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Process-Oriented Guided Inquiry Learning and Students' Mathematical Reasoning Ability in Indonesia: A Systematic Literature Review and Meta-Analysis

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Abstract: This study analyzes the effectiveness of the Process-Oriented Guided Inquiry Learning (POGIL) model in enhancing the mathematical reasoning ability of students in Indonesia. A systematic literature review and meta-analysis approach was employed. The inclusion criteria required data to be sourced from international journals and proceedings indexed in the Science and Technology Index (SINTA), Scopus, and Web of Science. Research data were collected from databases such as Google Scholar, ScienceDirect, Mendeley, Wiley, Springer, and ERIC. Studies included in the analysis were published between 2020 and 2024, focused on the POGIL model and students' mathematical reasoning ability, and provided complete data for effect size calculation. Keywords used for data searches included "Process Guided Inquiry Learning," "Student Mathematical Reasoning," "Implementation of Process Guided Inquiry Learning," and "Effect of Process-Oriented Guided Inquiry Learning on Students' Mathematical Reasoning Ability." Data analysis was conducted using JSAP software version 0.8.5. The findings, based on the analysis of twenty-five effect sizes, indicate that POGIL is highly effective in enhancing students' mathematical reasoning ability in Indonesia. The summary effect size was 1.14, with a p-value less than 0.001 and a confidence interval ranging from 0.512 to 1.35, which is categorized as a very high effect size. Students taught using the POGIL approach demonstrated significantly improved mathematical reasoning skills compared to those taught with conventional methods. This improvement was particularly evident in their ability to analyze mathematical problems, construct logical arguments, and evaluate alternative solutions.

INTRODUCTION

Mathematical reasoning ability refers to the essential skill students need to solve mathematical problems effectively and draw accurate conclusions (Hidayat et al., 2022; Kartono &; Shora, 2020; Pahrudin et al., 2020). The ability to reason mathematically plays a crucial role in enabling students to make informed decisions during the process of learning mathematics (Akrom &; Triyanto, 2021; Siregar et al., 2023). In addition, mathematical reasoning enhances students' engagement and significantly improves their learning outcomes (Wirebring et al., 2022; Mukuka et al., 2023; Smit et al., 2023). Students with strong mathematical reasoning skills tend to be more creative and critical in their approach to learning mathematics (Andersson & Register, 2023; Thanheiser & Melhuish, 2023).

Developing students' mathematical reasoning is essential to fostering higher-order thinking skills in mathematics learning.

In mathematics learning, students' mathematical reasoning abilities remain relatively low (Nurjanah et al., 2020). This is evident from students' limited ability to analyze and draw conclusions from mathematical learning materials (Hartati et al., 2020; Rohana, 2015). Furthermore, many students still lack the mathematical reasoning and connections needed to solve problems effectively (Ayal et al., 2016; Sari &; Darhim, 2020; Kosasih et al., 2023). This is reflected in the low academic scores students achieve in mathematical reasoning and their limited ability to establish connections during mathematics learning activities (Marsitin, 2016). In addition, the selection of learning models used by teachers is not right to encourage students' mathematical reasoning skills (Mukuka et al., 2021).

Process Oriented Guided Inquiry Learning (POGIL) is one of the learning models that can improve students' mathematical abilities in mathematics learning (Kartono &; Shora, 2020; Kevin et al., 2021; Andriani et al., 2019). Process Oriented Guided Inquiry Learning (POGIL) is a student-centered learning model that encourages students to learn more actively through collaborative problem solving and critical thinking (Bodner & Elmas, 2020; Alghamdi &; Alanazi, 2020). POGIL model students work in small groups to explore concepts, apply knowledge, and build their understanding through guided inquiry activities (Putri et al., 2020). The POGIL model encourages students to engage deeply with the subject matter, develop communication skills, and learn from their peers (Douglas & Chiu, 2022).

