

# Students' Critical Thinking: The Effectiveness of Using a Global Warming E-book with PhET Interactive Simulation

Febri Tia Aldila<sup>1\*</sup>, Jumadi<sup>2</sup>, Siti Maryam Ulfa<sup>3</sup>, Abidaturrosyidah<sup>4</sup>, Nurdiyanti<sup>5</sup> 

<sup>1,2,3,4,5</sup> Department Physics Education, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

## ARTICLE INFO

### Article history:

Received July 08, 2024

Accepted November 23, 2024

Available online December 25, 2024

### Kata Kunci:

E-book, PhET, PBL, Pemanasan Global, Berpikir Kritis

### Keywords:

E-book, PhET, PBL, Global Warming, Critical Thinking



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## ABSTRAK

Perkembangan teknologi menyebabkan adanya inovasi pada bahan ajar seperti pengembangan electronic book (e-book). Pada mata pelajaran fisika, e-book perlu dikembangkan dan digunakan secara maksimal untuk menunjang pembelajaran. Penelitian ini bertujuan untuk mengetahui efektivitas penggunaan e-book fisika berbantuan PhET interactive simulation berbasis problem-based learning terhadap kemampuan berpikir kritis siswa pada materi pemanasan global. Penelitian ini merupakan penelitian kuantitatif dengan desain penelitian kuasi eksperimen satu kelompok pretest dan posttest. Subjek dalam penelitian ini terdiri atas 32 siswa kelas pemodelan dan 23 siswa kelas implementasi yang didapatkan dengan teknik cluster sampling. Teknik pengumpulan data yang digunakan adalah tes dan Teknik analisis data adalah N-Gain test. Hasil penelitian menunjukkan bahwa penggunaan e-book fisika berbantuan PhET interactive simulation berbasis problem-based learning pada materi pemanasan global berdampak pada peningkatan kemampuan berpikir kritis siswa. Kemudian, penggunaan e-book fisika tersebut cukup efektif (berada dalam kategori sedang) dalam meningkatkan kemampuan berpikir kritis peserta didik pada kelas modeling dan implementasi. Penggunaan e-book dalam pembelajaran fisika menjadikan siswa lebih tertarik untuk belajar sehingga berdampak pada kemampuan berpikir siswa.

## ABSTRACT

Technological developments have led to innovations in teaching materials such as the development of electronic books (e-books). In physics subjects, e-books need to be developed and used optimally to support learning. This research aims to determine the effectiveness of using physics e-books assisted by PhET interactive simulation based on problem-based learning in improving students' critical thinking skills on global warming material in modeling and implementation classes. This research is a quantitative research with a quasi-experimental research design with one pretest and posttest group. The subjects in this research consisted of 32 modeling class students and 23 implementation class students who were obtained using cluster sampling techniques. The data collection technique used is a test and the data analysis technique is the N-Gain test. The research results show that the use of physics e-books assisted by PhET interactive simulation based on problem-based learning on global warming material has an impact on increasing students' critical thinking abilities. Then, the use of physics e-books is quite effective (in the medium category) in improving students' critical thinking skills in modeling and implementation classes. The use of e-books in physics learning makes students more interested in learning so that it has an impact on students' thinking abilities.

## 1. INTRODUCTION

Along with the increasingly rapid progress of science and technology, learning now plays an increasingly important role in ensuring that students have the skills needed in the 21st century. One of the skills of the 21st century and one of the most important indicators in determining the quality of learning is the ability to think critically (Alsaleh, 2020; Arisoy & Aybek, 2021). Critical thinking as one part of Higher Order Thinking Skills (HOTS) is an ability that involves several processes such as interpreting, analyzing, evaluating and making judgments aimed at reaching conclusions (Arisoy & Aybek, 2021; Ramadhan et al., 2019). Critical thinking emphasizes the importance of in-depth thinking and analysis of the information received to gain a more precise understanding (Khan, 2017; Raj et al., 2022; Yuan & Stapleton, 2020).

\*Corresponding author

Email address: [febri.tia.2023@student.uny.ac.id](mailto:febri.tia.2023@student.uny.ac.id) (Febri Tia Aldila)

Critical thinking is very important for students at school and supports their lives in the future (Jamil et al., 2024; Toheri et al., 2020). The importance of critical thinking has been widely recognized as being able to prepare students for future careers, citizenship, and lifelong learning. Students need critical thinking skills to organize information, data or facts so they are able to solve the problems they face. Critical thinking allows students to be able to process information logically by being able to sort out important, relevant and useful information (A. M. Amin et al., 2020; Rahman, 2019). One of the subjects that requires students to be able to develop critical thinking skills is physics. Physics as a basic science that studies natural phenomena that occur in everyday life has an important role in developing students' abilities. Physics is a science lesson that requires experimental activities as an effort to understand concepts, requiring a high level of ability to explain concepts (Kurniawan et al., 2020; Mafarja et al., 2022; Wartono et al., 2018). Physics plays a role in preparing students to face the growing challenges of life (Rini et al., 2023). This preparation is carried out by equipping students with the ability to think logically, analytically, systematically, critically, creatively, as well as the ability to work together in solving problems (Ariani, 2017; Rini et al., 2023). Physics learning is meaningful learning in developing intellectuals, attitudes, interests, skills, creativity and critical thinking abilities. One of the goals of learning physics is to apply what is learned to everyday life, so students need to be trained to think critically to apply physics concepts in facing problems in everyday life. Learning physics itself helps strengthen and improve students' critical thinking abilities. In studying physics, students must use critical thinking skills to understand complex phenomena such as global warming (Jamil et al., 2024; Mknun, 2020; Misbah et al., 2018).

