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Meta-Analysis of Students' Critical Thinking Skills Improvement on Physics Learning

Nurul Hikmah and Mukhayyarotin Niswati Rodliyatul Jauhariyah
Undergraduate Programme of Physics Education, Universitas Negeri Surabaya, Indonesia
nurul.17030184022@mhs.unesa.ac.id

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Abstract

Critical-thinking skill is one of the 21st-century abilities that students must have. This study aimed to analyze the critical thinking abilities to improve physics learning that was reviewed: overall, learning model, education level, subject matter, and the media used. This research method used meta-analysis. The meta-analysis research stage was to determine the research topic, decide data selection criteria, search for data, visualize VOSviewer, classify data information, calculate the effect size, and then analyze the data and conclude. The data collection technique used secondary data from previous research of 18 scientific publication articles. The data analysis technique used the effect size. This meta-analysis concluded that critical-thinking skills significantly influence physics learning, with an average effect size of 1.33 and an influence of 90%. Critical thinking skills in learning physics can significantly affect vocational education with the cooperative-learning time-token type model, using the subject of static fluid, and assisted by real learning media using a puzzle.

Keywords: A Meta-Analysis; Critical-Thinking Skills; Physics Learning

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INTRODUCTION

In this 21st century, as science and technology are rapidly developing, everybody will be expected to grow into a global competitor. Humans must be superior human resources (A. Setiawan et al., 2019). Education is fundamentally a strategic effort to improve human resources' capabilities in the face of 21st-century problems (Nisa et al., 2018). Trilling and Hood's list of 21st-century skills contains life and career skills, communication, media, and learning skills, as well as critical thinking and innovation skills (Trilling & Hood, 1999). These skills are learned through a formal and informal learning process.

Physics is a branch of natural science that consists of knowledge (products), ways of thinking, ways of working (attitudes) and methods of carrying out scientific research whose studies are limited to the real world and aims to provide an understanding of natural phenomena (Nadiya et al., 2016). In physics learning, students do not learn the finished product or the result; instead, they should engage in specific experimental experiments that will contribute to the product development process. When studying physics, students memorize the content and comprehend and apply it (Diani et al., 2020). Therefore, learning physics needs

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critical-thinking skills (Wati & Fatimah, 2016).

Critical thinking is a natural ability and pattern founded on reasoning and interpretation that can be practiced as much as possible. Critical thinking is a component of the capacity to reason logically and rationally. It refers to the ability to investigate problems, questions, or scenarios using facts, real-world conditions, and beliefs (Rahim et al., 2019).

Critical thinking is one of the skills that students must possess to succeed in today's educational environment. Because the critical review helps to solve a variety of problems, both those specific to their subject of research and those that they will face in daily life (Miterianifa et al., 2019). Other than that, one of the most important goals of education is to improve students' critical-thinking skills (Hunaidah et al., 2018).

National Education Standards Agency (NESA, 2006) claimed that one of the goals of physics learning in school was to develop reasoning skills in inductive and deductive analytical thinking. It is created by using physics concepts and principles. Also, it aimed to solve problems either qualitatively or quantitatively and explain various natural phenomena. For this reason, critical thinking in physics learning is vital to make the concept of physics appropriately built and the objectives of learning physics in school achieved.

Due to the critical role in education, research about necessary thinking skills also grows so fast in physics learning and other learning. Starting from development, implementation, the influence of a learning model, and others.

Due to the speedy development of research, a visualization showing how far the result and scatter of research is and to find out the novelty of research. Using VOSviewer, you can imagine the analysis scatter in network visualization, overlay visualization and density visualization. Visualization of the dissemination of students' critical-thinking skills research using network visualization is shown in Figure 1.

