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The Impact of Blended Learning on Students' Critical and Creative Thinking Skills in Science Learning: A Meta-Analysis

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Abstract: This research is a meta-analysis to see the influence of Blended Learning in science learning on students' critical and creative thinking skills. The method used is meta-analysis with a population and research sample, namely scientific articles that have been published through Google Scholar on a national to international scale in 2016–2022, which discusses the application and influence of Blended Learning in science learning on students' critical and creative thinking skills. In the science subject category, which includes physics, biology, and chemistry. Blended learning influences in the highest category in its application in physics learning to students' critical and creative thinking skills. Whereas in chemistry lessons, has an effect on the medium category. Based on the level of education, blended learning has an influence on the high category when applied to the high school level. Meanwhile, if it is applied to the secondary school and university levels, blended learning only has an effect on the medium category. However, in general, the application of blended learning has a significant influence on students' critical and creative thinking skills. So, blended learning can be used as an innovation in science learning in an effort to improve students' critical and creative thinking skills.

Keywords: Blended Learning; Creative Thinking Skill; Critical Thingking Skill; Meta-Analysis; Science.

Introduction

Today's tremendous advancements in science and technology have shifted the focus of curriculum requirements. Currently, school-based learning practices necessitate instructors' ability to increase the abilities children will need to meet future obstacles (Fitria et al., 2023). Critical and creative thinking skills are required for the advancement of science and technology in the 21st century (Lestari, 2021) that allows students to solve the problems encountered (Asman et al., 2022). Critical thinking skills are used to prevent and filter information that is considered unreasonable through reasoning, analysis, and solving problems (Prafitasari et al., 2021). Creative thinking skills are a person's ability to create something new and useful as a new solution to solve a problem (Leasa et al., 2023).

Critical and creative thinking skills are needed in science learning. The abilities expected in science learning include cognitive, affective, and psychomotor abilities. So that teachers as educators still have to innovate in learning (Nasrulloh et al., 2022). The rapid development of science and technology must also be balanced with an increase in the quality of learning (Ashel & Lestari, 2023).

Blended learning is a learning model that combines direct face-to-face learning (traditional learning) with online learning (Trisnowati & Firmadani, 2020) using modern technology so that learning becomes more effective and so as to increase student achievement (Ibrahim, 2023). The application of Blended learning is also able to provide freedom for students to use the facilities for learning (Chekour et al., 2022). Blended learning is still considered a new learning model even though it has been around for a long time and has been

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applied in various developed countries (Nasrulloh et al., 2022). Blended learning is also a method in an interesting, flexible learning process that can optimize the benefits of in-person and online learning to support student learning (Syahrawati et al., 2022). The application of blended learning in learning provides opportunities for students to explore new ideas, discuss them, ask questions, and provide responses using technological devices. In addition, blended learning is also able to influence student skills, including student achievement (Hadiyanto et al., 2021).

Much research has been conducted on the effect of the application of blended learning in science learning on students' critical and creative thinking skills. Based on the research of Sri Wahyuni et al., in their research entitled "Edmodo-Based Blended Learning Model as an Alternative of Science Learning to Motivate and Improve Junior High School Students' Scientific Critical Thinking Skills," it was found that the application of blended learning can improve the ability to think critically of secondary school students in the moderate category (Wahyuni et al., 2019). The same thing happened in the research of Bowo Sri Mulyanto et al. with the title "Evaluation of Critical Thinking Ability with Discovery Learning Using Blended Learning Approach in Primary School," where the results obtained showed that the application of blended learning is able to improve students' critical thinking skills in the medium category (Mulyanto et al., 2020). Another research study on blended learning was conducted by Prihadi et al. with the title "Effectiveness of Blended Learning to Improve Critical Thinking Skills and Student Science Learning Outcomes." It was found that the application of the blended learning model was very effective and had a significant effect on increasing students' critical thinking skills (Prihadi et al., 2021).