Global warming is a very worrying issue today. The current global warming is inseparable from the impact of human activities, thus having a negative impact on the earth and human life itself. In the context of learning at school, material about global warming can support students' lives in the future. However, students' understanding of global warming is still very low. Therefore, knowledge about global warming must be introduced to students through the provision of learning materials. It is hoped that providing global warming material will make students more aware of the causes of global warming (Anandhakrishnaveni & Anusuyadevi, 2021; Rosidin & Suyatna, 2017). Studying the causes and impacts of global warming will stimulate students to develop their thinking skills in order to find solutions to the complex challenges of global warming. In other words, students will be trained to think scientifically when studying global warming material. Global warming is one of the physics materials that involves critical thinking skills and scientific literacy to seek further information and solve problems. Thinking skills such as critical thinking skills are important for solving the problem of global warming (Alika et al., 2018; Lestari & Setyarsih, 2021; Suwatra et al., 2018). Global warming material can be taught effectively through technology-based teaching materials such as e-books. E-books or electronic books are teaching materials packaged in electronic format. E-books have become teaching materials that are more interactive, varied and easy to use. E-books have the advantage of being able to integrate images, animation, graphics, sound, video and simulations so that they are able to present richer information compared to conventional books (Acar, 2022; Karagöz et al., 2023; Novita, 2023). The use of e-books in learning can improve students' problem solving abilities, students' learning performance and higher order thinking, and students' critical thinking skills. The use of physics e-books in this research was analyzed to improve students' critical thinking skills. Critical thinking skills in learning can be developed by applying appropriate learning models, in this case the learning model can be integrated into the e-book being developed (Cahyono et al., 2024; Suwatra et al., 2018; Vong & Kaewurai, 2017). One learning model that can help develop students' critical thinking skills and can be integrated into e-books is problem-based learning. Problem-based learning is a learning model that involves students to solve problems and guides them to be able to solve these problems through learning activities carried out during the learning process (Maskur et al., 2020; Sakir & Kim, 2020). Problem-based learning is a learning model that is able to develop high-level thinking skills and the ability to solve problems (Tama et al., 2020; Wilujeng et al., 2022). Problem-based learning can help students be actively involved in learning because students are required to be active in thinking, communicating, processing data and drawing conclusions. The problem-based learning model is able to develop students' curiosity so as to encourage students' critical thinking abilities to the maximum. The problem-based learning model prepares students to think critically and analytically by utilizing appropriate learning resources (S. Amin et al., 2020; Pebriana & Disman, 2017). The learning resource used in this research is a physics e-book assisted by Phet interactive simulation. The use of PhET interactive simulation in learning can improve students' critical thinking skills. Physics learning activities using PhET interactive simulation will make students more interested in doing practicums so that problem solving can be done effectively (Harizon et al., 2024; Widiarta et al., 2023). Research on the development and implementation of physics e-books assisted by PhET interactive simulations is still limited. Moreover, its development on the topic of global warming and its implementation using the problem-based learning model has not yet been conducted. Therefore, this research is important to undertake as it aims to develop and implement a physics e-book assisted by PhET interactive simulations

based on problem-based learning, as well as to understand the impact of its use in enhancing students' critical thinking skills on the topic of global warming. The novelty in this research is examining the implementation of a physics e-book which contains PhET interactive simulation and is supported by a problem-based learning model. Apart from that, global warming material is also the focus of study in the application of the physics e-book being developed. Therefore, it is necessary to carry out research regarding the implementation of physics e-books assisted by PhET interactive simulation based on problem-based learning on global warming material. This research is considered important because it aims to find out whether the use of physics e-books assisted by PhET interactive simulation based on problem-based learning helps improve students' critical thinking skills, especially on global warming material in modeling and implementation classes. Penelitian

## 2. METHOD

This research is a quantitative research with a quasi-experimental research design which was created using a 'one group pretest and posttest' research design. One group pretest-posttest design is a research design where a group is measured and observed before and after treatment is given. This research uses one modeling class and one implementation class. Each class (modeling and implementation) was given a pretest regarding global warming material through 9 multiple choice questions that test students' critical thinking skills. Next, students are given treatment by applying a physics e-book assisted by PhET interactive simulation based on problem-based learning as the main teaching material. In the modeling class, learning is taught by the researcher, while in the implementation class the learning is taught by the physics subject teacher. The final stage is giving a posttest regarding global warming material which contains the same questions as the pretest. This research was carried out at SMAN 4 Yogyakarta. The population in this study were all class X phase E students who took part in learning with the independent curriculum. Meanwhile, the sample in this study was 55 students consisting of 32 students in class XE2 as a modeling class and 23 students in class XE4 as an implementation class. The research sample was obtained using a cluster sampling technique. Cluster sampling divides the population into groups called clusters (for example classes) and then several clusters are selected randomly (Berndt, 2020; Mahargias et al., 2022; Mweshi & Sakyi, 2020). The data collection technique used in this research is the test technique. Tests are an evaluation technique using formal instruments to measure students' knowledge or abilities (Hidayat et al., 2018; Saraswati et al., 2021). An instrument in the form of a written test was used in this research to measure students' critical thinking abilities on global warming material. The test instrument grid used in this research is shown in Table 1.