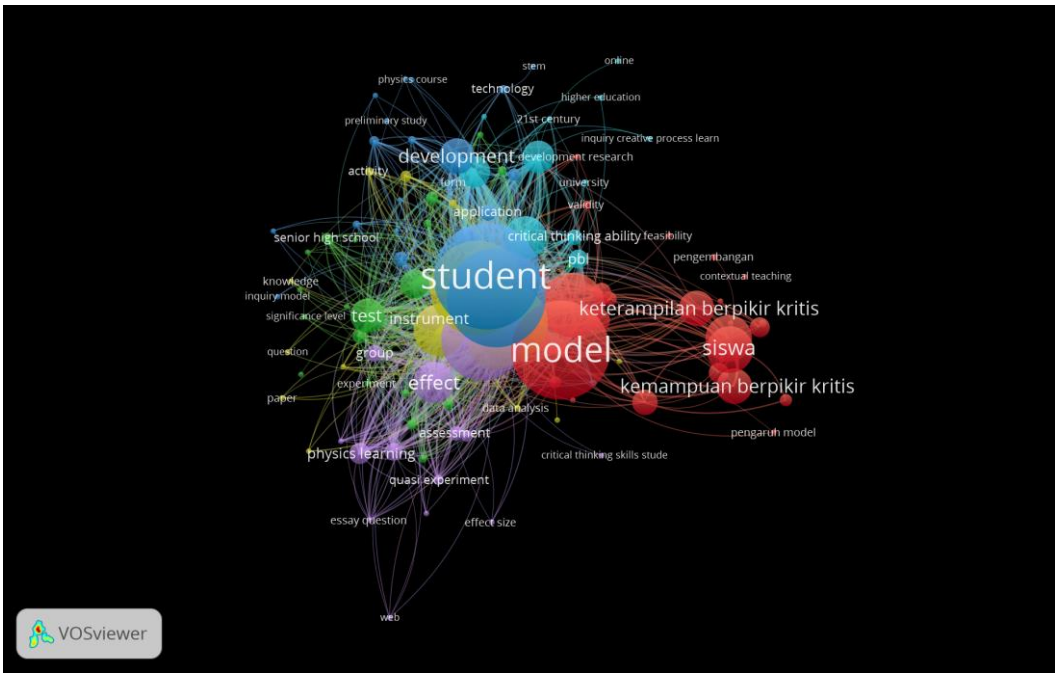

Figure 1 Visualization of Research Critical Thinking Skill in Physics Use Network Visualization

The journal visualized the average around the years 2016 until 2021. From Figure 1, it knows that the research scatters critical-thinking skills in physics learning, differentiated in 5 clusters in a different color. The color is blue, red, yellow, and violet. This visualisation informs the research on critical thinking which is dominant is that the student as the object with different learning pattern. To explore further research on critical thinking in physical learning using VOSviewer, we can see a visualization of density (Figure 2).

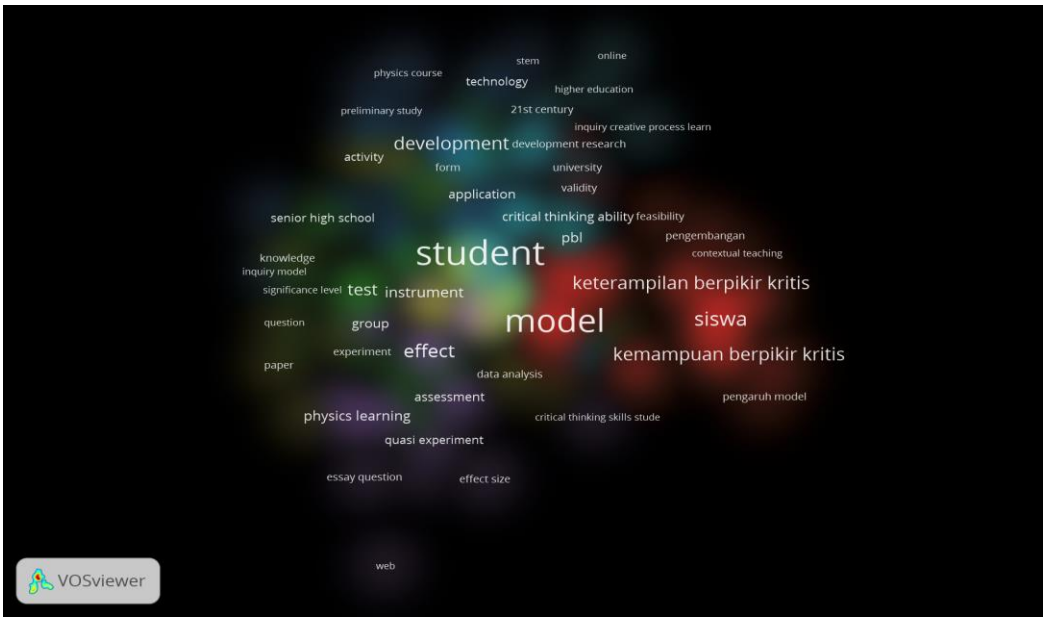

Figure 2 Visualization of Research Critical Thinking Skill in Physics Use Density Visualization

Figure 2 informs that critical-thinking skills in physics learning use many research designs, media, method, and learning model. From cluster with red color, research about critical-thinking skills is dominant in different learning models with research about the impact of a learning model or a development learning model for critical-thinking skills. Because of that, I need to do a meta-analysis about critical-thinking skills improvement in physics learning.

Meta-analysis states the study's findings with effect size (ES) (Miterianifa et al., 2019). This technique aims to answer questions about the differences between experimental and control groups based on research that develops from year to year. Meta-analysis' main goal is to provide a standard methodology for conducting the literature review necessary for experimental studies (Decoster & Hall, 2004).

During this time, the research using critical thinking skills with various learning models, applied to physics learning on various material topics. But we do not know how the capture of its relationship. We also don't know what the most appropriate model or strategy to improve the critical thinking skills in physics learning. Some researchers apply constructivist learning models to improve critical thinking skills such as Problem Based Learning (Alandia et al., 2019; Islamiah et al., 2018; Mundilarto & Ismoyo, 2017; Parno et al., 2019; Putri et al., 2018), Cooperative Learning (Latifah, 2015), Group Investigation (Santyasa et al., 2018), and Guided Inquiry (Maknun, 2020; Nurbaiti et al.,

