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The Effect of STEM-Based REACT Model on Students' Critical Thinking Skills: A Meta-Analysis Study

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Abstract. This study aims to determine the effectiveness of the STEM-based REACT model on students' critical thinking skills. This research is a meta-analysis study. This study collected previous meta-analysis studies related to the STEM-based REACT model that showed gaps in the current article. The data sources in the study came from 13 national and international journals published in 2018-2019. The process of searching for data sources through the google scholar database, Eric, Wiley, Taylor of Francis, ScienceDirect, ProQuest and Hindawi. Inclusion criteria are studies on the REACT model using experimental or quasi-experimental research methods and measurement of critical thinking skills to evaluate the effect of the REACT model. The results showed that the average effect size value (ES = 0.88) with high criteria. The findings show that the application of the STEM-based REACT model has a significant effect on students' critical thinking skills. Furthermore, the effect size in this study was influenced by the level of education, learning outcomes, and student competencies. The STEM-based REACT model has a positive impact on students in encouraging their critical thinking skills.

Keywords: REACT, STEM, Critical Thinking Skills, Meta-Analysis

INTRODUCTION

Critical thinking skills are an ability that students must have to formulate a problem systematically (Lestari et al., 2017; Alharbi, 2022; Yaki, 2022; Khalid et al., 2021). Critical thinking skills are very important for students in understanding the concept of the lesson (Haryati et al., 2022; Aminah, 2022). Critical thinking skills are able to focus students more actively in learning rather than gaining knowledge (Redhana, 2013; Pala, 2022; Amhar et al., 2022; Rahman et al., 2023). According to Hayati & Berlianti (2020) Students who have critical thinking skills can solve various problems in the teaching and learning process. Furthermore, critical thinking skills are one of the skills that students must have to face the 21st century (Suharyat et al., 2022; Kaowiwattanakul, 2021; Sofianora et al., 2023; Daga et al., 2022).

The level of thinking skills of students in Indonesia is still very concerning. This is based on the HDI Survey (*Human Development Indeks*) in (Munawwarah et al., 2020) The quality of human resources is still low, ranking only 110 out of 183 countries with a score of 0.689. PISA (Program for International Students Asessment) results in (Supriyadi et al., 2023; Rahman et al., 2023; Zulyusri et al., 2022; Elfira et al., 2023) In 2018 the science literacy level of Indonesian students was ranked 62 out of 73 members. Students' low critical thinking skills are influenced by the learning models and methods used by teachers (Sarwanto et al., 2021; Purwanto et al., 2022; Karim et al., 2023; Fradila et al., 2021), making it difficult for students to understand the subject matter (Zulhelmi et al., 2017; Suharyat et al., 2023; Rahman et al., 2023). According to (Chusni et al., 2020) The teacher still dominates the teaching and learning process and the test questions given by the teacher have not led to critical thinking skills.

REACT or Relating Experiencing Applying Cooperating and Transferring is a learning model that can improve students' critical thinking skills (Akay & Kanadli, 2021;Wulandari et al., 2015). The REACT learning model has five stages, namely relating, experiencing, applying, cooperating and

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transferring.(Cahyono et al., 2017; Farid & Nurhayati, 2014; Bílgín et al., 2017). The REACT model can improve students' science understanding and learning outcomes (Sirajuddin et al., 2018). This REACT learning model is able to improve student communication (Kusumaningsih et al., 2019). In addition, this REACT model is able to improve the process of understanding concepts in students (Jelatu et al., 2018; Quainoo et al., 2021; Karsli & Yigit, 2017). Furthermore, the STEM-based REACT model will help students develop critical thinking skills.

STEM is a learning approach that combines science, technology, engineering and math in the learning process (Taşdemir, 2022;Kazu & Yalçın, 2021). STEM approach can improve critical thinking and problem solving skills in students (Dogan & Kahraman, 2021). Therefore, the STEM-based REACT model is effective for improving students' thinking skills Hidayanti *et al*., (2019), and mastery of technology as a learning medium (Yusuf et al., 2020). Previous research shows that the REACT model can improve students' understanding of mathematical concepts. (Novri, 2018). Research by Syntia *et al.*, (2018) STEM-based REACT model is able to encourage concept understanding skills in students' science learning. Furthermore, research by this REACT model can improve students' 21st century thinking skills(Gokalp & Adem, 2020).

