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The Influence of the Stem-Based Guided Inquiry Model on Students' Creative Thinking Skills in Science Learning: A Meta-Analysis Study

Dewanto[1*], Tomi Apra Santosa[2], Arista Ratih[2], Asrizal[3], Hardeli[3]

[1] Universitas Negeri Surabaya, Surabaya, Indonesia.
[2] Doctor of Science Education, FMIPA, Universitas Negeri Padang, Padang, Indonesia.
[3] Postgraduate Lecturer, FMIPA, Universitas Negeri Padang, Padang, Indonesia.

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Corresponding Author:
Dewanto
dewanto@uns.ac.id

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Abstract: This study aims to determine the effect of STEM-based guided inquiry models on students' Creative Thinking Skills in science learning. This type of research is a meta-analysis. The study analyzed 15 primary studies published in 2018-2023 that had met the inclusion criteria. Search data sources through the Google scholar database; ERIC, Taylor of Francis, ScienceDirect and ProQuest. Data analysis with the help of the JSAP application verse 0.16.3. These results conclude that the overall value of effect size is 0.99 (95% CI [0.79; 1,19]) high category. These findings show that the application of STEM-based inquiry-based learning models affects students' 21st century thinking skills. In addition, these findings provide important information on STEM-based guided inquiry learning in schools.

Keywords: Guided inquiry; Learning model; STEM; 21st century thinking

Introduction

Creative thinking is a skill that students must have in facing the industrial revolution 4.0 in the 21st century (Sihaloho et al., 2017; Simanjuntak et al., 2021; Mursid et al., 2022). Creative thinking skills train students to provide new solutions or ideas in solving a problem (Hidayat et al., 2022; Ebrahim, 2014; Hong et al., 2014). Furthermore, creative thinking skills play an important role for students to produce a new product (Huff, 2014; Karunarathne & Calma, 2024; Zhan et al., 2023). Students who have creative thinking skills find it easier to understand the subject matter (Almulla, 2023; Ramdani, 2016). In addition, creative thinking skills can help students think higher order in learning (Ernawati et al., 2022; Yustiana el al., 2022).

But in reality, students' creative thinking skills in science learning are still relatively low (Imaroh et al., 2022; Lestari & Sumarti, 2018). The low creative thinking skills of students are due to learning not involving students and teacher-centered learning activities (Hariyadi et al., 2023; Fatimah, 2016; Suwendra et al., 202; Ummah & Yuliati, 2020; Nurtamam et al., 2023). This result is supported by the results of the 2018 PISA (*Programe For International Student Assessment*) survey organized by the OECD Indonesian students' skills in science ranked 71 out of 78 participating countries (Santosa et al., 2023; Razak et al., 2021; Utomo et al., 2023). In addition, the results of TIMSS research in 2015 creative and critical thinking skills in the fields of science and mathematics ranked 44 out of 49 countries (Fitriyah & Ramadani, 2021). In addition, the lace of creative thinking skills is influenced by the selection of inappropriate learning models carried out by teachers (Dika et al., 2023; Ernawati & Maniarta, 2022). Therefore, to overcome these problems, there is a need for a model that can encourage students' creative thinking skills in science learning.

The Guided Inquiry model is one of the effective learning models that encourages students' creative thinking skills in learning science (Pratama et al., 2020; Amida & Nurhamidah, 2019; Widia et al., 2021). Guided

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inquiry model is a learning model that trains active students to find their own concepts or theories but must be guided by the teacher so that they easily understand the material (Müge & Ozgecan, 2023; Eshetu et al., 2022; Asmoro, 2021; Kirk et al., 2023). Guided inquiry helps students learn more actively and can optimize knowledge and skills in learning (Nurmayani et al., 2018; Afriani & Agustin, 2019). In addition, *the guided inquiry model* fosters motivation and understanding of student learning concepts (Irdalisa et al., 2020).