**Table 1. Critical Thinking Ability Instrument Grid**

Indicators of Critical Thinking Ability	Question Indicator	Item
Provide a simple explanation	Identify the facts of environmental change as a result of global warming	2
Building Basic skills	Analyze environmental changes as the impact of global warming	2
Conclude	Analyze environmental changes as the impact of global warming	2
Provide further explanation	Identify human activities that cause global warming	1
Develop strategies and tactics	Formulate solutions to overcome environmental changes caused by global warming	2

The data analysis technique in this research was carried out by analyzing the results of the pretest and posttest using the N-Gain test. The N-Gain test was carried out with the aim of measuring the increase in understanding or mastery of concepts before and after treatment (Putri et al., 2019; Rusnayati et al., 2023). In this research, the improvement that will be measured is the increase in the results of students' critical thinking abilities before and after using physics e-books assisted by PhET interactive simulation based on problem-based learning as the main teaching material.

## 3. RESULT AND DISCUSSION

### Result

This research aims to measure the effectiveness of using physics e-books assisted by PhET interactive simulation based on problem-based learning on global warming material to improve students'

critical thinking skills. This research was conducted in two classes, namely the modeling class (lessons taught by researchers) and the implementation class (lessons taught by physics subject teachers). Modeling is carried out in class XE2 while implementation is carried out in class XE4. The pretest and posttest data obtained will go through prerequisite tests first. Where the prerequisite tests used are the normality test and homogeneity test. The normality test is a test carried out with the aim of assessing the distribution of data in a group of data or variables, whether the data distribution is normally distributed or not. The normality test results are shown in [Table 2](#).

**Table 2. Normality Test Results**

Class	Test	Shapiro-Wilk		
		Statistic	df	Sig.
Modeling	Pretest	0.937	32	0.060
	Posttest	0.943	32	0.093
Implementation	Pretest	0.969	23	0.672
	Posttest	0.931	23	0.114

The normality test analyzed using Shapiro-Wilk in the modeling class and implementation class. It can be seen that the pretest and posttest in the modeling and implementation classes obtained a significance value of  $> 0.05$ . This shows that the data on students' critical thinking abilities (pretest and posttest) in the modeling and implementation classes is normally distributed. After the data is declared normally distributed, homogeneity testing can then be carried out. The homogeneity test is a statistical test procedure which aims to find out whether the group of data samples taken has the same variance or not. It can also be used to find out whether the sample group is homogeneous or not. The results of the homogeneity test in this research can be seen in [Table 3](#).

**Table 3. Homogeneity Test Results**

Class	Levene Statistic	df1	df2	Sig.
Modeling	3.317	1	62	0.073
Implementation	1.899	1	44	0.175

The homogeneity test where critical thinking skills in the modeling and implementation classes obtained a significance value of  $> 0.05$ . This means that the data on students' critical thinking abilities in modeling and implementation classes is homogeneous or comes from the same variance. After the data is normally distributed and homogeneous, the test can be continued with the one way ANOVA test. One way ANOVA testing was carried out to determine the comparison of the average pretest and posttest scores in the modeling class and in the implementation class. Then, to determine the magnitude of the effect of the difference in average pretest and posttest results in the modeling class and implementation class, an ANOVA test with eta squared was carried out. The results of the one way ANOVA test with eta squared can be seen in [Table 4](#).

**Table 4. One-way ANOVA results with Eta-squared**

Class	df	Mean Square	F	Sig.	Eta Squared
Modeling	1	15385.540	124.157	0.000	0.468
Implementation	1	15848.984	84.443	0.000	0.513

The results of the one-way ANOVA test in the modeling class and implementation class can be seen that the significance value obtained is  $0.000 < 0.05$ . Because the significance value is smaller than 0.05, it can be concluded that the average pretest and posttest results in the modeling class and also in the implementation class are significantly different. The eta squared value used to determine how much these differences affect the results of students' critical thinking abilities. It can be seen that the partial eta squared (effect size) value in the modeling class is 0.468. This shows that the effect size of the difference in pretest and posttest results in the modeling class is 46.8%. The difference in pretest and posttest results was 46.8% due to the use of physics e-books assisted by PhET interactive simulation based on problem-based learning on global warming material which influenced the results of students' critical thinking abilities in the modeling class. It can also be seen that the partial eta squared (effect size) value in the implementation class is 0.513. This shows that the effect size of the difference in pretest and posttest results in the implementation class is 51.3%. The difference in pretest and posttest results was 51.3% due to the use of