Based on the above problems, this study aims to determine the effect of the STEM-based REACT model on students' critical thinking skills.

METHODS

Design Model

This research is a type of meta-analysis research. Meta-analysis is a type of research that analyzes each study that can be analyzed quantitatively (Wang et al., 2022; Oktarina et al., 2021; Razak et al., 2021). Meta-analysis aims to systematically answer studies by testing research hypotheses.

Data Source and Search Strategy

Tracing data sources using the PRISMA method (Jeong et al., 2019). Data sources were searched through the google scholar database, Eric, Doaj, Eric, ScienceDirect and ProQuest. Studies that can be used as data sources are articles published from 2018 to 2023. Furthermore, each study was written in Indonesian or English published in the form of journals and conferences. This study refers to the meta-analysis research strategy (Saraç, 2018; Kim et al., 2018). The keywords used for the meta-analysis were REACT model; STEM and critical thinking skills.

Inclusion and Exclusion Criteria

The inclusion criteria used in this study are 1) Studies have been published in 2018 to 2023; 2) each study focuses on the effect of the REACT model; 3) All studies must provide data that can be calculated effect size (ES). Furthermore, the exclusion criteria used are studies not published in English; 2) Studies did not have enough data to calculate the effect size value; 3) Studies that did not have a control class; 4) Studies that focused on REACT issues.

Furthermore, the process of data collection, searching, screening and collecting articles that have met the inclusion criteria can be seen (Figure 1.). 48 The included research articles will be subjected to a selection process that has met the predetermined eligibility. The researcher further read each study that met the inclusion and exclusion criteria. Furthermore, there were 13 national or international journals that met the criteria for meta-analysis.

Data analysis

The steps of meta-analysis in research are suggested by Borenstein, Hedges, Heggins and Rotstein in (Belland et al., 2017) namely 1) calculate the effect size value of each article; 2) Determine the average effect size (weighted effect size) between studies; 3) Calculate the standard deviation for the average effect size; 4) Determine whether the effect size is influenced by moderator variables or not by paying attention to the value of hereogeneity (paying attention to the statistical value of Qb). Furthermore, to calculate experimental research studies without tests using Cohen's formula which is used to calculate the effect size value (Yücelyiğit & Toker, 2021). For experimental or quasi-experimental research with pretests with respect to publication bias values (Yanagawa et al., 2020). So, the Fuktak formula is used to calculate the effect size value of each study in the pretest and posttest classes. (Xue et al., 2021; Sun et al., 2021). The effect size criteria can be seen in (Table.2).

Table 1. Effect Size Criteria

Effect Size	Kriteria
$0 \leq ES \leq 0.2$	Low
$0.2 \leq ES \leq 0.8$	Medium
$ES \geq 0.8$	Hight

Source: (Suharyat et al., 2022; Zulkifli et al., 2022; Santosa et al., 2021)

Furthermore, calculating the effect size value in this meta-analysis uses the help of the Comprehensive Meta-analysis (CMA) version 3.0 application.