Several studies in Indonesia show that the Process Oriented Guided Inquiry Learning (POGIL) model effectively improves students' mathematical reasoning skills (Kartono &; Shora, 2020; Muhammad &; Purwanto, 2020; Sumanti et al., 2023; Suharno et al., 2023). Furthermore, other research conducted outside Indonesia Model Process Oriented Guided Inquiry Learning is effective in encouraging students' mathematical reasoning ability (Secadron & Tan, 2023; Safian & Mailok, 2020; Artuz & B. Roble, 2021). However, the study was conducted by (Fitria & Hidayah, 2021; Udu et al., 2020) shows inconsistent results. The application of the Process Oriented Guided Inquiry Learning model is not always better than the conventional model. Therefore, the results of the study provide different conclusions so that they can cause errors in drawing an accurate conclusion (Mawardi & Fitriza, 2019).

Furthermore, to address the gaps in this research, efforts must focus on providing more in-depth and accurate information about the implementation of the Process-Oriented Guided Inquiry Learning (POGIL) model in mathematics education. Conducting a meta-analysis is essential to systematically analyze existing studies, enabling the generation of accurate and reliable conclusions about the effectiveness of POGIL in fostering mathematical reasoning skills (Tamur et al., 2020; Chamdani et al., 2022; Shi et al., 2022; Juandi et al., 2022). Therefore, this study aims to evaluate the effectiveness of the Process-Oriented Guided Inquiry Learning (POGIL) model in enhancing the mathematical reasoning abilities of students in Indonesia.

METHOD

This research adopts a systematic literature review and meta-analysis approach, focusing on literature published between 2018 and 2024. The data filtering process follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines, which involve four key stages: identification, screening, eligibility, and inclusion. The PRISMA framework is illustrated in Figure 1, providing a detailed overview of how input and excluded data were filtered to ensure the relevance and quality of the research data. This method ensures transparency and rigor in the selection process (James et al., 2022; Hamilton & Philbin, 2020).

Literature Search

The literature search was conducted using databases such as Google Scholar, ScienceDirect, ResearchGate, Taylor & Francis, ERIC, and Mendeley. Keywords used for the search included "process-oriented guided inquiry learning," "implementation of process-oriented guided inquiry learning in mathematics learning," "effectiveness of process-oriented guided inquiry learning on students' mathematical reasoning abilities," and "effectiveness of process-oriented guided inquiry learning in student mathematics learning." Through this comprehensive search, a total of 615 journal articles were initially reviewed.

Inclusion/Exclusion Criteria

From the 615 journals obtained during the literature search, a selection process was conducted based on specific inclusion and exclusion criteria. The inclusion criteria required the articles to be published in international journals or proceedings indexed by the Science and Technology Index (SINTA), Scopus, or Web of Science. The publications needed to be from 2020 to 2024, relevant to Process-Oriented Guided Inquiry Learning (POGIL) and students' mathematical reasoning abilities, and contain complete data necessary for calculating the effect size. The exclusion criteria eliminated research derived from unpublished theses or dissertations and studies that lacked sufficient data to calculate the effect size.

Coding

The purpose of this study is to evaluate the effectiveness of Process-Oriented Guided Inquiry Learning (POGIL) in enhancing the mathematical reasoning abilities of students in Indonesia. Data coding was performed in two stages: first, by describing the research characteristics, including author name, year of publication, independent and dependent variables, and research outcomes; second, by recording the research sample size (N) and the standard deviation (SD) obtained from both the experimental and control groups, which were used to calculate the effect size.

Effect Size Calculation

Effect size quantifies the magnitude of impact in meta-analyses, providing a clearer understanding of underlying phenomena (Vural, 2022). The classification of effect size values includes categories such as no effect, low effect, medium effect, high effect, very high effect, and extraordinary effect (Thaleimer & Cook, 2002). In this study, the meta-analysis calculations for the mean (X), effect size (ES), and standard deviation (SD) were conducted using the JSAP 0.8.5 application, ensuring precise and efficient data processing.

Interpretation Effect Size

The meta-analysis uses "Hedges' g" to calculate effect size, providing a standardized measure of the impact of Process-Oriented Guided Inquiry Learning (POGIL) on students' mathematical reasoning abilities. The effect size values are interpreted based on established benchmarks, categorizing them as small, medium, or large. This classification helps to clearly understand the effectiveness of the POGIL model in mathematics education (Thaleimer & Cook, 2002).