2016; Rinaldo et al., 2017; Suryanti et al., 2018). Some researchers also use the learning model such as Blended Learning (W. Suana et al., 2020; Wayan Suana, Istiana, et al., 2019a; Wayan Suana, Raviany, et al., 2019), Direct Instruction (Risdianto et al., 2020), Fera Learning Model (Diani et al., 2020), Inductive Learning Model (Barra et al., 2019), and Mobile Learning (Astuti et al., 2018). Almost all these research only aims to implement or determine the effect of a learning model on critical thinking skills in physics learning but do not calculate effect sizes or perform meta-analysis of the research results. Research related to meta-analysis of critical thinking skills was carried out by (Syafrial, 2018) and (Miterianifa et al., 2019), but the analysis is limited to one learning model and no other learning model is used as a comparison. However, it has never investigated in detail about critical-thinking skills, having a more substantial effect on what learning models, what material, what media, or education level. Therefore, a meta-analysis on improving critical thinking skills in physics learning has to be performed. This meta-analysis aims to understand the correlation, or a general conclusion based on related research findings about critical-thinking skills improvement in physics learning. We hope that the results of the meta-analysis of this research can provide recommendations to the teacher or prospective teachers in improving students' critical thinking skills. They can use what kind of learning model, what media, and what material in physics.

METHOD

This research is a type of library research to analyze students' critical-thinking skills improvement in physics learning using the meta-analysis method. Meta-analysis is a statistical method that combines data from similar previous studies and obtains general synthesis. The steps in this research are performed through the meta-analysis steps presented in Figure 3.

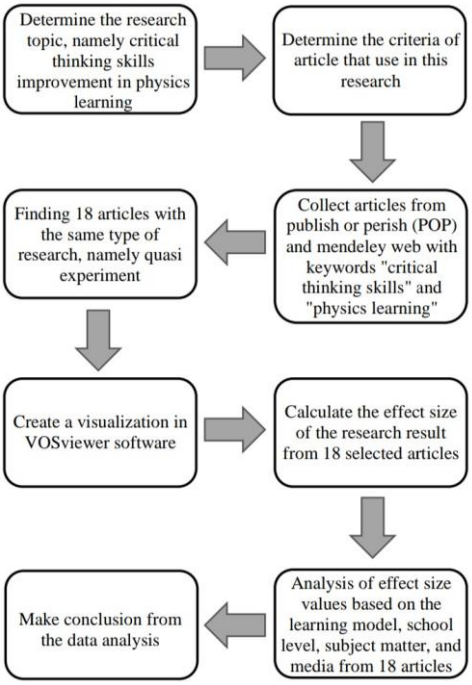

Figure 3 Methods of Data Collection and Data Processing
(Adapted from research conducted by Rachman & Jauhariyah, 2020)

The research data collection technique uses secondary data from previous research in the form of scientific publication articles with the following criteria: (1) The article topic is critical-thinking skills improvement in physics learning; (2) Articles come from journals accredited by SINTA, ranked one to SINTA ranked three and internationally accredited; (3) Articles published in the period 2015-2020. The number of articles used in this research is 18 articles; (4) The article uses a quasi-experimental research type; (5) Articles qualify statistical data in the calculation of the effect size; (6) The article contains information about the learning model, education level, media, and subject in physics learning.

The data collection process can be made more accessible by using coding

data. In accordance with Figure 3, coding data is used when 18 articles have been obtained by the same type of research, namely quasi experiment. Coding data that use in this research is CST which abbreviation for "Critical Thinking Skill". The 18 articles that have been obtained are coded “CST 1” until “CST 18” with the aim of distinguishing one article and the other article. The method of analyzing and testing existing raw data by labeling (adding labels) in the form of words, phrases, or sentences are referred to as coding data (Junaid, 2018). Information on the results of coding data shown in Table 1.

Table 1 Information The Result of Coding Data

Information	**Education Level**	**Subject**	**Media**
Elementary School	1		
Junior High School	1		
Senior High School	14		
Vocational High School	1		
Higher Education	1		
Static Electricity		2	
Wave		1	
Energy, Impulse and Momentum		1	
Elasticity And Hooke's Law		1	
Refraction Of Light		1	
Light Material		1	
Static Fluid		1	
Optical Eye		1	
Dynamic Of Motion		1	
Optics		1	
Optical Instrument		1	
Heat And Temperature		1	
Direct Current Electricity		1	
Not Identify		4	
Schoology			2
WhatsApp			1
Puzzle			1
Student Worksheet			6
Textbook			1
Mind map, Mindjet, Mindmanajer			1
Pocket Mobile			1
Web			1
Observation Sheet			1
Non-Media			3
Total Articles	**18**	**18**	**18**

Table 1 informs the results of coding data based on education level, subject in physics, and the media used. Research related to critical thinking skills in physics learning has been developed from the lowest level of education to higher education levels, namely elementary school, junior high school, senior high school, vocational high school, and higher education. Although most of the research is carried out at the senior high school level with total article is 14. Table 1 also informs about subject in physics that can be used to improve critical thinking skills in physics learning, where there are 12 articles using different subjects, 2 articles using the same subject namely static electricity

and 4 other articles that were not identified. These subjects can be categorized into electrical, thermodynamic, mechanical, and optical subject which can be real or abstract. Mechanical and optical are included in real subjects because they can be observed directly in everyday life. An example is the phenomenon of a car moving in a straight line at a certain speed and a pencil that appears to break when immersed in water. Meanwhile, electricity and thermodynamics are subject that tend to be abstract where electricity deals with invisible electric charges and thermodynamics deals with gas molecules that move freely. In addition to education level and subject, table 1 also informs about the media used, namely real and virtual media. Real media used include puzzle, student worksheets, observation sheet, and textbook. While the virtual media used include schoology, WhatsApp, mind map, mindjet, mindmanager, pocket mobile, and web. The number of articles that list the media used is 15 articles and the other 3 articles do not include the media used. Later all the data in table 1 will be carried out meta-analysis in accordance with existing data analysis techniques.