physics e-books assisted by PhET interactive simulation based on problem-based learning on global warming material which influenced the results of students' critical thinking abilities in the implementation class. The pretest and posttest scores are calculated using the N-gain test to get an increase in students' critical thinking skills. The results of the students' critical thinking skills test for the modeling class are shown in table 5 and the results of the N-gain analysis are shown in Table 6. Furthermore, to calculate the magnitude of the increase or change in test scores before and after treatment the N-Gain test was used . N-Gain was used to determine the increase in students' critical thinking skills before and after using physics e-books assisted by PhET interactive simulation based on problem-based learning on global warming material in modeling classes and also implementation classes. The N-Gain test results can be shown in [Table 5](#).

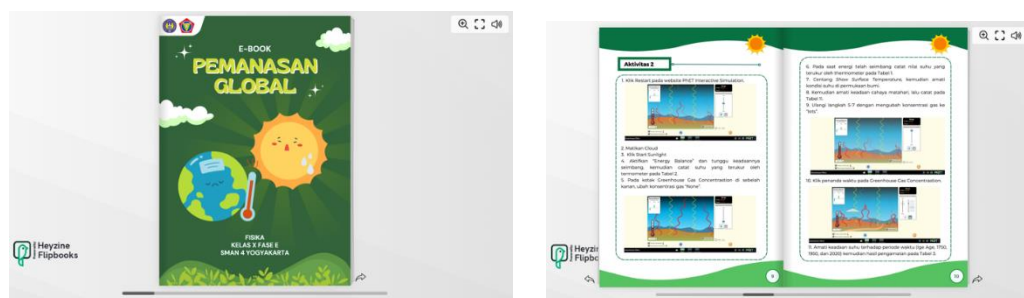
**Table 5. N-Gain Test Results**

Class	Test	Mean
Modeling	Pretest	48.61
	Posttest	77.43
	N-Gain	0.5576
	N-Gain (%)	55.76%
Implementation	Pretest	41.06
	Posttest	74.88
	N-Gain	0.5926
	N-Gain (%)	59.26%

The average N-Gain score in the modeling class is 0.5576 (medium criteria). In other words, there was an increase in students' critical thinking skills by 55.76% after using the physics e-book assisted by PhET interactive simulation based on problem-based learning on global warming material in the modeling class. Meanwhile, the average N-Gain score in the implementation class was 0.5926 (medium criteria). In other words, there was an increase in students' critical thinking skills by 59.26% after using the physics e-book assisted by PhET interactive simulation based on problem-based learning on global warming material in the implementation class. So, it can be concluded that the physics e-book product assisted by PhET interactive simulation based on problem-based learning on global warming material is quite effective in improving students' critical thinking skills in modeling classes and also in implementation classes.

**Discussion**

The increasingly widespread use of technology in learning has a significant impact on learning itself because it can enrich the learning experience. This also happens in physics learning which gets many benefits from the use of technology in it. Learning that uses information and communication technology can improve students' physics learning outcomes (Criollo-C et al., 2021; Zhai & Shi, 2020). The use of technology in learning physics can be done in many ways, one of the ways used in this research is the development of physics e-books. This research developed a physics e-book assisted by PhET interactive simulation based on problem-based learning on global warming material which can be accessed using a smartphone or computer. The physics e-book was developed by following the syntax of the problem-based learning model, namely problem orientation, organizing students, conducting investigations, developing work results, and analyzing and evaluating. Apart from that, the physics e-book is equipped with PhET interactive simulation which supports students' understanding of global warming material. The appearance of the physics e-book being developed is shown in [Figure 1](#).



**Figure 1. Physics E-book**

This research examines the use of physics e-books assisted by PhET interactive simulation based on problem-based learning in improving students' critical thinking skills, especially on global warming material. The research was conducted in two classes, namely the modeling class and the implementation class. Modeling class is a class where learning is carried out with direction from students (students act as teachers). Meanwhile, the implementation class is a class where learning is carried out directly by the physics subject teacher. In each modeling and implementation class, a pretest and posttest are given to test students' critical thinking skills regarding global warming material. Based on the partial eta squared value obtained, the use of physics e-books assisted by PhET interactive simulations based on problem based learning on global warming material has a quite effective impact (in the medium category) on improving students' critical thinking skills in modeling and implementation classes. The value of increasing students' critical thinking skills can also be calculated using the N-Gain test. N-Gain functions to determine the increase in students' critical thinking skills before and after using physics e-books assisted by PhET interactive simulation based on problem-based learning on global warming material. This improvement was studied in both classes, namely the modeling class and the implementation class. Physics e-books assisted by PhET interactive simulations based on problem based learning on global warming material are quite effective (in the medium category) in improving students' critical thinking skills in modeling classes and also in implementation classes. E-books as a form of innovative teaching material are currently increasingly being used in learning. E-books provide a variety of additional instructional materials that can be used and support learning (Alsadoon, 2020). E-books as a medium for learning activities can increase students' learning motivation because they have many interesting features to use (Alsadoon, 2020; Ramadhani & Khusniati, 2022). Many studies have been carried out on developing and studying e-books and show that the use of e-books can provide many benefits. This research is in line with research conducted by other researches which states that e-books used effectively in learning can improve students' critical thinking abilities. Of course, this research is in line with the research the author conducted. Students feel that e-books are easier to access anywhere and at any time so they are effective in training students' critical thinking skills. Increasing students' critical thinking skills as a result of using e-books can occur because of special content, interactive elements, interesting learning designs, and so on (Cahyono et al., 2024)(Adam et al., 2023; Nabila et al., 2023; Pratiwi et al., 2022). E-books have great potential to develop critical thinking skills or other abilities in the current era of digital technology-based learning.