Guided inquiry models can be combined with STEM approaches (Salmi et al., 2023; Islamyah et al., 2019). STEM is a learning approach that combines science technology engineering and mathematic in learning activities (Akoz et al., 2022; Yang et al., 2020; Fadlelmula, 2022). STEM learning can be implemented through utilizing technology (So et al., 2021). These STEM can help students learn more independently and creatively (Friedensen et al., 2018; Xu et al., 2021). STEM-based learning helps students more easily understand the subject matter (Sudarsono et al., 2022).

Furthermore, research from the STEM-based Indonesia *guided inquiry* model can improve creative thinking skills, understanding of science concepts and processes as well as student literacy in science learning (Dewi et al., 2019; Nasir et al., 2022; Parno et al., 2020; Suryana et al., 2020). Research from outside Indonesia guided inquiry STEM-based models provide a significant influence on students' creative skills (Kırıcı & Bakırcı, 2021). As for the gap in research, there are many studies related to STEM-based guided inquiry learning there has been no research to know the effect of the size. Based on this, the research aims at the influence of STEM-based guided inquiry models on students' Creative Thinking Skills in science learning.

Method

This type of this research is a meta-analysis. The meta-analysis research aims to quantitatively analyze the effect of STEM-based guided inquiry models on students' creative thinking skills. Meta-analysis is a study that analyzes and collects data from quantitative primary studies (Öztürk et al., 2022; Zulyusri et al., 2023; Yıldırım, 2022; Razak et al., 2021). According to Borenstein et al. (2009) the meta-analysis research procedure can be seen in Figure 1.

Figure 1. Procedures in meta-analysis

Eligibility Criteria

In the meta-analysis consisting of several article inclusion criteria, namely research derived from journals or proceedings indexed SINTA, Scopus and WOS, research must be experimental methods guided inquiry models based on STEM and conventional control classes; The research will be published between 2020-2023; The study reported complete data in calculating effect size. The process of selecting data sources using the PRISMA method consisting of *identification, eligibility* and *included* can be seen in Figure 2.

Data Collection

Data was collected through the journal database ScienceDirect; Taylor of Francis; ERIC, Google Scholar, IOP Proceedings, AIP Proceedings, and ProQuest. The keyword of data source tracing is guided inquiry model; STEM-based guided inquiry model; The effect of the STEM-based guided inquiry model on creative thinking skills in science learning and the implementation of STEM-based guided inquiry in science learning.

Data Analysis

Data analysis in the study calculates the effect size value of articles that have met the criteria. According to Borenstein et al. (2009) statistical analysis in meta-analysis consists of calculating the effect size value of the primary study; conducting heterogeneity tests and determining estimation models; checking the publication bias of the study and calculating the p-value to test the hypothesis. In this meta-analysis analyze the data with the help of JSAP 0.16.3 application. The criteria for the effect size value of each study are guided by Cohen et al. (2007) which can be seen in Table 1.

Table 1. Effect Size Value Criteria

Effect Size	Category Effect Size
$0.00 \leq ES \leq 0.20$	Low
$0.20 \leq ES \leq 0.80$	Medium
$ES \geq 0.80$	High

The heterogeneity test is performed by analyzing the statistics of Q and p values. If the p value < 0.05, then the analyzed effect size H_0 is rejected while if the p value > 0.05 the effect size H_1 is accepted. The estimation model used in this study is random effect size (Setiawan et al., 2022; Tamur et al., 2020). Furthermore, checking publication bias in this study through funnel plot analysis and Rosenthal Fail Safe N test (Chamdani et al., 2022; Diah et al., 2022; Sun, 2015). If the Rosenthal Fail Safe test value N/ (5k + 10) > 1 then the research in the meta-analysis is resistant to publication bias (Mullen, 2001).