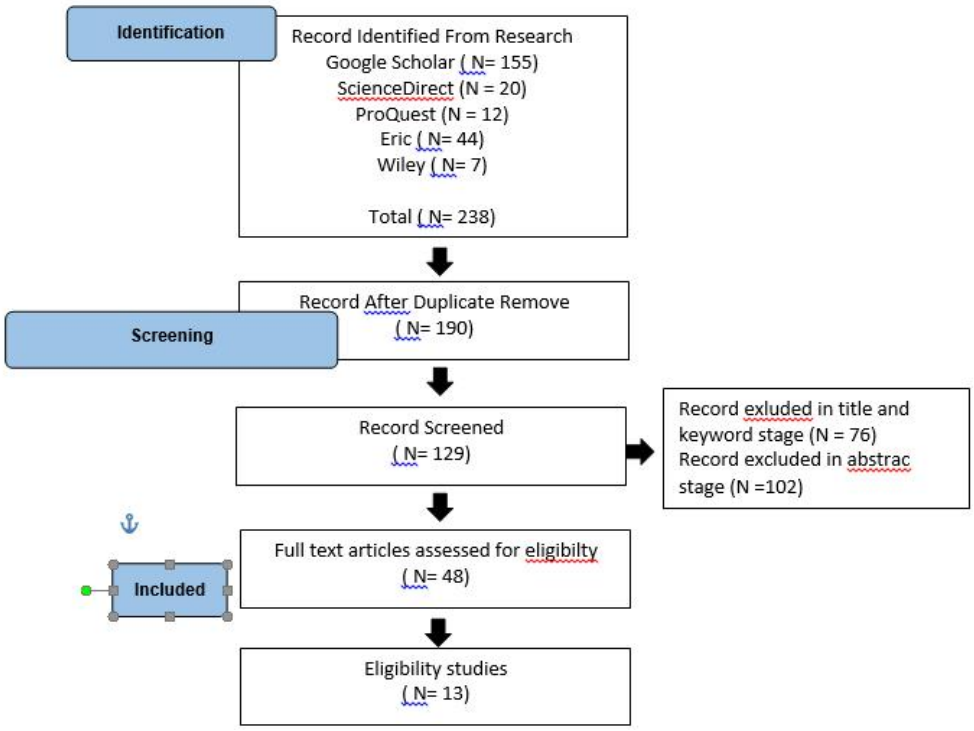

Figure 1. PRISMA Article Screening Process for Meta-analysis

RESULT AND DISUCUSSION

From the meta-analysis of 238 national and international journals related to the effect of the STEM-based REACT model on students' critical thinking skills, only 13 studies met the inclusion criteria. Furthermore, each study that meets the inclusion is calculated the effect size value which can be seen (Table 2.).

Table 2. Effect size of each study

No	Author	Year	Journal Type	Negara	Effect Size	Kriteria Effect Size
1	Ihsani *et al.*,	2020	National	Indonesia	0.20	Low
2	Kurniasih	2017	National	Indonesia	0.87	Hight
3	Mawarni *et al.*,	2019	National	Indonesia	0.66	Medium
4	Wulandari *et al.*,	2015	National	Indonesia	1.20	Hight
5	Sari & Nugroho	2021	National	Indonesia	0.92	Hight
6	Wulandari & Maulana	2019	National	Indonesia	0.72	Medium
7	Nisa *et al.*,	2018	National	Indonesia	0.45	Medium
8	Cahyono *et al.*,	2017	National	Indonesia	1.35	Hight
9	Syntia *et al.*,	2018	National	Indonesia	0.80	Hight
10	Hasanah *et al.*,	2019	National	Indonesia	1.10	Hight
11	Putu *et al.*,	2021	International	Indonesia	1.39	Hight
12	Qadri *et al.*,	2019	International	Indonesia	0.45	Medium
13	Jelatu et al.,	2018	International	Turki	1.40	Hight
Average effect size (ES) value					**0.88**	**Hight**

Based on Table 2. Shows the average effect size value (ES = 0.88) with high criteria. This concludes that the STEM-based REACT model has a significant effect on students' critical thinking skills. The application of the STEM-based REACT model has a major influence on students' critical thinking and problem solving skills (Saka, 2011; Nurhasanah & Fauzan, 2018; Eshetu & Assefa, 2019) . According to Elpina *et al.*, (2019) REACT model can foster students' communication skills in

learning. In addition, the STEM-based REACT model can improve students' problem-solving thinking skills and motivation to learn actively (Kaya, 2021; Heleni & Zulnaidi, 2021). Students in teaching and learning activities in the classroom should be easier to understand the subject matter. The STEM-based REAC model provides positive benefits for students and teachers in the learning process.

Furthermore, the effect size value of the students' education level on critical thinking skills using the STEM-based REACT model can be seen in Figure 1.