This study's analysis technique is a descriptive statistical methodology that involves calculating the effect size. Effect size is a measure of the size of effect variables in other variables, the magnitude of the differences and relationships, free from the influence of the sample size (Olejnik & Algina, 2003). The variables associated are the response variable, the independent variable and the outcome variable, or the dependent variable (Santoso, 2010).

If an experimental study uses two groups, namely the control group, the experimental group, and the means and standard deviations, the effect size calculation uses the Cohen formula (Cohen et al., 2007).

$$ES = \frac{M_{posttest} - M_{pretest}}{\sqrt{\frac{SD^2_{posttest} + SD^2_{pretest}}{2}}} \quad (1)$$

Suppose an experimental study uses two groups: the control group, the experimental group, the t-test, and the t-test value for a between-subjects t-test and the degrees of freedom. In that case, the effect size calculated using the equation below (Cohen et al., 2007) :

$$ES = \frac{2t}{\sqrt{df}} \quad (2)$$

The results of the effect size calculation then interpreted into the criteria presented in Table 2.

Table 2 The Criteria of Effect Size

Effect Size (ES)	Criteria
ES ≤ 0.15	Negligible effects
$0.15 < ES \leq 0.40$	Small effect
$0.40 < ES \leq 0.75$	Medium effect
$0.75 < ES \leq 1.10$	High effect
ES > 1.10	Very high effect

Glass in (Miterianifa et al., 2019)

After obtaining the effect size value, it is interpreted to determine how much influence the independent variable has on the dependent variable with the conditions shown in Table 3.

Table 3. Effect Size Interpretation

Effect size	Influence (%)
0.0	50
0.1	54
0.2	58
0.3	62
0.4	66
0.5	69
0.6	73
0.7	76
0.8	79
0.9	82
1.0	84
1.2	88
1.4	92
1.6	95
1.8	96
2.0	98
2.5	99
3.0	99.9

(Coe, 2002)

RESULT AND DISCUSSION

This meta-analysis research uses 18 articles on the topic of critical-thinking skills improvement in physics learning. These articles qualify the data analysis criteria and have observed previously. Most of these articles aim to apply a learning model to improve students' critical-thinking skills in physics learning. Figure 4 shows articles related to necessary thinking skills in physics learning since 2015 until 2020. From the 18 selected papers, the number of articles on critical-thinking skills in physics learning, increased every year but has decreased in 2020 (fluctuating). Articles on critical-thinking skills in physics learning were primarily published in 2018 and 2019 and published in 2015 and 2016. It explains that research related to this topic still can be further researched, considering that critical thinking skill is one of the abilities from a 21st-century aptitude that students must have (Santyasa et al., 2018).

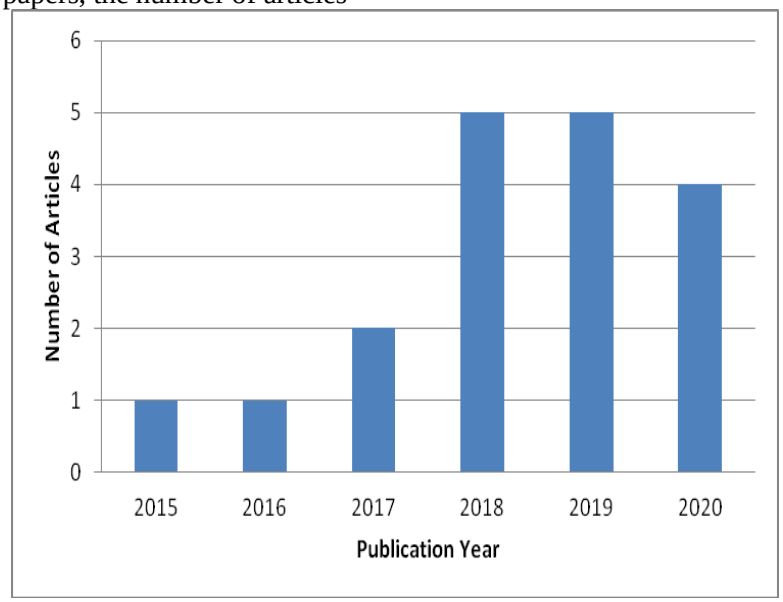

Figure 4 Publication of Students' Critical-Thinking Skills Articles from 2015 to 2020

This research analyzed in two stages: a bibliometric analysis using VOSviewer and meta-analysis using the effect size. Bibliometric analysis using VOSviewer visualizes the relationship and influence of critical-thinking skills in physics learning on various learning models. Meanwhile, meta-analysis using the effect size provides quantitative data on the impact and significance of critical-thinking skills in physics learning on learning models, education levels, subjects, and the learning media used.