On students' creative thinking skills, based on research by Nurrijal et al. in their research on "Creative Problem Solving Process Instructional Design in the Context of Blended Learning in Higher Education," the results showed that the application of blended learning was effectively used to improve students' creative thinking skills through the application of models. This is able to optimize students' skills (Nurrijal et al., 2023). Wahyudi et al., in a study entitled "Development of Blended Learning Activities Based on 3 CM (Cool-Critical-Creative-Meaningful) to Support Creativity and Good Character Students," concluded that the application of the blended learning model was very effective in improving students' creative thinking skills (Wahyudi et al., 2023; Nasution, 2016). Another study was conducted by Desi Anggraini et al. regarding "The Influence of Problem-Based Learning and Blended Learning on Students' Creative Thinking Ability in Class XI SMAN Plus Riau Province Material Body Defense System" and obtained the results of applying blended learning in learning to be able to make the learning process more effective and significantly able to improve students' critical thinking skills (Anggraini et al., 2023).

The results of previous studies still have limitations, including the results described in the research do not explain the effect of similar studies on different science topics; and they do not explain the effect that the application of Blended Learning at different grade levels and educational levels has on students' critical and creative thinking skills. Based on these limitations, this research was conducted to determine the magnitude of the influence of several similar studies regarding the application of blended learning in science learning on students' critical and creative thinking skills using the meta-analysis method.

According to Glass (1976), meta-analysis is a statistical analysis of a set of analysis results from individual studies for the purpose of integrating the findings (Kulik & Kulik, 1989). Meta-analysis is research conducted to analyze empirical studies that have been conducted by previous researchers. This research is conducted by summarizing, integrating, combining, and interpreting the results of selected studies in certain fields of science (Retnawati et al., 2018). This research was chosen as a research method because there have been many studies discussing the effect of blended learning in science learning on students' critical and creative thinking skills, but there has been no research on the effect of several similar studies regarding the use of blended learning in physics learning on critical and creative thinking skills. student.

Method

This study uses a meta-analysis method. The meta-analysis method is research conducted by summarizing, reviewing, and analyzing data from several studies with similar problems (Sanuaka et al., 2022). The data used is secondary data, where secondary data is data obtained from the results of previous studies without having to conduct research in the field. Data collection in the research was carried out by searching a number of articles through Google Scholar with the keywords "blended learning," "critical thinking skills," and "creative thinking skills" . The results of the article search found 20 articles that matched the predetermined criteria.

There are three dependent variables used in this study: critical thinking skills, creative thinking skills, and learning outcomes. While the moderator variable is based on the level of education, subject matter, and skills. The steps taken in this study were begun by

choosing the topics to be studied, collecting article data that matched the criteria for the selected topics, looking for the effect size value of each article, determining the category effect size of each article, grouping articles according to predetermined moderator variables and the last is drawing conclusions from the results of data processing.

The data collection technique used is coding, with data analysis techniques using effect size techniques. The calculation of the effect size can be seen in Table 1. After calculating the effect size using the appropriate formula, the effect size is categorized according to the criteria listed in Table 2.

Table 1. Effect Size Formula

Effect size	Category
Average on a group	$ES = \frac{\bar{x}_{post} - \bar{x}_{pre}}{SD_{pre}}$
Average in each group	$ES = \frac{\bar{x}_{eksperimen} - \bar{x}_{kontrol}}{SD_{kontrol}}$
Average in each group	$\frac{(\bar{x}_{post} - \bar{x}_{pre})_e - (\bar{x}_{post} - \bar{x}_{pre})_k}{\frac{SD_{Pre\,k} + SD_{pre\,e} + SD_{post\,k}}{3}}$
T-test	$ES = \sqrt{\frac{1}{n_{eksperimen}} + \frac{1}{n_{kontrol}}}$
Chi-Square	$ES = \frac{2r}{\sqrt{1-r^2}}; r = \sqrt{\frac{X^2}{n}}$

