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Meta-analysis: the influence of learning styles on critical thinking of science learning

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Abstract

This study aims to investigate whether learning styles significantly affect the critical thinking ability of science learning students. The method in this study is a second-order integrative meta-analysis using many data sets from the results of previous research obtained from as many as 13 research journal articles with literature search using electronic databases using the keywords "Learning style", "Critical thinking", and "Science learning" conducted using *the DOAJ, ERIC, Scopus, publish or perish* 8.12 websites, *research gate* and *Google Scholar* in the form of international and national journals. This analytical study includes research comparing students' learning outcomes using different learning styles with *quasi-experimental, experimental,* and *research and development methods*. The results showed that there was a significant influence of learning style on the critical thinking ability of science learning students, with a representation obtained of 1.35 in the "high" category to conclude the effect of the effectiveness of the independent variable, namely the influence of learning style on the dependent variable critical thinking 88%.

Keywords: learning style; critical thinking; science learning

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INTRODUCTION

The problems faced in the world of education today, especially those that often affect science learning, are the low learning outcomes of students; some parties examine the results of student learning. This occurs because of errors not only in students but also in educators. Understanding the concept of science learning is formative, which only focuses on teachers conveying their knowledge to students without student back-involvement to know the importance of learning to be learned and implemented in daily life so that students look less active and students think learning is difficult and tedious, this can affect student learning outcomes that are not optimal. An in-depth understanding of science learning is essential to hone students' critical thinking knowledge (Ramdani et al., 2020).

The ability to think critically allows students to analyze information systematically, evaluate arguments, and make logical conclusions (Syarifah et al., 2018). Critical thinking skills involve analyzing and questioning assumptions, adjusting facts and opinions, and understanding the implications of

statements or ideas (Timuçin & Çimer, 2022). Through critical thinking, students can develop strong analytical skills, improve their performance in learning, and reduce the risk of less accurate information they obtain (Ryan, 2023). Students' critical thinking skills have been widely researched such as through the application of learning media (Efendi & Sapwani, 2022; Laskaryani et al., 2020) and through the application of learning models (Luvia Ranggi et al., 2021; Umrah et al., 2019).

Learning theory is a conceptual framework that understands how students process information and apply knowledge efficiently (Sari B K, 2017). One well-known theory is the VARK (Visual, Auditory, Reading/Writing, and Kinesthetic) learning theory, developed by Neil Fleming. According to this theory, each student will always have a preference for specific instruction methods, such as visual (using diagrams or pictures), auditorial (using sound, narration), reading or writing (using books or texts, emphasizing key points), and kinesthetic (Wijaya et al., 2022). However, some research suggests that classifying learning styles into specific categories only partially captures individual complexity, which requires a more holistic approach to understanding learning styles (Rambung et al., 2023).

In addition, learning style theory also highlights the importance of using various learning methods in the educational process (Sandong et al., 2023). By understanding the dominant learning styles of each student, educators can design more diverse and inclusive teaching strategies (Nasution et al., 2023). This approach can increase learning effectiveness, facilitate better understanding (Sabarun et al., 2023) and promote students' active involvement in teaching-learning (Magdalena et al., 202et al. nonetheless, it is essential to remember that learning style is only one aspect of the learning process, and other factors such as motivation, learning environment, and previous experience also play an essential role in creating experiences (Waluyo, 2014).

The interaction between critical thinking and learning is a complex aspect in the context of education and personal cognitive development. Although critical thinking is considered an essential universal skill in education, individual learning can hurt how people process information and respond to questions (Ginanjar et al., 2019). For example, some students prefer the visual learning style, finding it easier to understand and evaluate information (Rahmi et al., 2020) presented in graphs or diagrams. In contrast, some students who prefer the auditive learning style may find it more challenging to answer questions clearly and concisely (Muthoharoh, 2019). However, the complex interaction between learning and critical thinking also considers external factors such as the learning environment, the type of material learned, and the educational context that might moderate the relationship between the two constructs (Davidi et al., 2021).

