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Does Ethnoscience Based STEM Improve Student Critical Thinking Skills Ability in Chemistry Learning? Meta-analysis

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Abstract: The purpose of this study is to synthesize the effect of Ethnoscience-based STEM model size on students' critical thinking skills in chemistry learning. This type of research is a meta-analysis study. The research sample came from an analysis of 15 national and international journals that met the inclusion criteria. Data sources are accessed through Google Scholar, Wiley, ProQuest, ScienceDirect and Taylor of Francis. The data search keyword is the STEM model; Ethnoscience; The influence of ethnoscience-based STEM; and Students' critical thinking skills. Data analysis calculates the value of summary effect size or mean effect size with JASP. The results showed a positive influence of ethnoscience-based STEM models on students' critical thinking skills ($Z = 8.685$; $p < 0.001$). This finding explains that ethnoscience-based STEM models have a significant impact on students' critical thinking skills in chemistry learning with high categories ($rE = 0.853$). The ethnoscience-based STEM model provides solutions for teachers to encourage students' critical thinking skills in chemistry learning at school.

Keywords: Critical Thinking; Ethnoscience; Effect Size; Meta-analysis; STEM model

Introduction

Critical thinking is an ability that students must have to face the challenges of the 21st century (Maison, 2022; Patandung, 2023; Kanmaz, 2022). The ability to think critically helps students solve a problem in life (Ariani, 2020; Sutoyo et al., 2023; Silva et al., 2022; Orhan, 2023; Suharyat et al., 2023). Aminah (2022) said that critical thinking skills train students to think logically and systematically in learning. Furthermore, critical thinking skills encourage students to be more active in learning (Mugisha et al., 2021; Hamdani et al., 2022; Haryati et al., 2022). The ability to think critically helps students make the right and logical decisions in science learning (Küçükaydın et al., 2023).

Science learning requires students to have the ability to think critically in learning. One of the lessons of science is the study of chemistry. The ability to think critically in chemistry learning experiences many problems (Siwa et al., 2013). In the chemistry learning process, teachers do not involve students actively and students have difficulty in understanding chemical material (Listari, 2018; Wahyudiati, 2022). Furthermore, teachers in the chemistry learning process do not direct students to think critically (Andriani, 2021; Miterianifa et al., 2021). Furthermore, the results of *the Trends in International Mathematics and Science Study* (TIMSS) research in 2015 explained that the level of students' critical thinking skills in mathematics and science obtained a score of 396 classified as rendh compared to the international average score of 500 (Suryono et al., 2023; Utomo et al., 2023; Nurtamam et al., 2023). Low critical thinking skills in chemistry learning are also

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influenced by the selection of inappropriate learning models.

STEM is one of the learning models that can encourage students' critical thinking skills in learning (Topsakal et al., 2022; Hacioglu, 2021; Pahruddin et al., 2019). The STEM model is a learning model that combines *Science, Technology, Engineering* and *Mathematica* in supporting the learning process (Marwani &; Sani, 2020; Zainil et al., 2023; Yaki, 2022; Zulyusri et al. , 2023; Hebebci &; Usta, 2022). The STEM learning model trains students to learn higher-order thinking through technology to solve a problem (Ariyatun &; Octavianelis, 2020). STEM learning models can be integrated with ethnosciences.

Ethnoscience is a learning principle that incorporates local wisdom (Wanggi et al., 2023; Dewi et al., 2021). Ethnoscience-based learning trains students to learn to implement learning in accordance with the local wisdom of a community (Solheri et al., 2022). According to (Zidny & Eilks, 2022), ethnoscience-based learning can improve students' cognitive abilities in science learning. The results of research (Dantes et al., 2023) ethnoscience-based learning can encourage critical thinking skills and learning outcomes of theself-centered. Furthermore, the implementation of this Ethnoscience-based STEM learning model provides solutions for teachers in improving students' higher-order thinking skills in learning chemistry.

Research (Sudarsono et al., 2022; Rahman et al., 2023) STEM models based on local wisdom can improve problem-solving and creative thinking skills in students. Research (Mohtar et al., 2016; Idrus, 2022) Ethnoscience-based STEM learning models have a positive impact on increasing interest and motivation in science learning. Furthermore, the results of the study of Sartika et al., (2022) Ethno-STEM models are effective for improving students' analytical thinking skills. The gap in research is that there is a lot of research on ethnoscience-based STEM models, not many studies that describe the effect of ethnoscience-based STEM model size in chemistry learning. Based on this, this study aims to synthesize the effect of Ethnoscience-based STEM model size on students' critical thinking skills in chemistry learning.