Visualization of the relationship and influence of critical-thinking skills in physics learning on various learning models can see in Figure 5—the visualization results obtained from the mapping results of the similarity of the keywords in each article. Based on the mapping of the products on keyword similarity in the critical-thinking skills in physics learning, four groups (clusters) obtained according to their respective colours with 13 related keyword terms regarding critical-thinking skills in physics learning. These keywords have previously selected according to the aim of this research.

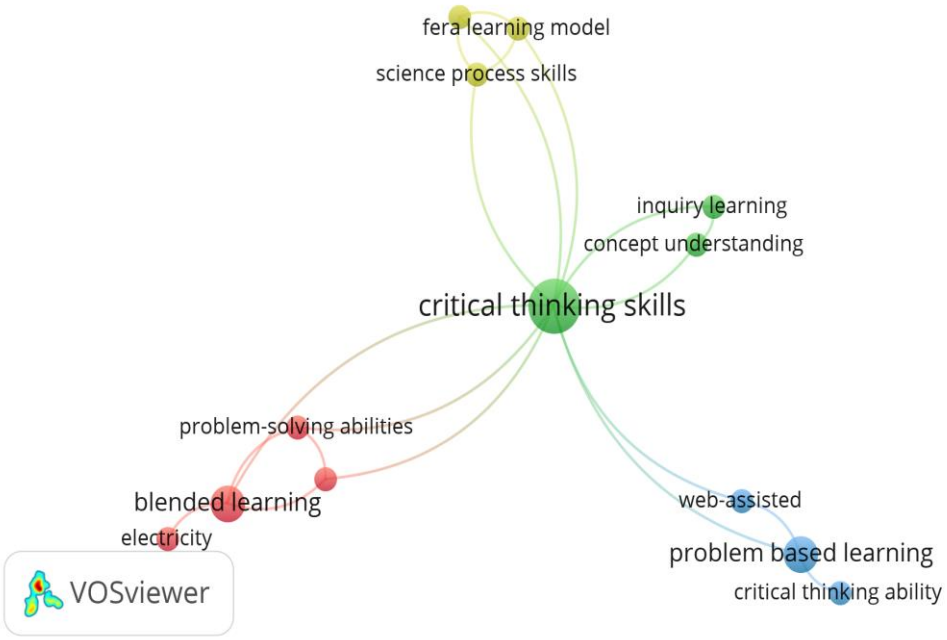

Figure 5 Map of Network Visualization on Keywords

The larger circle on a keyword indicates that the keyword widely used by authors and has a strong relationship with other keywords from the results obtained. Figure 5 has three big loops that are critical-thinking skills, blended learning, and problem-based learning. It shows a strong relationship between critical-thinking skills with blended learning and problem-based learning. We may interpret that blended learning and problem-based learning are among the major learning models that have a significant influence. The following research conducted by Suana et al. (2019) concluded that the blended learning model substantially affects students' critical-thinking skills. The study conducted by Parno et al. (2019) concludes that the problem-based learning model implemented has a more substantial influence in improving students' critical-thinking skills. Visualization of the relationship between blended learning or problem based learning with critical-thinking skills shown in Figure 6 and Figure 7.

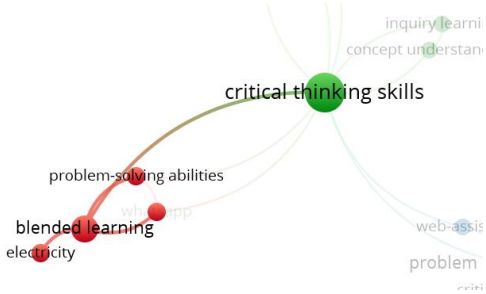

Figure 6 Visualization Between Blended Learning and Critical-Thinking Skills

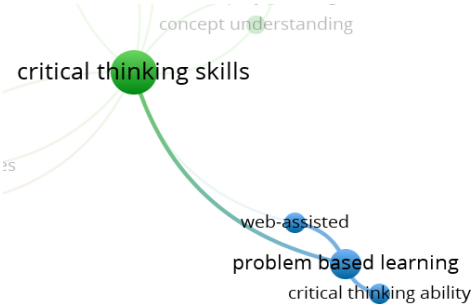

Figure 7 Visualization between Problem-Based Learning and Critical-Thinking Skills

In addition to blended learning and problem-based learning, which significantly influence critical-thinking skills, two other learning models visualize and affect students' critical-thinking skills, namely inquiry learning and the FERA learning model. Research by Maknun (2020) concludes that guided inquiry learning models tend to significantly improve students' critical-thinking skills, and the research from Diani et al. (2020) which suppose that the FERA learning model with the SAVIR approach was effective in enhancing students' critical-thinking skills. Visualization of the relationship between inquiry learning or FERA learning with critical-thinking skills shown in Figure 8 and Figure 9.

