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Effectiveness of Ethno-STEM Based Chimistry to Improve Students Critical Thinking Skills

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Abstract: Ethno-STEM based chemistry learning has a significant impact on students' knowledge and competencies. However, ethno-STEM based chemistry learning experiences many problems in its application and several issues that need to be clarified. This research aims to determine the effectiveness of ethno-STEM based chemistry learning in improving students' critical thinking skills. This type of research is meta-analysis. This meta-analysis synthesizes 19 articles consisting of 1021 participants published in 2018-2023. The research results show that ethno-STEM based chemistry learning has a big influence on students' critical thinking skills (Hedges'g = 0.915; $p < 0.001$). Research can provide important information in ethno-STEM-based chemistry learning in schools.

Keywords: Chemistry Learning; Critical Thinking; Ethno-STEM; Meta-analysis

Introduction

Critical thinking is a skill that students must have in facing 21st century learning (Zulyusri et al., 2022; Kuloğlu &; Karabekmez, 2022; Illene et al., 2023). Critical thinking skills play an important role in assisting students in analyzing and inferring information (Toheri et al., 2020; Kanmaz, 2022; Amin et al., 2020). In addition, critical skills train students to think higher-order in learning (Yaki, 2022; Maison, 2022). Students who have critical thinking skills are more active and creative in learning (Rahman et al., 2023; Suryono et al., 2023; Putra et al., 2023). Furthermore, critical thinking skills can encourage students to make a decision in learning (Sudirman et al., 2021; Hidayati et al., 2022; Zhou, 2018).

But in reality, students' critical thinking skills at school are still relatively low (Ariani, 2020; Ichsan et al., 2023; Birgili, 2015; Supriyadi et al., 2023; Fitriani, 2020). The results are also supported by the results of PISA research in 2018 the science literacy ability of Indonesian students obtained a score of 396 ranking 71 out of 78 countries (Hariyadi et al., 2023; Nurtamam et al., 2023; Luciana et al., 2023; Sofianora et al., 2023; Utomo et al., 2023; Oktarina et al., 2021). Furthermore, the results of the 2015 TIMSS survey stated that students' critical thinking skills in science and mathematics only obtained a score of 396 lower than the international score of 500 (Putra et al., 2023; Rahman et al., 2023). The low critical thinking skills of students are also caused by inappropriate model selection encouraging students to think critically in chemistry learning (Rijal et al., 2021; Yustiana el al., 2022).

In chemistry learning, students must be required to have the ability to think logically and systematically to solve a problem (Lay &; Usman, 2018; Kozma et al., 2020). In chemistry learning, students are able to apply materials and concepts with the surrounding environment (Permatasari et al., 2022; Huda &; Rohaeti,

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2022; Azizah &; Yonata, 2023). In addition, in chemistry learning students can explain concepts related to reactions, chemical structure of substances and composition of an object that can be applied in everyday life (Risnita, 2020; Astiningsih, 2020).

Ethno-STEM-based chemistry learning has a significant impact on students' analytical thinking skills (Sartika et al., 2022). Ethno-STEM is a learning that combines ethnoscience and STEM to support the learning process (Wahidah et al., 2022). Ethno-STEM learning helps students have science and technology literacy in the learning process (Sudarmin et al., 2022). Ethno-STEM learning students can reconstruct local wisdom with the material of the lessons learned (Reffiane et al., 2021; Sudarmin et al., 2023).

Research Sumarni &; Kadarwati, (2020) ethno-STEM learning has a significant influence on students' creative thinking skills. Ilyas & Ikram (2021) research said ethno-STEM-based learning can improve students' understanding of concepts. Azis &; Yulkifli (2020) Ethno-STEM learning effectively encourages students' 21st century thinking skills. However, many ethno-STEM-related studies still have little to find a comprehensive effect size of ethno-STEM-based chemistry learning. Based on these problems, the study aims to determine the effectiveness of ethno-STEM-based chemistry learning in improving students' critical thinking skills so that it can provide important information in ethno-STEM-based chemistry learning at school.

Method

This study is a type of meta-analysis research. The meta-analysis study aims to determine the effectiveness of ethno-STEM-based chemistry learning on students' critical thinking skills. The meta-analysis research steps consist of formulating a problem; literature search; collect data; conduct an evaluation of the quality of research; analyze and interpret research data (Borenstein et al., 2009; Cohen et al., 2007; Ridwan et al., 2021; Cooper, 2010) can be seen in Figure 1.