Table 1. Effect Size Value.

Effect Size	Category
-0.15 – 0.15	No Effect
0.15 – 0.40	Low Effect
0.40 – 0.75	Medium Effect
0.75 – 1.10	High
1.10 – 1.45	Very High
> 1.45	Amazing Effect

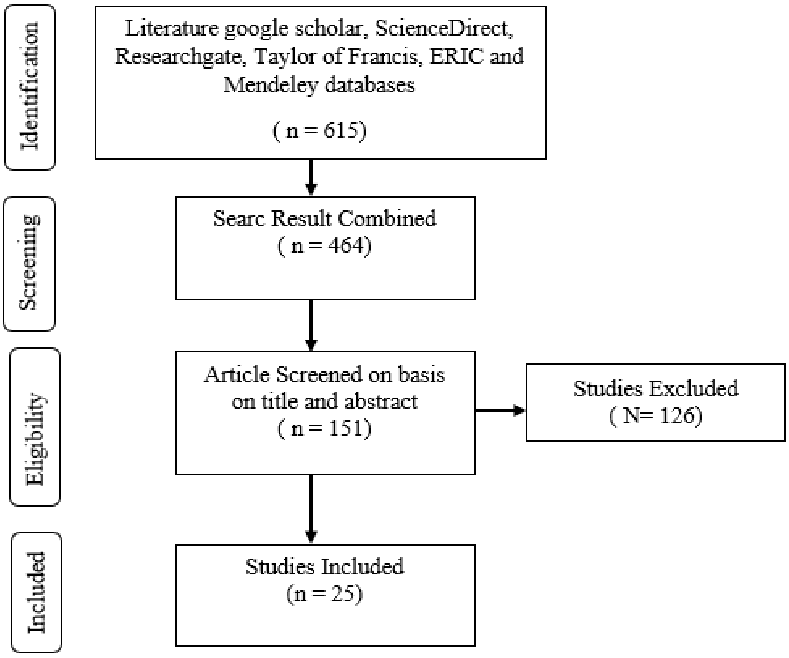

Figure 1. Data Selection Through (PRISMA).

RESULT AND DISCUSSION

From the results of literature search through Google Scholar, ScienceDirect, Researchgate, Taylor of Francis, ERIC and Mendeley obtained 615 studies, but there were 25 studies that met the inclusion criteria that had been set. Data that meet the inclusion criteria are calculated effect size and standard deviation values which can be seen in Table 2.

Table 2. Effect Size and Standard Deviation Research.

Journal Code	Year	Effect Size	Standard Error
Study 1	2020	2.10	0.44
Study 2	2020	0.92	0.30
Study 3	2021	1.18	0.39
Study 4	2022	0.53	0.22
Study 5	2021	2.61	0.61
Study 6	2023	0.92	0.33
Study 7	2023	0.71	0.20
Study 8	2018	0.86	0.19
Study 9	2019	2.02	0.71
Study 10	2019	1.94	0.45
Study 11	2023	2.19	0.52
Study 12	2022	1.15	0.42
Study 13	2024	2.52	0.66
Study 14	2024	0.96	0.39
Study 15	2023	0.82	0.29
Study 16	2022	1.92	0.57
Study 17	2021	0.71	0.36
Study 18	2020	1.32	0.41
Study 19	2020	1.98	0.39
Study 20	2023	2.16	0.60

Journal Code	Year	Effect Size	Standard Error
Study 21	2023	1.28	0.49
Study 22	2023	0.88	0.44
Study 23	2020	0.38	0.14
Study 24	2021	0.53	0.17
Study 25	2023	1.05	0.31

Based on Table 2, the effect size values from 25 studies analyzed in this meta-analysis ranged from 0.38 (lowest category) to 2.61 (amazing effect category). According to the effect size classification criteria proposed by Thaleimer & Cook (2002), the distribution of the 25 studies is as follows: one study falls into the low effect size category (n = 1), four studies are categorized under medium effect size (n = 4), seven studies fall into the high effect size category (n = 7), five studies are classified as having a very high effect size (n = 5), and eight studies exhibit an amazing effect size (n = 8).