Figure 8 Visualization between Inquiry Learning and Critical-Thinking Skills

Figure 9 Visualization between FERA Learning Model and Critical-Thinking Skills

Based on the analysis results, VOSviewer is only limited to the influence and the relationship between critical-thinking skills and the learning model. But, it has not provided information related to quantitative data which learning models that have more impact on critical-thinking skills, the learning media used, physics material and education level. Therefore, a more in-depth analysis carried out, namely meta-analysis, calculating the effect size on each learning model, learning media, material, and the education level. Before the effect size calculation was carried out, mapping and selecting 18 articles were carried out related to the learning model used, learning media, material, and education level, as shown in Table 4.

Table 4 Distribution Of Mapping 18 Articles in Learning Models, Education Level, Subjects, And Media

Code	Learning Model	Source	Education Level	Subject	Media
CST 1	Blended Learning	(W. Suana Et Al., 2020)	Senior High School	Not Identify	Schoology
CST 2	Blended Learning	(Wayan Suana, Istiana, Et Al., 2019)	Senior High School	Static Electricity	Schoology
CST 3	Blended Learning	(Wayan Suana, Raviany, Et Al., 2019)	Senior High School	Static Electricity	WhatsApp
CST 4	Cooperative Learning	(Latifah, 2015)	Senior High School	Wave	Puzzle

Code	Learning Model	Source	Education Level	Subject	Media
	Time-token Type				
CST 5	Direct Instruction	(Risdianto Et Al., 2020)	Senior High School	Not Identify	Non-Media
CST 6	Fera (Focus, Explore, Reflect and Apply)	(Diani Et Al., 2020)	Senior High School	Not Identify	Student Worksheet
CST 7	Group Investigation	(Santyasa Et Al., 2018)	Senior High School	Energy, Impulse and Momentum	Student Worksheet
CST 8	Guided Inquiry	(Nurbaiti Et Al., 2016)	Senior High School	Elasticity And Hooke's Law	Textbooks
CST 9	Guided Inquiry	(Rinaldo Et Al., 2017)	Junior High School	Refraction Of Light	Student Worksheet
CST 10	Guided Inquiry	(Suryanti Et Al., 2018)	Elementary School	Light Material	Non-Media
CST 11	Guided Inquiry	(Maknun, 2020)	Vocational High School	Static Fluid	Non-Media
CST 12	Inductive Learning	(Barra et al., 2019)	Senior High School	Optical Eye	Mind map Mindjet Mind manager
CST 13	Mobile Learning	(Astuti et al., 2018)	Higher Education	Dynamics Of Motion	Pocket Mobile
CST 14	Problem Based Learning	(Alandia et al., 2019)	Senior High School	Optics	Web
CST 15	Problem Based Learning	(Parno et al., 2019)	Senior High School	Optical Instrument	Student Worksheet
CST 16	Problem Based Learning	(Islamiah et al., 2018)	Senior High School	Not Identify	Student Worksheet
CST 17	Problem Based Learning	(Putri et al., 2018)	Senior High School	Heat And Temperature	Student Worksheet
CST 18	Problem Based Learning	(Mundilarto & Ismoyo, 2017)	Senior High School	Direct Current Electricity	Observation Sheet

Table 4 informs that nine learning models of the 18 articles that qualify the criteria affect improving critical-thinking skills. The learning models are Blended Learning, Cooperative Learning time-token type, Direct Instruction, FERA Learning Model, Group Investigation, Guided Inquiry, Inductive Learning,

Mobile Learning and Problem Based Learning. Other information obtained is there are five levels of education, 13 physics learning materials, and eight learning media used. The effect size calculated for each article, learning model, education level, material, and the media used from the obtained data.

The calculations of effect size divided into two different counts. The first uses the pretest, posttest, and standard deviation values, and the second uses the t value and the degree of freedom. Table 5 shows the results obtained from the effect size of the entire article. Eleven articles were measured using the pretest, posttest, and standard deviation values, and seven pieces calculated using the t value and the degree of freedom. Each article categorized by effect size criteria, where nine articles have a very high effect, eight papers have a high impact, and one-piece has a medium effect. The effect size value of each amount accumulated and averaged, so bring on an overall effect size value of 1.33 with a very high category and an influence of 90%. It proves that critical-thinking skills have a significant impact on learning physics. It is under the research by Rodrigues & Oliveira (2008) that Critical-thinking skills have an essential role in science learning, especially in physics learning, other than critical thinking is fundamental to physics learning that clearly stated in the purposes of many Physics' curricula.