Method

Design Research

This study is a type of meta-analysis research. Meta-analysis is a type of research that analyzes and collects primary data that can be analyzed statistically (Taşdemir, 2022; Kazu &; Yalçın, 2021; Zulkifli et al., 2022). According to Borenstein & Rothstein (2007), the steps in conducting a meta-analysis consist of 1) collecting relevant research, 2) coding data, 3) calculating the effect size value of the entire study analyzed and 4) investigating the moderator effect of the research characteristics Figure 1.

Figure 1. Stages of Meta-analysis

Collection of Relevant Research

Data collection in this study was through the databases of Google Scholar, Wiley, ProQuest, ScienceDirect and Taylor of Francis. Inclusion criteria are research derived from journals or proceedings indexed by Scopus, WOS, and SINTA; Research published in 2020-2023, research must be experimental methods (experimental classes of ethnoscience-based STEM models on critical thinking skills) and conventional model control, research must be in Indonesian and English, research results of critical thinking skills and data must have sample size, standard deviation and mean value. The process of selecting data sources through the PRISMA method consists of 1) identification, 2) Screening, 3) Eligibility and 4) Included can be seen in figure 2.

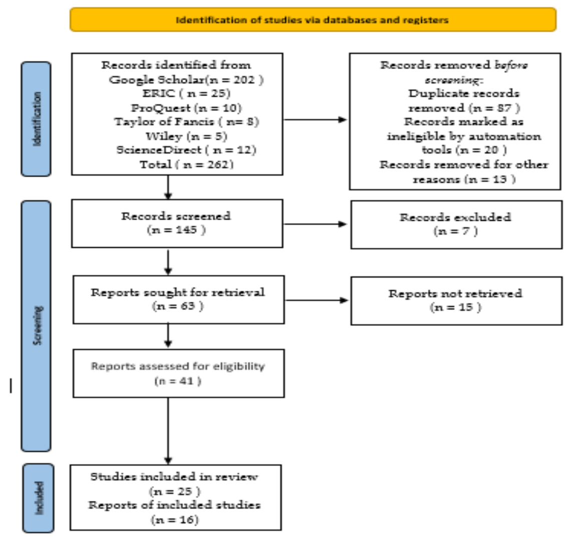

Figure 1. PRISMA Method

Data coding

The data coding process in this study consists of research code, year of publication, research origin, sample size, effect size, research index. Furthermore, the coding of valid data aims to increase the validity of the data in the meta-analysis (Yalcin, 2022). The results of data encoding can be seen in Table 1.

Table 1. Research Data Encoding

Journal Code	Year	Publication	Sampe Size (N)	Effect Size	Index
PA 1	2020	Journal	110	0.90	Scopus
PA 2	2021	Journal	80	1.03	Scopus
PA 3	2021	Journal	60	0.87	SINTA
PA 4	2021	Journal	45	0.66	SINTA
PA 5	2022	Journal	90	1.10	SINTA
PA 6	2023	Proceeding	200	0.93	Scopus
PA 7	2023	Journal	40	0.81	Scopus
PA 8	2020	Journal	86	1.15	WOS
PA 9	2023	Proceeding	124	2.08	Scopus
PA 10	2022	Journal	60	0.95	WOS
PA 11	2021	Journal	92	0.76	SINTA
PA 12	2020	Jurna;	118	0.86	Scopus
PA 13	2023	Journal	40	0.69	Scopus
PA 14	2023	Prodising	88	1.21	Scopus
PA 15	2023	Journal	40	0.72	SINTA
PA 16	2020	Journal	84	0.70	WOS

Statistical Analysis

Data analysis in meta-analysis research is calculating the value of effect Size (Glass, 1974). The effect size in this study illustrates the influence of ethnoscience-based STEM models on students' critical thinking skills in chemistry learning. Statistical analysis follows stages (Borenstein et al., 2009) which consists of calculating the effect value of the primary research, conducting heterogeneity tests, selecting the estimation model used, analyzing publication bias and calculating the p-value to test the hypothesis. Data analysis using JASP applications. The criteria for effect size values are guided by (Cohen et al., 2007) can be seen in Table 2.