E-books as a learning medium have been widely used and provide positive benefits in various subjects, one of which is physics. E-books are one of the innovations in teaching physics in order to provide a more interesting learning experience to students. Apart from that, there are many developments in physics e-books with problem-based learning models. The combination of physics e-books and problem-based learning models makes students learn physics more interestingly because they try to solve physics problems given through technological innovation in the form of physics e-books. This research is in line with research conducted by other researches which states that the use of e-books based on problem-based learning in science learning can improve students' critical thinking skills through innovations such as narratives, videos, animations, digital media and practice questions. Apart from that, other researches also found that the effective use of e-books based on problem-based learning was able to improve students' critical thinking skills in physics subjects. Of course, there are many additional instructional innovations that can be included in physics e-books to improve students' critical thinking skills, one of which is PhET interactive simulation (Susanto et al., 2022; Zulaikha et al., 2022).

PhET interactive simulation is a medium that can be integrated into physics e-books because it will make students more active in learning. Learning assisted by PhET interactive simulation can improve students' critical thinking skills. The e-book developed in this research contains PhET interactive simulations on global warming material. This research is in line with research conducted by other researches which states that learning physics using PhET interactive simulation does not take a long time so that students can carry out experiments effectively, efficiently and can improve students' critical thinking skills. PhET interactive simulation is able to make students feel happy and interested in conducting experiments so that its use gives rise to very positive student responses. Other researches stated that there was an increase in students' critical thinking results after using PhET interactive simulation. Furthermore, the use of PhET interactive simulation in physics subjects is also able to improve students' critical thinking abilities. Research conducted by other research shows that the use of e-handouts assisted by PhET with a problem-based learning model can improve students' critical thinking skills and learning independence. Then, other research found that learning physics using PhET interactive simulation was able to improve students' critical thinking skills as seen from the problem solving patterns carried out by students. The use of PhET interactive simulation makes learning a discovery process which is characteristic of physics learning itself (Alfiyanti et al., 2020; Harizon et al., 2024; Ramadan et al., 2020; Viratama & Maskhuliah, 2022). The relevance between previous research and this research is the use of teaching materials in the

form of e-books, the use of problem-based learning models, and the use of PhET interactive simulation. The novelty of this research is that it combines the use of e-books, problem-based learning models, PhET interactive simulation in learning physics about global warming. Apart from that, this research also examines the effectiveness of using e-books in improving students' critical thinking skills in modeling classes and implementation classes. It was found that the use of physics e-books assisted by PhET interactive simulation based on problem-based learning on global warming material was able to improve students' critical thinking skills in modeling and implementation classes. So, this research has implications for physics learning, especially on global warming material, where the use of the physics e-book can improve students' critical thinking skills. This research still has shortcomings where the limitation in this research is the limited features or additional instructions available in physics e-books. So, the author suggests that further research be able to develop a physics e-book assisted by PhET interactive simulation based on problem-based learning with various additional instructional and interesting features so that it can be interesting to use in learning. Apart from that, e-book development can be carried out on other physics material, on other subjects, or integrated with other learning models.

#### 4. CONCLUSION

The use of physics e-books assisted by PhET interactive simulation based on problem based learning on global warming material affected students' critical thinking skills both in modeling and implementation classes. The increase in students' critical thinking skills when using the physics e-book assisted by PhET interactive simulations based on problem-based learning on global warming material in both the modeling class and the implementation class is categorized as medium. Furthermore, the author suggests to physics subject teachers in schools to be able to vary or develop technology-based teaching materials such as physics e-books assisted by PhET interactive simulation based on problem based learning on other physics materials.