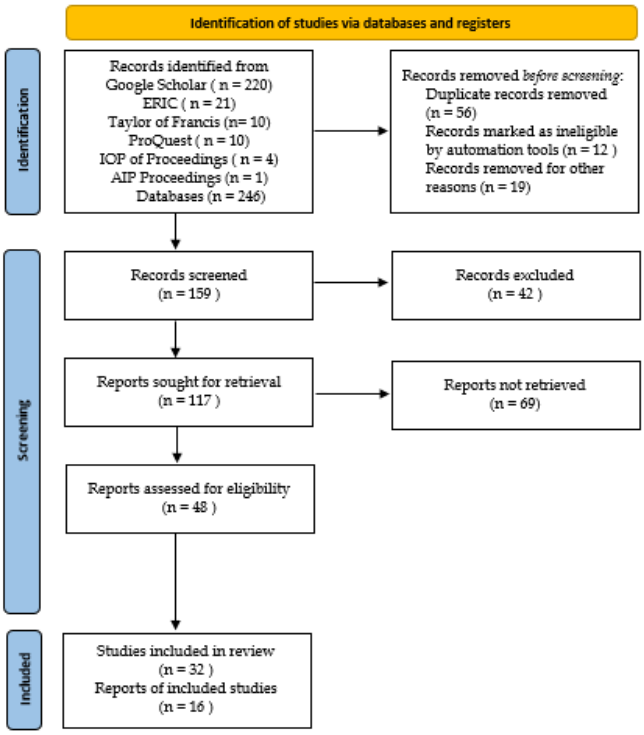

Figure 2. Data selection through PRISMA

Result and Discussion

Results Based on literature search through journal databases, 16 articles were obtained that met the inclusion criteria. Data that meet the inclusion criteria analyzed characteristics consisting of publication code, year, effect size and error standards can be seen Table 2.

Table 2. Results of Study Characteristics Analysis

Publication Code	Year	Effect Size	Standard Error	95% Confidence Interval	
				Lower	Upper
AP1	2023	2.12	0.45	0.51	1.16
AP2	2023	0.80	0.25	0.49	0.95
AP3	2021	0.65	0.15	0.32	0.84
AP4	2022	1.18	0.33	0.57	1.52
AP5	2023	1.68	0.49	0.62	1.84
AP6	2023	0.83	0.36	0.42	0.96
AP7	2020	0.72	0.28	0.58	1.14
AP8	2020	0.98	0.42	0.40	0.85
AP9	2021	1.10	0.51	0.34	0.91
AP10	2023	0.92	0.44	0.47	1.05
AP11	2022	0.88	0.30	0.39	0.76
AP12	2022	0.75	0.29	0.61	1.82
AP13	2021	1.17	0.62	0.34	0.87
AP14	2023	2.05	0.71	0.56	1.27
AP15	2023	1.72	0.40	0.41	1.02
AP16	2021	0.83	0.35	0.33	0.82

Based on Table 2, the analysis of the characteristic characteristics of the 2020-2023 published study obtained the highest effect size value of 2.12 with 95% confidence level lower 0.51 and upper of 1.16 and the lowest effect size of 0.65 with lower 0.32 and upper of 0.84. Furthermore, according to Keriteria effect size Cohen et al. (2007) obtained 4 effect size medium criteria (25%) and 12 effect size high criteria (75%). Next, conduct heterogeneity tests and determine estimation models from 16 analyzed articles. The results of heterogeneity tests and determination of estimation models with fixed and random effect can be seen in Table 3.

Table 3. Fixed and Random Effect

	Q	Df	P
Omnibus test of Model Coefficients	94.167	1	< 0.01
Test of Residual Heterogeneity	239.083	15	< 0.01

Table 3, the results of fixed and random effects obtained a value of Q = 239.083 greater than the value of 94.167 with 95% confidence level p < 0.001. These results conclude that the effect size analyzed is heterogeneously distributed. The model used is a random effect model more effective to determine the average value of effect size and 16 articles analyzed.