Differential learning styles that support student learning styles can assist educators in tailoring their teaching methods to student needs and cognitive preferences. However, this understanding also includes holistic approaches applied in assessment and development (Mustoip, 2023), educational strategies, and students' understanding of their needs and characteristics in various educational contexts. Thus, understanding the complex interaction between learning and critical thinking becomes important in developing learning strategies that are thinking and responsive (Mustoip, 2023).

The implications in the educational context of understanding the relationship between learning and critical thinking are significant (Shafi'i, 2023). By considering the unique learning styles of each student (Dewantara et al, 2020), educators can design more diverse and responsive learning strategies for students' cognitive needs (Hadijaya, 2015). This approach allows educators to use various teaching methods that better suit each student's preferred learning style (Al Fajri, 2018), increasing their understanding and enthusiasm for learning (Safaringga et al., 2022).

The urgency to understand the relationship between learning styles and critical thinking skills is increasingly pronounced in the context of contemporary science education. Recent research indicates that alignment between students' learning styles and teaching methods can significantly enhance critical thinking abilities (Hwang, Wang, & Lai, 2020). However, this complex and multifaceted relationship necessitates further investigation to optimize learning outcomes. Learning styles, as individual preferences in receiving and processing information, can influence the development of critical thinking skills. A study by Çetin (2021) revealed that students with visual learning styles demonstrate more vital analytical skills, while those with kinesthetic learning styles excel in practical problem-solving (Çetin, 2021). These findings emphasize the importance of tailored approaches in teaching critical thinking.

Furthermore, Lin et al. (2019) highlight that understanding the relationship between learning styles and critical thinking can assist educators in designing more effective interventions to enhance higher-order thinking skills (Lin, Wu, & Chiu, 2019). This is particularly crucial in science education, where the ability to analyze data, evaluate evidence, and draw logical conclusions is highly valued. Given the rapid technological advancements and changes in the educational landscape, the urgency to understand these dynamics is increasing. As Tian et al. (2022) suggest, integrating adaptive learning technologies that respond to individual learning styles can significantly improve the development of critical thinking skills (Tian, Fang, & Li, 2022). Therefore, further research on the relationship between learning styles and critical thinking skills is academically relevant and essential for developing innovative and effective educational strategies in the digital era.

Based on the description above, understanding the implications of learning styles for critical thinking also allows educators to develop a more inclusive and diverse curriculum in science learning (Pata'dungan et al., 2023). This research is expected to contribute by taking into account different learning styles (Sari, 2019); educators can compile learning materials that offer a variety of learning approaches (Zubaidah, 2020), including visual, auditory, kinesthetic, and a combination of the three (Rafiska & Rahmi, 2023). This allows students with various learning styles to reach their maximum potential in developing critical thinking skills (Hasan & Husna, 2023) and creates a more diverse and inclusive learning environment for all students (Rambung et al., 2023). Therefore, this study aims to determine whether learning styles significantly affect the critical thinking skills of science learning students.

METHODS

The second-order integrative meta-analysis method uses many data sets from previous research results (Made et al., 2020). This research has several stages: problem formulation, literature study, data coding, analyzing data, and data interpretation. The procedure is carried out using several different approaches. A literature search using electronic databases with keywords "Learning style", "Critical thinking" and "Science Learning".

A literature search was conducted using *DOAJ, ERIC, Scopus, publish or Perish* 8.12, *research Gate* and *Google Scholar websites* in the form of international and national journals. The necessary literature data comes from all levels of education. The qualification of this research method is needed to determine the influence of learning styles on the critical thinking of science learning students. This analytical study includes research comparing students' learning outcomes using different learning styles with *quasi-experimental, experimental,* and *research and development* methods. Synthesis in research only uses a learning style towards critical thinking science learning. Research in which a differentiating

group may be needed if the group has two direct and gradual treatments. The study will be excluded if statistical data and *effect size* are unavailable.