Table 2. Categorizes of Effect Size

Effect size	Category
$0 \leq ES \leq 0.2$	Low
$0.2 \leq ES \leq 0.8$	Medium
$ES \geq 0.8$	High

(Becker, 2000)

Result and Discussion

Based on the results of the heterogeneity test that has been carried out, it can be seen that the random effect model is suitable to be used to determine the magnitude of the influence of several similar studies regarding Blended Learning in science on students' critical and creative thinking skills. Based on the data that has been collected, so far there are only 20 articles that meet the criteria, and the effect size can be determined from the 50 articles found. To see the magnitude of the influence between variables in each of the studies studied and used to draw conclusions, the 20 articles were summarized in the form of coding for analysis.

The limitation of the explanation in this meta-analysis article is that it uses stages to test the hypothesis. By calculating the effect size, the p-value will be calculated. The assessment criterion from the results of the meta-analysis is that if the p value < significance value (0.05), then there is an influence from the application of Blended Learning in science learning on students' critical and creative thinking skills.

Based on the results of the heterogeneity test that has been carried out, it is known that the random effect model is suitable for calculating the effect of similar research from similar studies on the effect of Blended Learning on critical thinking skills and creative thinking abilities. The calculation of the effect of several similar studies on critical thinking skills and creative thinking skills can be seen in Table 3.

Based on the presentation of Table 3, there are 20 similar studies that use BLM to influence critical thinking and creative thinking skills. The result of a Z value of 20 is the same as the research showing a Z value of 4.546. The results of testing the hypothesis show that the value of $p < \alpha$, which indicates that testing the hypothesis H_o is rejected. The results of H_o's rejection indicate that there is a significant influence of Blended Learning on critical thinking skills and creative thinking abilities.

The test results show that Blended Learning has a positive and significant impact on students' 21st-century abilities (Supriyadi et al., 2023). Blended learning can be an effective learning method for developing creative thinking skills and critical thinking in science learning. By integrating strategies such as online discussions, collaborative projects, and interactive simulations, students can develop deep and creative thinking skills to understand scientific concepts (Asrizal et al., 2022). The application of blended learning that is guided by the principles of effective learning provides holistic learning and strengthens student skills that are important in an ever-changing world (Khairi et al., 2020).

Table 3. The Result of Hypotesis Test of Calculating the Effect Size of a Number of Similar Articles on Students' Critical Thinking and Creativity Skills

Source	Code	Y_i	V_{Yi}	T^2	$V_{Yi} + T^2$	W_i*	W_i*Y_i
(Anggraeni et al., 2019)	A1	1.12	0.06	0.80	0.87	0.59	0.67
(Triyanti, 2022)	A2	0.74	0.02	0.80	0.83	0.60	0.45
(Andriana et al., 2022)	A3	0.67	0.08	0.80	0.89	0.58	0.39
(Habibah et al., 2022)	A4	1.47	0.06	0.80	0.87	0.59	0.87
(Suana et al., 2020)	A5	1.78	0.07	0.80	0.88	0.59	1.05
(Othman & AL-Hileh, 2022)	A6	0.15	0.06	0.80	0.87	0.59	0.08
(Nasution et al., 2016)	A7	0.42	0.04	0.80	0.85	0.60	0.25
(Zulhamdi et al., 2022)	A8	2.09	0.04	0.80	0.85	0.60	1.26
(Sinaga & Simanjuntak, 2020)	A9	3.81	0.07	0.80	0.88	0.59	2.25
(Suana et al., 2019)	A10	1.03	0.07	0.80	0.88	0.59	0.61
(Kesuma et al., 2022)	A11	0.90	0.06	0.80	0.87	0.59	0.53
(Alsalhi et al., 2019)	B12	0.30	0.03	0.80	0.84	0.60	0.18
(Hasanah & Malik, 2020)	A13	0.64	0.04	0.80	0.85	0.60	0.38
(Ernawati & Sari, 2022)	A14	1.02	0.15	0.80	0.96	0.56	0.57
(Al-Shaye, 2021)	A15	0.44	0.04	0.80	0.85	0.60	0.26
(Diana Silfiani Putri et al., 2022)	B16	1.94	0.00	0.80	0.81	0.61	1.19
(Sutriyono et al., 2022)	B17	3.68	0.07	0.80	0.88	0.59	2.17
(Nurlina et al., 2021)	B18	1.15	0.06	0.80	0.87	0.59	0.68
(Haka et al., 2020)	B19	0.99	0.07	0.80	0.88	0.59	0.58
(Siboro & Piliang, 2022)	B20	1.97	0.07	0.80	0.88	0.59	1.16
M*							1.31
VM*							0.08
SEM*							0.28
LLM*							0.75
ULM*							1.88
Z							4.54
p-Value One-Tailed Test							0.00
p-Value Two-Tailed Test							0.00