Figure 1. Meta-analysis procedure

Inclusion criteria

The inclusion criteria in this study consist of experimental or quasi-experimental research; research comes from international journals or proceedings indexed by Scopus or WOS, and SINTA, Publications published in 2018-2023; Research related to chemistry learning; ethno-STEM and critical thinking skills; Journals must report data on average grades, standard deviations, t grades, r and F grades, as well as education levels from elementary, junior high, high school and tertiary institutions.

Literature Seacrh and Coding Data

Literature search through google scholar database, ScienceDirect, ProQuest, ERIC, Hindawi Journal, IEEE Explore, AIP Proceedings, IOP Proceedings, and Taylor of Francis. From a literature search, 219 articles were obtained. However, 13 articles included in the meta-analysis were selected through the *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA) method consisting of identification; Eligibility and Included can be seen in Figure 2.

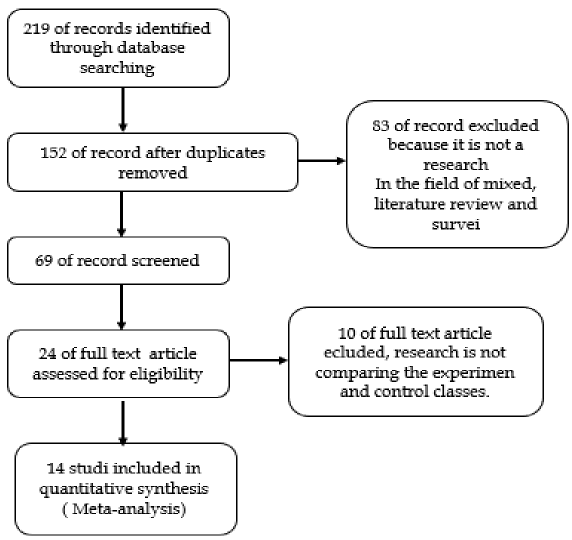

Figure 2. The Process of Selecting Data Through PRISMA Method

Data Analysis

Data analysis in the analysis study calculated the effect size value of each primary study (Ramdani et al., 2022; Ridwan, 2022). Furthermore, statistical analysis steps guided by (Borenstein et al., 2009) can be seen in Figure 3.

Analyze the data in this meta-analysis with the help of the SAP application. The effect criteria are guided by (Cohen et al., 2007; Cooper, 2010) can be seen Table 1.

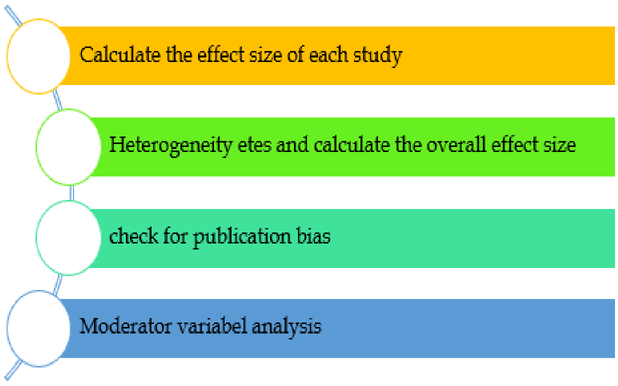

Figure 3. Meta-analysis data analysis

Table 1. Category Effect Size

Effect Size	Category
0.00 ≤ ES ≤ 0.20	Low
0.20 ≤ ES ≤ 0.80	Medium
ES ≥ 0.80	High

Furthermore, Q parameter analysis serves to test the heterogeneity of the entire study and to determine the estimation model used and analyze the summary effect size (Suyantiningsih et al., 2023). Furthermore, checking publication bias with funnel plot analysis and *rosenthal fail safe* N (FSN) test (Diah et al., 2022; Tamur et al., 2020; Sun et al., 2021; Chamdani et al., 2022).

Result and Discussion

In the initial meta-analysis research, it involves determining the effect size of each study analyzed. In the meta-analysis, 14 articles were obtained that had met the inclusion criteria for summary effect size analysis. The results of the summary effect size analysis of each study were obtained with the help of the JSAP application which can be seen in Table 2.