This study used statistical data on standard deviation, *mean*, t and *chi-square test results*. The coding of variable data and *effect size* based on code sheets is intended to extract data into several codes to concentrate on critical thinking variables, treatment duration less than one month, more than one month), at all levels of education, publication years (2014-2024), for sample sizes required by 30 participants or more publications in the form of previous research journal article sources.

Effect size *values* to see the influence of bound and independent variables harmonized in the equation in Table 1 (Adawiyah et al., 2023):

Table 1. ES Equation

Information	Equation
Chi-square	$\boldsymbol{ES} = \frac{2r}{\sqrt{1-r^2}}; r = \sqrt{\frac{x^2}{\mathrm{n}}}$
t count	$\boldsymbol{ES} = t\sqrt{\frac{1}{n_{eksperimen}} + \frac{1}{n_{kontrol}}}$
Standard deviation and mean in one group	$\boldsymbol{ES} = \frac{\bar{\mathrm{x}}_{post} - \bar{\mathrm{x}}_{pre}}{SD_{pre}}$
Standard deviation and mean in each group (two groups were only posttest)	$\boldsymbol{ES} = \frac{\bar{\mathrm{x}}_{eksperimen} - \bar{\mathrm{x}}_{kontrol}}{SD_{kontrol}}$
Standard deviation and mean in each group (the posttest conducted in two groups)	$\boldsymbol{ES} = \frac{(\bar{\mathrm{x}}_{post} - \bar{\mathrm{x}}_{pre})\boldsymbol{eksperimen} - (\bar{\mathrm{x}}_{post} - \bar{\mathrm{x}}_{pre})\boldsymbol{kontrol}}{\frac{\boldsymbol{SD}_{pre\ kontrol} + \boldsymbol{SD}_{pre\ eksperimen} + \boldsymbol{SD}_{post\ kontrol}}{\mathbf{3}}}$

After the ES calculation is obtained, the results are concluded in Table 2 according to Cohen's criteria (Utami & Indarini, 2021):

Table 2. Category ES

ES	Category
Low	$0 \leq ES \leq 0{,}2$
Medium	$0{,}2 \leq ES \leq 0{,}8$
High	$ES \geq 0{,}8$

It is concluded the effect of the independent variable on the dependent variable in Table 3 (Coe, 2002) based on the calculation of ES which can:

Table 3. The effect of ES on the independent variable

ES	(%)
0,1	*50*
0,2	54
0,3	58
0,4	62

ES	(%)
0,5	66
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**

The research method uses references, research flows, data analysis techniques, and relevant modifications and is focused on literature review articles.

RESULTS AND DISCUSSION

This assessment has passed all stages of research methods. The results obtained from the research data were obtained using a literature review that included predetermined standard considerations, then, after analysis, a total of 13 journal articles were displayed in Table 4 below:

Table 4. Journal Articles The Influence of Learning Styles on Critical Thinking Science Learning

Writer	Bound Variables	Research Methods
(Christiana Niken Larasati at al, 2018)	Critical Thinking Skills	Export Facto
(Nurasia, 2015)	Critical Thinking Skills	Quasi Experiment
(Dyah Aini Purbarani at al, 2018)	Critical thinking skills and learning outcomes	Quasi Experiment
(Dedi Riyan Rizaldi at al, 2021)	Learning Styles and Critical Thinking Skills	pre-experimental
(Diah Mulhayatiah at al, 2024)	Learning Styles and Critical Thinking Skills	Correlation Analysis
(Luning et al., 2023)	Critical thinking	Questionnaire Design
(Anna Maria et al, 2023)	Students' critical thinking skills in terms of learning style	Quantitative Research Approach.
(Mahmood at al, 2020)	Critical thinking	Cross-Sectional Survey
(M. Aini et al, 2020)	Critical Thinking	descriptive research
(Nur Afdila at al, 2020)	Learning Style	qualitative research
(Yuli Hartawati dkk, 2020)	Learning Style	Quasi experiment
(Subhan Harie, 2016)	Critical Thinking Skills	experiment