#### 5. REFERENCES

- Acar, A. (2022). A Step-by-Step Guide to Building a Computer-Based Digital Education (CBE) Model with an Interactive Electronic Book (E-book). *International Journal of Environmental Trends*, 6(2), 48–64. <https://dergipark.org.tr/en/pub/ijent/issue/74172/1211477>.
- Adam, A. S., Supriana, E., & Nasikhudin, N. (2023). All-in-One E-Book Development in Proposing Automatic Critical Thinking Skill Assessments. *Studies in Learning and Teaching (SiLeT)*, 4(2), 273–284. <https://doi.org/10.46627/silet>.
- Alfiyanti, I. F., Jatmiko, B., & Wasis, W. (2020). Studies in Learning and Teaching Studies in Learning and Teaching The Effectiveness of Predict Observe Explain (POE) Model with PhET to Improve Critical Thinking Skills of Senior High School Students. *Studies in Learning and Teaching*, 1(2), 76–85. <https://doi.org/10.46627/silet>.
- Alika, M. F., Darsono, T., & Linuwih, S. (2018). Pengembangan Soal Model Pisa untuk Mengukur Kemampuan Berpikir Tingkat Tinggi Siswa SMP pada Materi Pemanasan Global. *UPEJ Unnes Physics Education Journal*, 7(3), 58–65. <http://journal.unnes.ac.id/sju/index.php/upej>.
- Alsadoon, H. (2020). Obstacles to Using E-Books in Higher Education. *International Journal of Education and Literacy Studies*, 8(2), 44. <https://doi.org/10.7575/aiac.ijels.v.8n.2p.44>.
- Alsaleh, N. J. (2020). Teaching Critical Thinking Skills: Literature Review. *TOJET: The Turkish Online Journal of Educational Technology*, 19(1). <https://eric.ed.gov/?id=EJ1239945>.
- Amin, A. M., Corebima, A. D., Zubaidah, S., & Mahanal, S. (2020). The correlation between metacognitive skills and critical thinking skills at the implementation of four different learning strategies in animal physiology lectures. *European Journal of Educational Research*, 9(1), 143–163. <https://doi.org/10.12973/eu-jer.9.1.143>.
- Amin, S., Utaya, S., Bachri, S., Sumarmi, S., & Susilo, S. (2020). Effect of problem-based learning on critical thinking skills and environmental attitude. *Journal for the Education of Gifted Young Scientists*, 8(2), 743–755. <https://doi.org/10.17478/jegys.650344>.
- Anandhakrishnaveni, A. R., & Anusuyadevi, S. (2021). A Study on Global Warming Awareness among Student Teachers. *Journal of AKCE*, 4(1), 1–9. [www.akcequest.com](http://www.akcequest.com).
- Ariani, T. (2017). Pembelajaran Kooperatif Tipe Team Assisted Individualization (TAI): Dampak Terhadap Hasil Belajar Fisika Siswa. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, 6(2), 169–177. <https://doi.org/10.24042/jipfalbiruni.v6i2.1802>.
- Arisoy, B., & Aybek, B. (2021). The effects of subject-based critical thinking education in mathematics on students' critical thinking skills and virtues\*. *Eurasian Journal of Educational Research*, 1(92), 99–