Table 5 The Result of Effect Size Analysis

Code	Effect Size Using Standard Deviation	Effect Size Using T-Test	Criteria	Influence (%)
CST 1		1.83	Very High	96.0
CST 2	1.26		Very High	88.0
CST 3	0.87		High	82.0
CST 4		2.20	Very High	98.0
CST 5	0.96		High	84.0
CST 6	0.87		High	82.0
CST 7	1.60		Very High	95.0
CST 8		0.97	High	84.0
CST 9		0.84	High	79.0
CST 10		0.74	Medium	76.0
CST 11		3.07	Very High	99.9
CST 12		0.79	High	79.0
CST 13	1.92		Very High	98.0
CST 14	1.30		Very High	90.0
CST 15	0.79		High	79.0
CST 16	0.91		High	82.0
CST 17	1.12		Very High	84.0
CST 18	1.85		Very High	96.0
Average	**1.33**		**Very High**	**90**

Table 6 shows the data for each article grouped based on the learning model, then calculated and categorized in the effect size. Blended Learning, Cooperative Learning Time-token Type, Group Investigation, Guided Inquiry, Mobile Learning and Problem Based Learning have a very high effect with different influence values on increasing critical-thinking skills. Direct Instruction, FERA Learning Models and

Inductive Learning have a high impact on improving critical-thinking skills.

Based on table 6, the cooperative learning time-token type has the most excellent effect size that is 2.20, with a very high category and an influence of 98%. Research conducted by Syafrial (2018) also shows that the cooperative learning model has a high effect on improving critical-thinking skills with an effect size value of 0.71.

The cooperative learning time-token type is a model used in learning to speak during learning activities actively. Thus, during the implementation of education, students must be active in asking, answering questions, or expressing opinions (Arum Perwitasari, 2014). The time-token learning model is very efficient to use in learning activities. It can increase students' ability evenly both in reading or answering questions that are given appropriately and quickly and do not make one student or group dominate during learning because learning will be limited by a specific time (Iqbal & Mustika Dewi, 2017).

Critical-thinking skills can improve by learning using a time-token type learning model. Critical thinking is thinking, reasoned, and reflective by emphasizing making decisions about what to believe and do. In the end, it will produce conclusions and decisions that can be communicated by the listener (Latifah, 2015). So, the students dare to ask, answer, or express their opinion in public.

Increasing critical-thinking skills is not only by implementing cooperative learning time-token type, but also implements other learning models that also have an effect size value with the very high effect category. For example, group investigation, guided inquiry, and problem-based learning is learning models with a scientific approach. Learning with a scientific method requires students to think systematically and critically to solve problems with six stages: observing, asking questions, gathering information, conducting experiments, processing data, and communicating results (A. R. Setiawan, 2020).

From table 4, It can see that the use of the cooperative time-token type learning model only used in one article—different from the use of guided inquiry learning models and problem-based learning. The guided inquiry was used by four research articles, while five research articles used problem-based learning. Based on the data above, it can be said that to improve students' critical-thinking skills, teachers not only see the value of the effect size in choosing a learning model. They must be able to see and analyze the distribution of a learning model in research or learning itself. Teachers and prospective teachers can use one of the learning models listed in Table 6 with the very high effect category to improve critical-thinking skills adjusted to student conditions and learning objectives.

Table 6 Effect Size Based on Learning Model

Learning Model	**Effect Size (Es)**	**Criteria**	**Influence (%)**
Cooperative Learning Time-token Type	2.20	Very High	98
Direct Instruction	0.96	High	84
Fera Learning Model	0.87	High	82
Group Investigation	1.60	Very High	95
Guided Inquiry	1.41	Very High	92
Inductive Learning	0.79	High	79
Mobile Learning	1.92	Very High	98
Problem Based Learning	1.19	Very High	88

Each article is grouped based on education level, namely Higher Education (HE), Senior High School (SHS), Vocational High School (VHS), Junior High School (JHS), and Elementary School (ES). Table 7 shows that each level of education value was calculated and categorized in the effect size. At the Higher Education level, Senior High School and Vocational High School level have an effect size value with a very high effect category. Meanwhile, at the elementary school level and junior high school level, it has an effect size with an increased effect category. Based on the effect size value, the vocational high school has the most excellent effect size value so that it has the highest effect on the increasing critical-thinking skills in physics learning. Research by Maknun (2020) states that students' critical-thinking skills in vocational high school have increased with the implementation of guided inquiry. It allowed students to independently create a hypothesis by presenting a problem, formulating ideas, collecting data, analyzing it, and making conclusions.

Vocational high school is one form of vocational education investment. The Vocational High School established to meet the workforce needs and provide students with life skills and knowledge (D. Lestari et al., 2020). The graduates from vocational high school are required to work and perform competently in specific fields based on the demands of the business and industrial worlds. Vocational High School students in the 21st century increasingly expected to have critical and creative thinking skills as they live in a world of modern education, global competitiveness, and a more vibrant democratic life that can adapt to a constantly changing world for the advancement of their careers (Suarniati et al., 2018).

Learning in vocational high school is carried out within forming the Graduates Competency Standards (GCS) of students. Putu (D. D. Lestari et al., 2017) states that learning in vocational high school uses the outcome paradigm, namely, what competencies students must master, not knowing that imposes what must be taught by a teacher. This statement implies that the primary purpose of vocational education is to prepare students to enter the world of work. The learning process carried out in vocational high school has a more significant portion of practical learning to equip various skills. Because the teaching is more on-field practice, vocational students must be creative and solve problems quickly. These skills cannot separate from the critical-thinking skills of vocational high school students, so it is not wrong if the vocational high school has the highest effect size value to improve students' critical skills.