Writer	Bound Variables	Research Methods
(Witri Nor at al, 2022)	Critical Thinking Skills, Learning Outcomes and Learning Styles	non-experimental

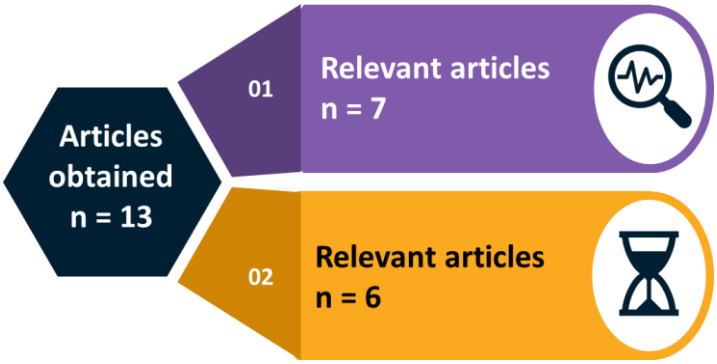

Figure 1. Flowchart for selecting studies to be included

Based on the diagram above, which states the large number of articles obtained is 13 journal articles and found seven relevant journals that discuss the influence of learning styles on critical thinking science, being one of the essential reasons to calculate metrics to determine ES calculations, which are shown in table 5 below:

Table 5. Journal Articles The Influence of Learning Styles on Critical Thinking Science Learning

Writer	X	SD	ES	Category
(Subhan Harie, 2016)	$n_{experiment}$ = 73 $n_{control}$ = 70	t count = 11,2	0,3	Medium
(Yuli Hartawati at al, 2020)	$n_{experiment}$ = 55,8 $n_{control}$ = 50	t count = 5,5	1	High
(Christiana Niken Larasati at al, 2018)	-	-	0,8	Medium
(Dyah Aini Purbarani at al, 2018)	$n_{experiment}$ = 31 $n_{control}$ = 27	t count = 17,167	0,23	Low
(Dedi Riyan Rizaldi at al, 2021)	X_{post} = 56,54 X_{pre} = 22.87	t count = 5,31	6,34	High
(Diah Mulhayatiah at al, 2024)	-	-	0,11	High
(Nurasia, 2015)	X_{post} = 63,53 X_{pre}	t count = 9,15	0,7	Medium

Writer	X	SD	ES	Category
(Subhan Harie, 2016)	$n_{experiment}$ = 73 $n_{control}$ = 70 = 57,05	t count = 11,2	0,3	Medium
	Average		**1,35**	**High**