Table 2. Effect Size Value Criteria

Effect Size	Criterion
0.0 ≤ ES ≤ 0.2	Low
0.2 ≤ ES ≤ 0.8	Medium
ES ≥ 0.8	High

The heterogeneity test is performed by analyzing the statistics of Q and P values. If the p value < 0.05 then the null hypothesis showing that effect sizes are homogeneously distributed is rejected. Furthermore, if p > 0.05 then the null hypothesis (H_0) is accepted and evaluates *the fixed efefct model*. The meta-analysis in this study used a *random effect model.* Furthermore, publication bias analysis aims to address the error rate of findings (Chamdani et al., 2022; Jang &; Kim, 2020). Publication bias was checked with funnel plots and conducted *Roshental Fail Safe* (FSN) tests (Suparman et al., 2021; Tamur et al., 2020). If indigo FSN/5k + 10 where k = number of studies analyzed in the meta-analysis. In this meta-analysis research is resistant to publication bias (Setiawan et al., 2022; Kozikoğlu, 2019)

Result and Discussion

Results From searching journals or proceedings through the Google Scholar database, Wiley, ProQuest, ScienceDirect and Taylor of Francis regarding ethnoscience-based STEM models on students' critical thinking skills in chemistry learning. The search obtained 16 studies that met the inclusion criteria included in the meta-analysis. Before conducting a hypothesis test, first conduct a heterogeneity test of the entire study. The results of the heterogeneity test can be seen in Table 3.

Table 3. Heterogeneity Test Results

Type	Test of mean				Heterogeneity	
	k	ES	Z	p	Q	p
Fixed	16	0.819	11.072	0.00	63.279	0.001
Random	16	0.853	8.685	0.00		

Based on Table 3. Explaining the results of the heterogeneity test of the whole study with values (Q = 63.279; p < 0.001) then the effect size is heterogeneously distributed. Furthermore, the value of the fixed effect model is 0.819 and *the random effect model* is 0.996. The next step is to analyze the summary effect size or mean effect size which can be seen in Table 4.

Table 4. Hajj test Summary Effect Size or Mean Effect Size

	Estimates	Standard Error	z	p	Lower bound	Upper bound
Inter-cept	0.853	0.398	8,685	< 0.001	0.661	1,046

Based on Table 5. explain the results of the summary effect model analysis or mean effect model obtained values (r_E = 0.853; Z = 8.685; p < 0.001) then ethnoscience-based STEM models have a positive effect with high category on students' critical thinking skills in chemistry learning. In addition, the *summary effect size* analysis test is also depicted with *the forest plot* in figure 3.

Based on the figure 2. *Forest plots* show the magnitude of the influence of relevant research in the meta-analysis. The effect size ranges from 0.70 – 2.08 and the standard error ranges from 0.29 – 0.67. next, analyzing publication bias to determine the degree of false findings from the overall studies analyzed (Yusuf, 2023; Borenstein et al., 2010). Analysis of publication bias in this study with funnel plots. The results of the funnel plot analysis can be seen in figure 4.