Analysis of The Effect of Similar Articles on Students' Critical and Creative Thinking Skill

Based on the results of heterogeneity testing, it can be seen that in students' critical and creative thinking skills, Q > df, the estimation of variance between articles is quite large and heterogeneous. The model that is suitable for use in two types of 21st century skills is the random effect model. The calculation of the effect of several similar studies based on the type of skill can be seen in Table 4.

Based on the data in Table 4, these two skills show the influence of the application of Blended Learning on students' critical and creative thinking skills, with varying Z scores. Critical thinking skills show a Z value of 0.359 with a p-value of 0.35. Critical thinking skills have a Z value of 3.524 and a p value of 0.0002. These results indicate that testing the hypothesis on the type of skill shows a p value < α which indicates the hypothesis H_o is rejected. Meanwhile, students' creative thinking skills obtained a Z value of 3.728 with a p-value of 0.000, so Ho was rejected. The test results obtained show that the application of blended learning in science learning has a significant influence on students' critical thinking and creative thinking skills.

In this challenging 21st century, studying science and technology is very important to deal with rapid global changes. In science education, it is important for students to develop creative and critical thinking skills (Indriani et al., 2023). Creative thinking allows students to see problems from new perspectives and come up with innovative solutions (Khofifah & Sulastri, 2022), while critical thinking allows students to analyze information objectively and challenge existing assumptions (Pradana et al., 2020).

Tabel 4. The Result of Hipotesis Tetst of Calculating the Effect Size of a Number of Similar Articles on Students' Critical Thinking and Creativity Skills

Skills	Code	ES	SEM	LLM	ULM	Z	*P*	Decision
Critical Thinking Skill	A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14 A15	1.10	0.31	0.49	1.72	3.52	0.00	Rejected H_o
Creative Thingking Skill	B16 B17 B18 B19 B20	1.94	0.52	0.92	2.97	3.72	0.00	Rejected H_o

Analysis of The Effect of Similar Articles on Students' Critical and Creative Thinking Skill Based on Subject Learning

The influence of a number of similar studies based on the type of science lesson using three different subjects The subject matter analyzed was three items in the science cluster, namely, physics, biology, and chemistry. A calculation of the influence of a number of similar studies based on learning materials can be seen in Table 5.

A number of similar studies on the application of Blended Learning show that all subjects, which include physics, biology, and chemistry, have varying Z scores. Testing the hypothesis on the three subjects yielded the result that $p < \alpha$, this indicates that the hypothesis Ho is rejected. Based on the conclusions obtained from the results of the data analysis, it can be seen that the application of blended learning in science learning, both in physics, biology, and chemistry in general, has a significant influence on students' critical and creative thinking skills. For the category of magnitude of the effect on physics and biology subjects, the application of blended learning gave an effect in the high category, while for chemistry learning, the effect was obtained in the medium category.