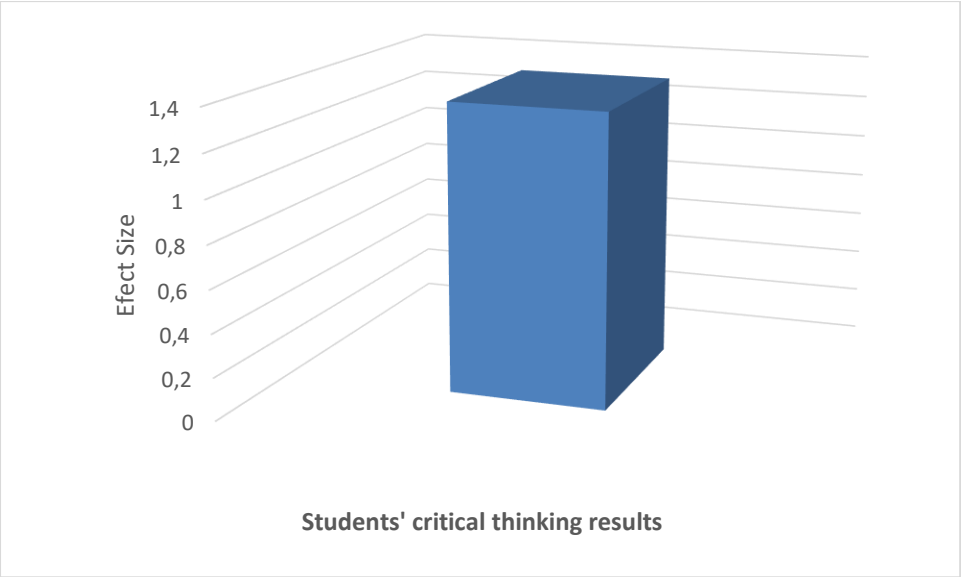

Figure 2. Graph of ES scores on students' critical thinking outcomes)

Based on literature studies, the results of this study obtained as many as 13 journal articles based on the standards set previously and then presented in Table 4. Seven journal research articles discussed the influence of learning styles on critical thinking. However, they selected variables bound to critical thinking because they fulfilled the meta-analysis of the stages of research methods. Based on these stages, seven journal articles can be determined by the ES value according to the equation in Table 1, which is included in one of them. The calculation results are presented clearly and in detail in Table 5 to the overall average stage of the research data. Based on the calculation of ES in Table 5. A percentage of 1.35 was obtained with a high category, concluding the effect of the effectiveness of the independent variable, namely the influence of learning style on the dependent variable, namely critical thinking, 88%.

The results of this study found that learning styles have a significant effect on students' critical thinking. They are reinforced by the results of previous studies, although the results are not in line with research (Hartawati, 2020), which found that when students are faced with a concept given by the teacher, it was found that learning styles to some extent do not affect students' critical thinking skills. When students process information conveyed by the teacher, students form an understanding that is more influenced by what is conveyed, not influenced by the way students get the information conveyed.

However, the current results align with research (Yang et al., 2023), which found that the relationship between student learning styles and critical thinking skills states that there is a positive influence related to student learning styles on critical thinking in science learning. Therefore, the implications of understanding the relationship between learning and critical thinking in the educational context are very significant (Syafi'i, 2023).

By considering the unique learning styles of each student (Dewantara et al., 2020), educators can design more diverse and responsive learning strategies for students' cognitive needs (Hadijaya, 2015). This approach allows educators to use various teaching methods that better suit each student's preferred learning style (Al Fajri, 2018), increasing their understanding and enthusiasm for learning (Safaringga et al, 2022). the implications of learning styles on critical thinking also allow educators to develop a more inclusive and diverse curriculum in science learning (Pata'dungan et al., 2023).

This research is expected to contribute by taking into account different learning styles (Sari, 2019); educators can compile subject matter that offers a variety of learning approaches (Zubaidah, 2020), including visual, auditory, kinesthetic, and a combination of the three (Rafiska & Rahmi, 2023). This allows students with various learning styles to reach their maximum potential in developing critical thinking skills (Hasan & Husna, 2023) and creates a more diverse and inclusive learning environment for all students (Rambung et al., 2023).

CONCLUSION

This study aims to investigate whether learning styles have a significant effect on students' critical thinking skills. From the search results for journal articles, 13 research journals were obtained, seven research article journals that had discussed the influence of learning styles on critical thinking but selected variables bound to critical thinking because they had fulfilled the meta-analysis of the stages of research methods. Based on these stages, the ES value can determine seven journal articles. A percentage of 1.35 was obtained with a high category, concluding the effect of the effectiveness of the independent variable, namely the influence of learning style on the dependent variable, namely critical thinking, 88%.

The results showed that learning styles significantly influenced critical thinking skills. The results also revealed that students' critical thinking skills were in the "high" category. This program can awaken and sharpen students' critical thinking skills because it requires students to create something creatively in groups. This research is expected to contribute by considering different learning styles; educators can compile subject matter that offers various learning approaches, including visual, auditory, kinesthetic, and a combination of the three.

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