pengembangan e-lkpd materi efek doppler berbasis inkuiri terbimbing berbantuan aplikasi phyphox untuk meningkatkan pemahaman konsep fisika. *ORBITA: Jurnal Kajian, Inovasi dan Aplikasi Pendidikan Fisika*, *8*(1), 15-20.