120. <https://doi.org/10.14689/ejer.2021.92.6>.
- Berndt, A. E. (2020). Sampling Methods. *Journal of Human Lactation*, 36(2), 224–226. <https://doi.org/10.1177/0890334420906850>.
- Cahyono, B. T., Qodr, T. S., & Budiarto, M. K. (2024). Improving the Critical Thinking Ability of Vocational High School Students through Digital Teaching Material. *Journal of Education Research and Evaluation*, 8(1), 143–153. <https://doi.org/10.23887/jere.v8i1.61457>.
- Criollo-C, S., Guerrero-Arias, A., Jaramillo-Alcázar, Á., & Luján-Mora, S. (2021). Mobile learning technologies for education: Benefits and pending issues. *Applied Sciences (Switzerland)*, 11(9). <https://doi.org/10.3390/app11094111>.
- Harizon, H., Asrial, A., Haryanto, H., Kurniawan, D. A., Rini, E. F. S., Aldila, F. T., Fitriani, R., & Sinaga, F. P. (2024). Study of Correlation: Science Process Skills and Persistence Character of Middle School Students. *Mimbar Ilmu*, 29(1), 23–31. <https://doi.org/10.23887/mi.v29i1.68267>.
- Hidayat, T., Susilaningsih, E., & Kurniawan, C. (2018). The effectiveness of enrichment test instruments design to measure students' creative thinking skills and problem-solving. *Thinking Skills and Creativity*, 29(1), 161–169. <https://doi.org/10.1016/j.tsc.2018.02.011>.
- Jamil, M., Abdul Hafeez, F., & Muhammad, N. (2024). Critical Thinking Development for 21 st Century: Analysis of Physics Curriculum. *Article in Journal of Social & Organizational Matters*, 2(3), 1–10. <https://doi.org/10.56976/jsom.v3>.
- Karagöz, E., Çavaş, B., Güney, L. Ö., & Dizdaroğlu, A. (2023). design model proposal for digital learning platform based on interactive e-books. *Ukrainian Journal of Educational Studies and Information Technology*, 11(3), 156–176. <https://doi.org/10.32919/uesit.2023.03.02>.
- Khan, S. I. (2017). Critical Thinking in a Higher Education Functional English Course. *European Journal of Educational Research*, 6(1), 59–67. <https://doi.org/10.12973/eu-jer.6.1.59>.
- Kurniawan, W., Pathoni, H., Muliawati, L., Kurniawan, D. A., Romadona, D. D., Ningsi, A. P., & Dari, R. W. (2020). Relationship of science process skills and critical thinking of students in physics subject. *Universal Journal of Educational Research*, 8(11), 5581–5588. <https://doi.org/10.13189/ujer.2020.081162>.
- Lestari, D., & Setyarsih, W. (2021). Analysis of Students' Scientific Literacy Skills and the Relationship with Critical Thinking Skills on Global Warming Materials. *Journal of Physics: Conference Series*, 1805(1). <https://doi.org/10.1088/1742-6596/1805/1/012040>.
- Mafarja, N., Zulnaidi, H., & Mohd. Fadzil, H. (2022). Using Reciprocal Teaching Strategy to Improve Physics Students' Critical Thinking Ability. *Eurasia Journal of Mathematics, Science and Technology Education*, 18(1). <https://doi.org/10.29333/EJMSTE/11506>.
- Mahargias, H., Wekadigunawan, & Wahidi, K. R. (2022). The Effectiveness of Patient Safety Training in Cikupa Hospitals: Study Quasi Experiment. *European Journal of Business and Management Research*, 7(6), 141–146. <https://doi.org/10.24018/ejbmr.2022.7.6.1646>.
- Maknun, J. (2020). Implementation of Guided Inquiry Learning Model to Improve Understanding Physics Concepts and Critical Thinking Skill of Vocational High School Students. *International Education Studies*, 13(6), 117. <https://doi.org/10.5539/ies.v13n6p117>.
- Maskur, R., Sumarno, R., Y., P., K., S., M., S., A., & Palupi, E. K. (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. <https://doi.org/10.12973/eu-jer.9.1.375>.
- Misbah, M., Mahtari, S., Wati, M., & Harto, M. (2018). Analysis of Students' Critical Thinking Skills in Dynamic Electrical Material. *Physics Education Journal*, 1(2), 103–110. <http://jurnal.unipa.ac.id/index.php/kpej>.
- Mweshi, G. K., & Sakyi, K. (2020). Application of sampling methods for the research design. *Archives of Business Research*, 8(11), 180–193. <https://doi.org/10.14738/abr.811.9042>.
- Nabila, A., Soendjoto, M. A., & Winarti, A. (2023). Effectiveness of e-book “Ethno-ecology study of Magnoliopsida in Desa Kiram” to train students' critical thinking skills. *BIO-INOVED : Jurnal Biologi-Inovasi Pendidikan*, 5(3), 321. <https://doi.org/10.20527/bino.v5i3.16584>.
- Novita, R. R. (2023). Physics E-book with Augmented Reality to Improve Students' Interest in Physics. *JPI (Jurnal Pendidikan Indonesia)*, 12(1), 145–154. <https://doi.org/10.23887/jpiundiksha.v12i1.52764>.
- Pebriana, R., & Disman, D. (2017). Effect of Problem Based Learning to Critical Thinking Skills Elementary School Students in Social Studies. *Primaryedu: Journal of Primary Education*, 1(1), 109–118. <https://doi.org/10.22460/pej.v1i1.487>.
- Pratiwi, A. D. P., Kristiani, & Noviani, L. (2022). The Effectiveness of Using E-Book to Improve Student's Critical Thinking Skill. *International Journal of Multicultural and Multireligious Understanding*, 9(10), 196–201. <https://doi.org/10.18415/ijmmu.v9i10.4095>.