Table 7 Effect Size Based on Education Level

Education Level	Effect Size (Es)	Criteria	Influence (%)
Elementary School	0.74	Medium	76.0
Junior High School	0.84	High	79.0
Senior High School	1.24	Very High	88.0
Vocational High School	3.07	Very High	99.9
Higher Education	1.92	Very High	98.0

Table 8 shows the data for each article grouped by subject matter, then calculated and categorized in the effect size. Subject about Wave, Energy, Impulse and Momentum, Static Fluid, Dynamic of Motion, Optics, Heat and Temperature, and Direct Current Electricity have a very high effect category to increase students' critical-thinking skills. Subject about Static Electricity, Elasticity and Hooke's Law, Refraction of Light, Optical Eye, And

Optical Instrument has a high effect category to increase students' critical-thinking skills. Subject about Light Material has a medium effect category to improve student's critical-thinking skills. Critical thinking is to develop the ability to reason the concepts and principles of physics to solve problems in daily life. Based on this, subject in physics learning with very high effect is easily associated with everyday life problems compared to the issue that included in the high or medium category.

Static fluid is the subject with the highest effect size value. The effect size value is 3.09 with an influence of 99.9%. With a tremendous effect, it can say that static fluid is one of the materials that must be studied and developed in line with developing students' critical-thinking skills. Static-fluid is a material that has real applications in everyday life. Students expected to find and understand existing concepts and solve daily life problems related to the static-fluid material. One way to practice students' critical-thinking skills is to ask questions or motivation by demonstrating phenomena related to static fluids. As an example, research by Yahyana et al. (2017) indicates that an object suspended from a spring balance has weight when measured in air and immersed in a measuring cup. Then ask students to respond to the demonstration. These questions can trigger students to develop their critical-thinking skills.

Table 8 Effect Size Based on Subject in Physics

Subject	**Effect Size (Es)**	**Criteria**	**Influence (%)**
Static Electricity	1.07	High	84.0
Wave	2.20	Very High	98.0
Energy, Impulse and Momentum	1.60	Very High	95.0
Elasticity And Hooke's Law	0.97	High	84.0
Refraction Of Light	0.84	High	79.0
Light Material	0.74	Medium	76.0
Static Fluid	3.07	Very High	99.9
Optical Eye	0.79	High	79.0
Dynamic Of Motion	1.92	Very High	98.0
Optics	1.30	Very High	90.0
Optical Instrument	0.79	High	79.0
Heat And Temperature	1.12	Very High	84.0
Direct Current Electricity	1.85	Very High	96.0

The last analysis is about effect size in the media used in the learning process from 18 articles analysis. The real media consists of the puzzle, student worksheets, textbook, and observation sheet. The virtual media consists of the Schoology, WhatsApp, mind map, mind jet, mind manager, pocket mobile and web. The student worksheet is media the most used because six articles used it, but three papers did not explain what media they use in their research. From table 9, it can see about effect size value in media that use in physics learning. A puzzle is the highest effect size value with a very high effect and influence of 98%. A puzzle is an exciting and straightforward game media that is easy to apply in learning. Puzzle game media is a game that arranges the pieces of the picture to create a complete picture. The puzzle is simple props that are easy to make but fun to use as a learning media for students (Latifah, 2015).

The measurement of the average effect size for real media and virtual media based on the data from measuring the effect size on each learning media. The results obtained are that the effect size value of real media is higher than

virtual media. Real media have an average effect size of 1.526 with a very high effect and influence of 92%. In comparison, virtual media have a moderate effect size of 1.284, which also has a very high impact but an influence of 88%. One of the real media besides puzzles that can also recommend is student worksheets and observation sheets. In addition to the student worksheets used by six different research articles, the effect size calculation also has a high effect; the result is 1.02 with an influence of 84%. In contrast, the observation sheet has an effect size calculation of 1.85 with a very high effect and impact of 96%. Therefore, the selection of media must also be adjusted to the characteristics of students, learning models, the material to be taught and their influence and contribution in improving critical-thinking skills.

Table 9. Effect Size Based on Media

Media	Effect Size (Es)	Criteria	Influence (%)
Schoology	1.54	Very High	95
WhatsApp	0.87	High	82
Puzzle	2.20	Very High	98
Student Worksheet	1.02	High	84
Observation sheet	1.85	Very High	96
textbook	0.97	High	84
Mind map, mindjet, mindmanager	0.79	High	79
Pocket mobile	1.92	Very High	98
Web	1.30	Very High	90
Non-media	1.59	Very High	95

CONCLUSION

Based on the results and discussion of this meta-analysis research, the conclusion that students' critical-thinking skills greatly influence learning physics with an average effect size value of 1.33 with an influence of 90%. Critical-thinking skills in physics learning have a significant effect when applied to vocational high school, with the cooperative time-token type learning model. The improvement of critical-thinking skills can do by using real-life subjects such as static fluid. Besides, we can use appropriate media by real learning media such as puzzles to improve student's critical-thinking skills. It is hoped that the results of this study could be a recommendation for teachers to enhance students' critical-thinking skills in learning physics. Then it can become a reference for other research so that further studies are more in-depth and complete.

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