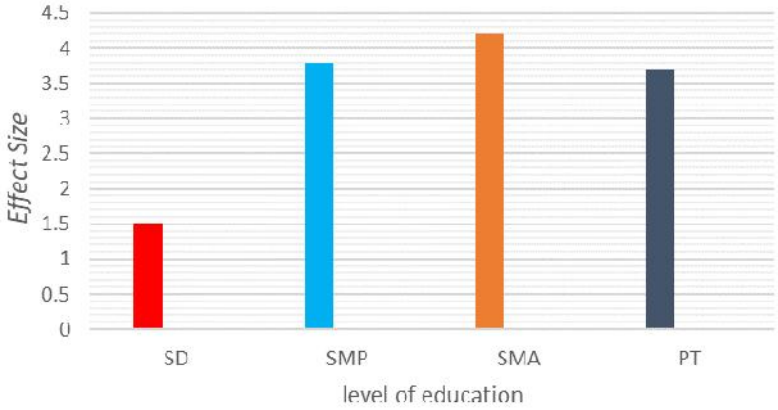

Figure 2. Effect Size by Student Education Level

Based on Figure 1. shows the effect size value of applying the STEM-based REACT model to elementary school students by 1.5, junior high school by 3.8, high school by 4.2 and university by 3.7. This explains that the application of the STEM-based REACT model is widely used by high school teachers in improving students' critical thinking skills. Students at the secondary education level are required to have critical thinking skills (Nurhasanah & Fauzan, 2018 ;Feronika et al., 2020). Critical thinking skills are very important for students in solving problems in learning (Martyaningrum et al., 2021; Noreen & Id, 2022; Snyder & Wiles, 2015). Furthermore, calculating the research heterogeneity of each study related to the STEM-based REACT model on students' critical thinking skills. The results of the heterogeneity test can be seen in (Table 3.)

Table 3. Heterogeneity Test Results

Model	n	Hedge's	Standard Error	95% CL	Q	P	Decision
Fixed	13	0.960	0.065	[0.671;0.534]	32.140	0.00	Reject H_0
Random	13	0.987	0.240	[0.761; 0.620]			

Based on Table 3. Shows the heterogeneity test value ($Q = 32.140$; $P < 0.05$) that the effect size value of each study is heterogeneously distributed. So, the random effect model was used in this meta-analysis. The average effect size value is 0.88, meaning that the STEM-based REACT model has a positive impact on students' critical thinking skills compared to the conventional model.

The next stage determines publication bias to see if each publication is resistant to bias. To calculate publication bias using the Rosenthal Fail-Safe N (FSN) test which can be seen in table 4.

Table 4. Rosenthal Fail-Safe N (FSN) Test Hail

Classic Fail-Safe N	
Z-Value for observed studies	11.67
The P-value for observed studies	0.00
Alpha	0.05
Tails	2.00
Z for alpha	1.86
Number of observed studies	13.00
Number of missing studies that would bring p-value to > aplha	242.012

Based on Table 4. Shows the Rosenthal Fail-Safe N (FSN) test value of 242.012, then obtained (242.012 / 5.13 + 10) = 3.22 > 1. Thus, all studies in this study are resistant to publication bias. The next step is to conduct hypothesis testing to see the effectiveness of the STEM-based REACT model as a whole based on the random effect model. The results of hypothesis testing based on the random effect model can be seen in Table 5.

Table 5. Hypothesis Test Results Based on Random effect model

Model	n	Z	P	Effect size	Standard Error	95% CL
Random	13	6.780	0.00	0.885	0.240	[0.752;0.631]

Based on Table 5. Shows the effect size value of 0.885 with a standard error = 0.240 with high criteria. Furthermore, the Z value is 6,780 with a p-value = 0.00, it can be concluded that the STEM-based REACT model is very effective in improving students' thinking skills rather than using conventional models. This REACT model is effective in improving learning outcomes and students' critical thinking skills in science learning (Sulastri et al., 2021; Amaria & Hendriyanto, 2013; Suharyat et al., 2022). The REACT model encourages students to improve their understanding of concepts in learning. In addition, the STEM-based REACT model can improve student learning outcomes (Suleman et al., 2022); Taraufu et al., 2020). So, the application of the REACT-based model supports students in developing the potential of the mind in learning (Gökalp & Adem, 2020; Ferdyan et al., 2021).

CONCLUSION

From the meta-analysis it can be concluded that the average effect size value (ES = 0.88) with high criteria. The application of the STEM-based REACT model has a significant effect on students' critical thinking skills. Furthermore, the effect size in this study was influenced by the level of education and learning outcomes. The STEM-based REACT model has a positive impact on students in encouraging their critical thinking skills. The STEM-based REACT model is very effective for teachers in developing students' critical thinking skills in learning. Because the STEM-based REACT model encourages students to be more active and creative in learning and finding solutions in problem solving.

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