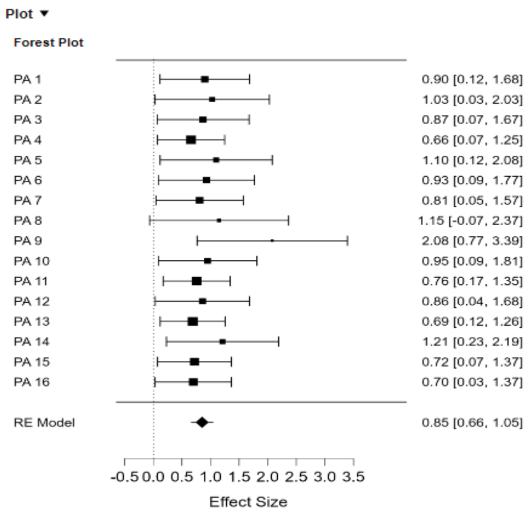

Figure 2. Forest Plot

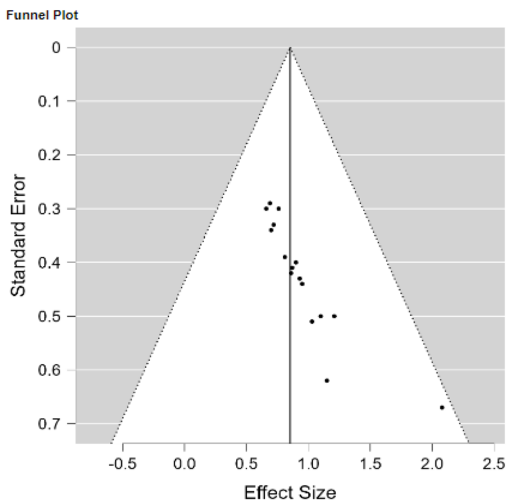

Figure 3. Funnel Plot Standard Error

Based on figure 4. Explains that the research points that domina expanded are in the middle of the curve. This shows the effect size of akurat but it is difficult to determine the shape of symsteria or asymmetry. then Egger tested. The results of the Egger test can be seen in Table 6.

Table 5. Egger Test Results

	z	p
Sei	2.134	0.001

Based on Table 5. The results of Egger's test show a value (Z = 2.134; p-value < 0.05) then the distribution of effect size in the *funnel plot* is symmetrical. The funnel plot showed no publication bias in this study. Furthermore, to increase the validity regarding publication bias, it is necessary to conduct *a Fasil Safe* N (FSN) test. The rosenthal fail save N (FSN) test is very accurate for analyzing the publication bias of meta-analysis research data (Tamur &; Wijaya, 2021; Jeong et al., 201; Yildirim & Kurt, 2022). The results of the *safe N file* test can be seen in Table 6.

Table 6. *Safe N File* Test Results

	Fail safe N	Target Significance	Observed significance
Rosenthal	457	0.050	< 0.001

Based on table 6. The *safe* N (FSN) file value is 457. Next, the value of the safe N file is compared to the value of k = (5.16) + 10 = 90. Therefore the *safe file* value N 457/ 90 = 5.07> 1. These results show that in the meta-analysis there was no publication bias and no studies were added or omitted. Therefore, ethnoscience-based STEM models are effective for improving students' critical thinking skills in chemistry learning.

Research by Made et al., (2023) said the ethnoscience-based STEM learning model is effective for cultivating students' mental chemistry in learning. Research (Izalia &; Wisnuadi, 2020; Qori et al., 2020) ethnoscience-based STEM models in encouraging students in higher-order thinking. The STEM learning model of students learns actively and innovatively by combining science and technology in solving a problem (Yang et al., 2020; Eroğlu, 2021; Fadlelmula et al., 2022). Furthermore, the STEM learning model can train students to cultivate scientific attitudes and students' scientific work in learning (Werdhiana et al., 2021).

Furthermore, the ethnoscience-based STEM learning model makes it easier for students to understand the subject matter because they directly see facts in the field. Research (Sudarmin et al., 2020; Mahyuny &; Manurung, 2023; Rahman et al., 2023; Eid al., 2023) Ethnoscience-based learning can help students to directly implement science material in society so that it can encourage them to think critically. Ethnoscience-based STEM models can also have conservation characters and foster students' entrepreneurial attitudes in chemistry learning (Sudarmin et al., 2023). In chemistry learning leads students to have the ability to think critically, innovatively and creatively in learning. This is because students must have critical thinking skills to find solutions in problem solving. In addition, the STEM-based learning model is very effective in increasing students' literacy skills in chemistry learning in the face of the 21st century (Primadianningsih &; Sumarni, 2023). The STEM model of students being more active in accessing information can be able to support their critical thinking skills in learning.

Conclusion

In the meta-analysis study, it can be concluded that there is a positive influence of ethnoscience-based STEM models on students' critical thinking skills (Z = 8.685; p < 0.001). This finding explains that ethnoscience-based STEM models have a significant impact on students' critical thinking skills in chemistry learning with a high category (rE = 0.853). The ethnoscience-based STEM model provides solutions for teachers to encourage students' critical thinking skills in chemistry learning at school. The ethnoscience-based STEM learning model helps the student learning process more interesting. Not only that, ethnicscience-based STEM models can help students develop high-level thinking skills in chemistry learning

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Conflicts of Interest

The authors declare no conflict of interest.

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