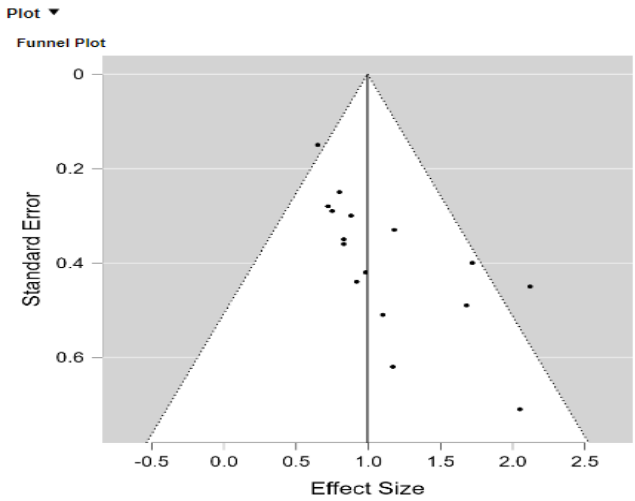

Figure 3. Funnel plot random effect size

Next, checking publication bias from 16 studies analyzed. In the meta-analysis, publication bias checking can be known through the funnel plot and Rosenthal Fail Safe N test (Yusuf, 2023; Kaçar et al., 2021; Cooper, 2017; Suparman et al., 2021). The results of checking publication bias with funnel plots are shown in Figure 3.

Figure 3, explaining the shape of the funnel plot 16 *effect size* is difficult to know symmetrical or asymmetrical shape. Therefore, it is necessary to perform the Rosenthal Fail Safe N test which can be seen in Table 4.

Table 4. Rosenthal Fail Safe N Test

File Drawer Analysis	Fail Safe N	Target Significance	Observed Significance
Rosenthal	824	0.050	< 0.001

Table 4, describes the results of the rosenthal fail safe N test obtained 824. Safe *file* value N > (5k + 10) or 824 / (5.16 + 10) = 824/90 = 9.15 > 1. These results show that the 16 effect sizes analyzed have no publication bias. Finally, analyze the p-value with summary effect size.

Table 5. Summary Effect Size or Mean Effect Size

	Estimate	Standard Error	Z	P	95 % CI Lower	Upper
Intercept	0.99	0.102	9.72	0.001	0.794	1.195

Table 5, the summary effect value of sie obtained the value of Z = 9.72; P < 0.001 with a confidence level of 95%, lower 0.794 and upper 1.195. The findings conclude that the STEM-based guided inquiry learning model has a significant effect on students' creative thinking skills in science learning with a high effect size category (r_{RE} = 0.99; SE = 0.10). The application of the STEM-based guided inquiry model provides positive benefits for students and teachers in encouraging students' creative thinking skills in learning science.

This research is in line with Hasancebi (2021) the STEM-based guided inquiry model has a significant effect on students' critical thinking skills in science learning. This result is supported by Kırıcı et al. (2021) research on STEM-based guided inquiry models that have a positive effect on students' creative thinking skills. Student-based guided inquiry learning students can learn independently to find concepts or theories through science and technology in science learning (Ariyani et al., 2019; Parno, 2020). STEM-based guided inquiry learning students learn more actively and innovatively so that it can stimulate creative thinking skills. Furthermore, STEM-based guided inquiry learning can foster student interest and motivation in learning science.

STEM-based guided inquiry learning can help improve students' science literacy so as to improve students' creative thinking skills (Pimvichai, 2022; Novitasari et al., 2022). In addition, the STEM-based guided inquiry model allows students to be more confident to investigate a problem that occurs. STEM-based guided inquiry model learning is accessible to students through specific technologies. Therefore, students' STEM-based guided inquiry learning model in learning science is more interesting (Hebebci & Usta, 2022). Guided inquiry model This STEM-based learning is effectively applied in the science learning process to encourage students' creative thinking skills (Khalil et al., 2023; Kahraman, 2021).

Conclusion

In the meta-analysis research it can be concluded that the overall value of effect size is 0.99 (95% CI [0.79; 1,195]) high category. These findings show that the application of STEM-based inquiry-based learning models affects students' 21st century thinking skills. In addition, these findings provide important information on STEM-based guided inquiry learning in schools. STEM-based guided inquiry learning mode students can learn through technology. This learning model can encourage science and technology literacy so as to stimulate students to think creatively in learning.

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Conflicts of Interest
The authors declare no conflict of interest.

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