Table 5. The Result of Hipotesis Tetst of Calculating the Effect Size of a Number of Similar Articles on Students' Critical Thinking and Creativity Skills Based on The Subject Learning

Subject Learning	ES	SEM	LLM	ULM	Z	*P*	Decision
Physics	1.6017	0.5764	0.472	2.731	2.779	0.002	Rejected H_o
Biology	1.4759	0.3144	0.860	2.092	4.694	0.000	Rejected H_o
Chemistry	0.648	0.219	0.219	1.077	2.958	0.001	Rejected H_o

The results of the analysis are in line with the results of the study (Syarah et al., 2021) which states that the application of Blended Learning has a significant impact on student learning outcomes, students' critical thinking skills, students' creative thinking abilities, and students' science skills. However, the application of the blended learning model to physics subjects is used more by educators because the blended learning model is able to develop 21st century skills in high school physics learning (Sutriyono et al., 2022).

Analysis of The Effect of Similar Articles on Students' Critical and Creative Thinking Skill Based on School Level

The influence of a number of similar studies based on educational level at three different levels The educational levels analyzed from lowest to highest are secondary schools, high schools, and universities. The calculation of the influence of a number of similar studies based on educational level can be seen in Table 6.

Based on the data in Table 6, at the three levels of education, it shows that there is an effect of the application of blended learning on students' critical thinking skills and creative thinking abilities with

varying Z scores. The application of blended learning in learning has an influence on the high category at the high school level. In its application at the secondary school and university levels, blended learning has an effect on the medium category of students' critical and creative thinking skills. In calculating the p-value, a p-value < 0.05 was obtained in the application of blended learning at the high school and university levels. This indicates that the application of blended learning has a significant influence on the critical and creative thinking skills of students in high schools and universities. Meanwhile, when calculating the p-value at the secondary school level, the p-value > 0.05, so it can be concluded that the application of blended learning does not have a significant effect on students' critical and creative thinking skills at the secndary school level.

Tabel 6. The Result of Hipotesis Tetst of Calculating the Effect Size of a Number of Similar Articles on Students' Critical Thinking and Creativity Skills Based on The School Subject

School Level	ES	SEM	LLM	ULM	Z	*P*	Decision
Secondary School	0.23	0.25	0.27	0.74	0.91	0.17	Accepted H_o
High School	1.66	0.32	1.04	2.29	5.20	0.00	Rejected H_o
University	0.56	0.14	0.12	0.85	3.80	0.00	Rejected H_o

This is also supported by research conducted by (Habibah et al., 2022), stating that after implementing blended learning in biology subjects it can improve the critical thinking skills of high school students.From the data analysis, it can be seen that the application of Blended Learning does not only improve critical thinking skills and creative thinking skills in secondary and high school students but also in university students. (Nur et al., 2022).

Conclusion

Based on the results of the analysis, the main conclusion is the effect of several similar studies on the application of Blended Learning shows that the application of blended learning has a significant influence on students' critical thinking skills and creative thinking abilities. The study of the effect of blended learning based on science subjects shows that the application of blended learning has a significant influence on its application in physics, biology, and chemistry subjects on students' critical thinking skills. The effect of research on the type of blended learning based on educational level shows that the application of blended learning has a significant effect on its application at the high school and university levels on students' critical and creative thinking skills, whereas if it is applied at the secondary school level, blended learning has an effect on the medium category of critical and creative thinking skills. The ability to think creatively and critically has an important role in helping students understand and apply science concepts more deeply. Creative thinking allows students to find innovative solutions, while critical thinking allows them to critically analyze information and question existing assumptions. These two abilities can improve conceptual understanding, problem-solving skills, and student motivation in learning science.

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Nur Hikmah: writing-original draft preparation, analyzing the research data, and editing; Dhea Febriya: writing the discussion and conclusion; Hermalina Daulay: Analyzing the research data and writing the methodology; Akmam and Asrizal proofreading and reviewing

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Conflict of Interest

The authors declare that there is no conflict of interestregarding the publication of this paper

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