Table 2, shows the results of the analysis of 14 effect sizes obtained the lowest effect size nillai 0.27 with lower - 0.44 and upper of 0.76 while the highest efefct size is 2.13 with lower 0.45 and upper of 1.16. In this analysis, one study had a low effect size criterion (n = 1), four studies had a medium effect size criterion (n = 4) and nine studies had a high effect size (n = 9). These findings conclude that the application of ethno-STEM-based chemistry learning has a diverse influence on students' critical thinking skills. Therefore, an overall effect size test must be carried out.

Next, test heterogeneity and determine the selection of models to analyze the summary effect size. The results of the heterogeneity test and determination of the estimation model used can be seen in Table 3.

Table 2. Effect Size of Each Study

Article Code	Year	Effect Size	Publication Type	95 % Confidence Interval	
				Lower	Upper
PL1	2020	1.19	Journal	0.42	0.98
PL2	2020	0.81	Journal	0.52	1.27
PL3	2023	0.62	Proceeding	0.36	0.91
PL4	2021	2.13	Journal	0.45	1.16
PL5	2018	1.10	Journal	0.39	0.92
PL6	2020	0.98	Journal	0.56	1.58
PL7	2023	0.52	Proceeding	0.39	0.85
PL8	2023	0.85	Journal	0.62	1.68
PL9	2018	1.08	Journal	0.39	0.85
PL10	2021	0.27	Journal	-0.44	0.76
PL11	2022	0.92	Journal	0.18	0.73
PL12	2019	0.77	Journal	0.47	1.92
PL13	2023	1.42	Journal	0.27	0.61
PL14	2023	0.53	Journal	0.39	0.94

Table 3. Heterogeneity Test Results and Determination of Estimation Models

Type	k	Effect Size (d)	95% CI	P	Df	Heterogeneity		
						Q	P	I^2
Random	14	0.915	[0.85, 1.14]	< 0.001	13	76.81	< 0.001	86.14
Fixed	14	0.917	[1.02, 1.45]	< 0.001	13			

Table 3, explaining the results of the heterogeneity test obtained a value of Q = 76.81 > chi square (df = 13). This finding shows that the 14 effect sizes analyzed have various values. The estimation model used in this meta-analysis is random effect size. The results obtained random effect size values (d- 0.915; p < 0.001). The effect size in this study is a high category. This finding can be concluded that ethno-STEM-based chemistry learning has a significant influence on students' critical thinking skills. Next, check publication bias. Checking publication bias in meta-analyses aims to avoid too significant data (Öztop, 2023). Checking publication bias in meta-analysis through *funnel plot* and *Rosenthal fail safe* N (FSN) test (Tamur et al., 2020; Diah et al., 2022; Rahman et al., 2023; Hawes et al., 2022). Funnel plot is a form of diagram in met-analysis to see the publication bias of the analyzed research (Hidayah, 2023). The results of the publication bias analysis of 14 effect sizes analyzed through funnel plots can be seen in Figure 4.

Based on figure 4, showing the results of funnel plot analysis, it is not yet known whether there is a publication bias. Therefore, it is necessary to perform the *Rosenthal Fail Safe* (FSN) test. Rosenthal Fail Safe N (FSN) test results can be seen in Table 4.

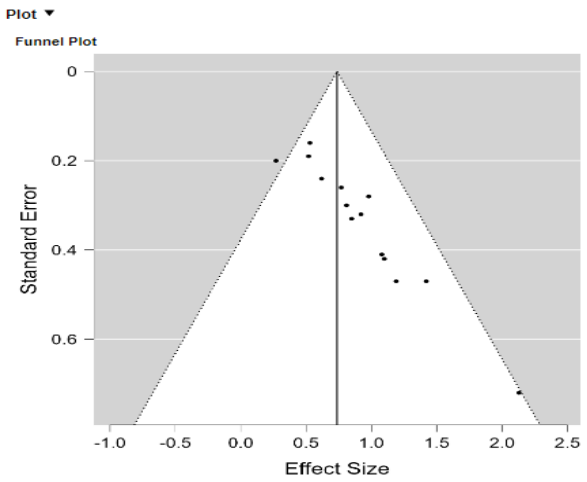

Figure 4. Funnel Plot

Table 4. Test Results Rosenthal Fail Safe N

	Fail safe N	Target Significance	Observed Significance
Rosenthal	530	0.050	< 0.001

Table 4, explains that the safe file value N = 530. This result is greater than the value of 5k + 10 = 5(14) + 10 = 80. This finding concludes in a meta-analysis of 14 effect sizes there is no publication bias. Next, analyze moderator variables to determine the effectiveness of ethno-STEM-based chemistry learning to improve students' critical thinking skills. The results of the analysis of moderator variables can be seen in Table 5.