- Putri, M. D., Rusdiana, D., & Rochintaniawati, D. (2019). Students' conceptual understanding in modified flipped classroom approach: An experimental study in junior high school science learning. *Journal of Physics: Conference Series*, 1157(2). <https://doi.org/10.1088/1742-6596/1157/2/022046>.
- Rahman, M. M. (2019). 21st Century Skill "Problem Solving": Defining the Concept. *Asian Journal of Interdisciplinary Research*, 2(1), 64–74. <https://doi.org/10.34256/ajir1917>.
- Raj, T., Chauhan, P., Mehrotra, R., & Sharma, M. (2022). Importance of Critical Thinking in the Education. *World Journal of English Language*, 12(3), 126–133. <https://doi.org/10.5430/wjel.v12n3p126>.
- Ramadan, E. M., Jumadi, & Astuti, D. P. (2020). Application of e-handout based on PhET simulation to improve critical thinking skills and learning independence of high school students. *Journal of Physics: Conference Series*, 1440(1). <https://doi.org/10.1088/1742-6596/1440/1/012025>.
- Ramadhan, S., Mardapi, D., Prasetyo, Z. K., & Utomo, H. B. (2019). The development of an instrument to measure the higher order thinking skill in physics. *European Journal of Educational Research*, 8(3), 743–751. <https://doi.org/10.12973/eu-jer.8.3.743>.
- Ramadhani, V. Y., & Khusniati, M. (2022). Development of Interactive E-Books containing Virtual Laboratory to Improve Students' Motivation Learning. *Journal of Environmental and Science Education*, 2(1), 49–57. <https://doi.org/10.15294/jese.v2i1.53125>.
- Rini, E. F. S., Aldila, F. T., & Wirayuda, R. P. (2023). A Study of Student Learning Discipline in Senior High School. *Jurnal Ilmiah Ilmu Terapan Universitas Jambi*, 7(1), 33–37. <https://doi.org/10.22437/jiituj.v7i1.26698>.
- Rosidin, U., & Suyatna, A. (2017). Teachers and Students Knowledge about Global Warming: a Study in Smoke Disaster Area of Indonesia. *International Journal of Environmental & Science Education*, 12(4), 777–785. <https://eric.ed.gov/?id=EJ1144822>.
- Rusnayati, H., Ruswandi, W., & Khotimah, T. H. (2023). The Effectiveness of the Problem-Based Flipped Classroom Learning Model to Improve Conceptual Understanding of Physics Teacher Candidates on Crystal Structure Material. *Journal of Science Learning*, 6(2), 194–203. <https://doi.org/10.17509/jsl.v6i2.56316>.
- Sakir, N. A. I., & Kim, J. G. (2020). Enhancing Students' Learning Activity and Outcomes via Implementation of Problem-based Learning. *Eurasia Journal of Mathematics, Science and Technology Education*, 16(12), 1925. <https://doi.org/10.29333/ejmste/9344>.
- Saraswati, D., Lestari, W., & Haryani, S. (2021). The Development of An Android-Based Assessment Instrument To Assess Fifth-Grade Students' Cognitive Ability. *Journal of Educational Research and Evaluation*, 10(2), 100–107. <http://journal.unnes.ac.id/sju/index.php/jere>.
- Susanto, T. T. D., Dwiyantri, P. B., Marini, A., Sagita, J., Safitri, D., & Soraya, E. (2022). E-Book with Problem Based Learning to Improve Student Critical Thinking in Science Learning at Elementary School. *International Journal of Interactive Mobile Technologies*, 16(20), 79–97. <https://doi.org/10.3991/ijim.v16i20.33173>.
- Suwatra, W., Suyatna, A., & Rosidin, U. (2018). Development of Interactive E-Module for Global Warming to Grow of Critical Thinking Skills. *International Journal of Advanced Engineering, Management and Science*, 4(7), 543–549. <https://doi.org/10.22161/ijaems.4.7.7>.
- Tama, N. S., Aisyah, N., Santoso, B., & Kurniadi, E. (2020). Learning higher-order thinking skills using problem-based learning model. *Journal of Physics: Conference Series*, 1480(1). <https://doi.org/10.1088/1742-6596/1480/1/012008>.
- Toheri, W., W., & Haqq, A. A. (2020). Where exactly for enhance critical and creative thinking: The use of problem posing or contextual learning. *European Journal of Educational Research*, 9(2), 877–887. <https://doi.org/10.12973/eu-jer.9.2.877>.
- Viratama, I. P., & Maskhuliah, P. (2022). The Effect of Phet Simulation Media on Critical Thinking Ability and Learning Outcomes of SMA Negeri Yokiwa. *Edumaspul: Jurnal Pendidikan*, 6(2), 1963–1966. <https://phet.colorado.edu>.
- Vong, S. A., & Kaewurai, W. (2017). Instructional model development to enhance critical thinking and critical thinking teaching ability of trainee students at regional teaching training center in Takeo province, Cambodia. *Kasetsart Journal of Social Sciences*, 38(1), 88–95. <https://doi.org/10.1016/j.kjss.2016.05.002>.
- Wartono, W., Hudha, M. N., & Batlolona, J. R. (2018). How are the physics critical thinking skills of the students taught by using inquiry-discovery through empirical and theoretical overview? *Eurasia Journal of Mathematics, Science and Technology Education*, 14(2), 691–697. <https://doi.org/10.12973/ejmste/80632>.
- Widiarta, I. G. K. A. A. P., Antara, I. G. W. S., & Dewantara, K. A. K. (2023). Problem Based Learning Model Assisted by PhET Interactive Simulation Improves Critical Thinking Skills of Elementary School Students. *Thinking Skills and Creativity Journal*, 6(1), 1–8.

- <https://doi.org/10.23887/tscj.v6i1.61945>.
- Wilujeng, S., Sudihartinih, E., & Hasanah, A. (2022). Problem Based Learning Model Based on High Order Thinking Skills for Enhancing Mathematic Literacy for High School Students. *Sriwijaya International Journal of Lesson Study*, 3(1), 1–12. <https://doi.org/10.36706/sij-ls.v3i1.22>.
- Yuan, R., & Stapleton, P. (2020). Student teachers' perceptions of critical thinking and its teaching. *ELT Journal*, 74(1), 40–48. <https://doi.org/10.1093/ELT/CCZ044>.
- Zhai, X., & Shi, L. (2020). Understanding How the Perceived Usefulness of Mobile Technology Impacts Physics Learning Achievement: a Pedagogical Perspective. *Journal of Science Education and Technology*, 29(6), 743–757. <https://doi.org/10.1007/s10956-020-09852-6>.
- Zulaikha, D. F., Dwandaru, W. S. B., & Rahmasari, A. A. (2022). Problem-Based Multimedia E-books: The Effect on Students Creative Thinking Skills in Physics Course. *ISTANBUL International Conference on "Arts, Literature, Humanities and Social Sciences"*, 22–28. <https://doi.org/10.17758/dirpub11.dir0522407>.