Based on Table 5, analysis of moderator variables at the education level. High school education level and PT effect size high category (d = 0.97 < 0.01; d = 0.85 < 0.01) and junior high school education level effect size medium category (d = 0.76 < 0.01). In the comparative analysis there was a significant difference in statistical calculations (Q_b = 15.10; p < 0.05). These results conclude that ethno-STEM-based chemistry learning is effective in improving students' critical thinking skills compared to conventional learning based on education levels.

Based on the analysis of moderator variables in the publication year, the high category effect size of 2018-2020 (d = 1.10 < 0.01) and the high cathogi effect size also the range of 2021-2023 (d = 0.98 < 0.01). This finding showed a significant difference (Q_b = 11.98; p < 0.05). It can be concluded that ethno-STEM-based chemistry learning is effective in improving students' critical thinking skills compared to conventional learning based onjournal publications. The ethno-STEM-based chemistry learning model is effective in the 2018-2020 journal issue.

Based on the analysis of moderator variables on the sample size, a small sample size effect size of 25 (d = 0.81 < 0.01) and a large sample size effect size of 25 (d = 1.26) were obtained. The results of statistical analysis showed no significant difference (Q_b = 0.62; P > 0.05). This finding explains that ethno-STEM-based chemistry learning is effective in improving students' critical thinking skills compared to conventional learning based on sample size. So, the application of ethno-STEM-based chemistry learning models is very effective to encourage students' critical thinking skills in schools.

Table 5. Moderator Variable Analysis

Variable	k	Effect Size (d)	p	Heterogeneity			
				Q	Df	Q_b	P
Education Level							
JUNIOR	2	0.76	< 0.01	21.09	1	15.10	0.00
SMA	7	0.97	< 0.01	18.70			
PT	4	0.85	< 0.01	23.15			
Year of publication							
2018-2020	7	1.10	< 0.01	24.52	1	11.98	0.00
2021-2023	6	0.98	< 0.01	22 .10			
Sample size							
25 or less	2	0.81	< 0.01	10.15	1	0.62	1.04
25 or over	12	1.26	< 0.01	56.89			

This research is in line with Ariyatun (2021) that ethno-STEM-based chemistry learning is effective for improving students' critical and creative thinking skills in learning. This finding is also supported by Sumarni & Kadarwati's (2020) research , ethno-STEM-based learning can encourage critical thinking in solving problems. Student chemistry learning must have knowledge and competence that can provide solutions to life problems. Not only that, ethno-STEM-based chemistry learning can encourage students' science and technology literacy (Hasyim &; Sujiono, 202; Primadianningsih &; Sumarni, 2023). In the process of learning chemistry, students can implement material with the surrounding environment.

Ethno-STEM-based chemistry learning is very helpful for students in improving higher-order thinking skills in learning. According to Idul et al., (2023) learning that combines ethnoscience-STEM is able to train students to think critically in learning. Ethnoscience-STEM-based chemistry learning makes it easier for students to understand the subject matter (Sudarmin et al., 2019). In addition, ethno-STEM-based chemistry learning develops students' entrepreneurial skills and character in everyday life (Asmaningrum et al., 2022; Syahrial et al., 2021). Therefore, ethno-STEM-based chemistry learning has a positive impact on students to grow their critical thinking skills.

Conclusion

In the meta-analysis research it can be concluded that ethno-STEM-based chemistry learning has a major effect on students' critical thinking skills (Hedges'g = 0.98; p < 0.001). Research can provide important information in ethno-STEM-based chemistry learning in schools. Ethno-STEM-based chemistry learning can encourage students' science literacy and technology skills in learning. Not only that, ethno-STEM-based chemistry learning students learn more actively and are innovative in learning activities and are able to relate to local wisdom.

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Author Contributions
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Conflicts of Interest
The authors declare no conflict of interest.

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