To determine the mean effect size across these studies, a random effects model was employed, which is appropriate for analyzing effect sizes when there is variability across study conditions. The results of the random effects model analysis are presented in Table 3, providing further insights into the overall impact observed across the included studies.

Table 3. Random Effect Models.

	Q	Df	p
Omnibus Test of Coefficients Mode	67.095	1	< 0.001
Test of Residual Heterogeneity	163.254	24	< 0.001

Note: p-value are approximate.

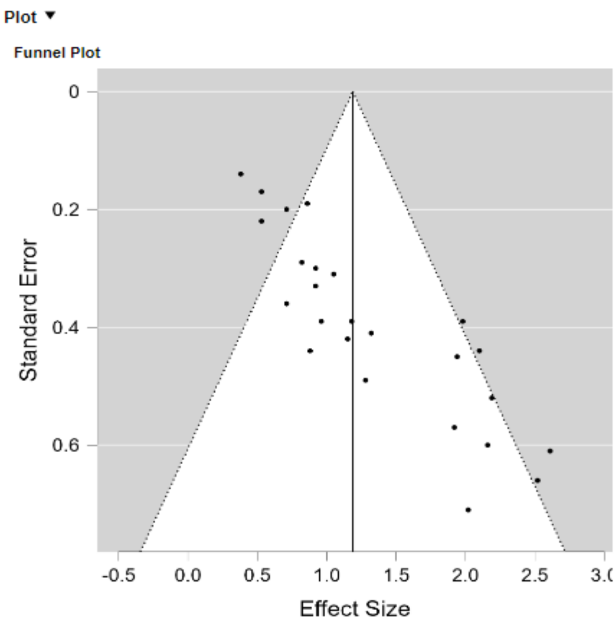

Figure 2. Funnel Plot.

Table 3. The results of the random effect analysis of the Q value model were 163. 254 is higher than 67.095 with a p-value of < 0.001. Effect size analysis in heterogeneously distributed meta-analyses. Therefore, an effective random effect model was used to analyze the 25 studies entered. Next, it examined publication bias against the 25 research studies analyzed. Suppression of

publication bias using funnel flot analysis and Rosenthal Fail Safe N test (Juandi et al., 2021; Tamur et al., 2020; Chamdani et al., 2022; Utomo et al., 2023).

The funnel plot analysis is presented in Figure 2. However, the results of the funnel plot make it challenging to determine whether the effect sizes are symmetric or asymmetric. Therefore, further analysis using the Rosenthal Fail-Safe N test is required to evaluate the potential presence of publication bias and to ensure the robustness of the meta-analysis findings.

Table 4. Fail Safe N.

File Drawer Analysis			
	Fail Safe N	**Target Significance**	**Observed Significance**
Rosenthal	2503	0.050	< 0.001

Table 5. Summary/Mean Effect Size.

Coeficients	**Effect Size**	**Standard Error**	**z**	**p**
Intercep	1.187	0.124	9.578	< 0.001

Table 4, the results of safe N files are obtained 2503 with a significance value of 0.050. Next, the value of k = 25 or 5k + 10 = (5.25) + 10 = 135. The value of Fail safe N > 5k + 10, it can be concluded that the 25 studies analyzed can this study have no publication bias so that the analyzed are valid and reliable.

Furthermore, the average value of effect size of the 25 studies analyzed can be seen in Table 5. The summary effect size analysis revealed a 95% confidence interval (CI) ranging from 0.944 (lower) to 1.430 (upper), with an average overall effect size of 1.187. This result falls within the very high effect size category. Furthermore, the Z-test yielded a value of 9.578, which is statistically significant with a p-value of < 0.001. These findings indicate that the application of the Process-Oriented Guided Inquiry Learning (POGIL) model has a significantly positive impact on the mathematical reasoning abilities of students in Indonesia, outperforming conventional teaching models.

These results are consistent with prior research. For example, Kartono & Shora (2020) highlighted that the POGIL model effectively enhances students' mathematical reasoning skills by emphasizing active learning. Similarly, Rifqi & Suyitno (2021) demonstrated that POGIL develops students' cognitive abilities in reasoning and analysis, fostering more active and creative participation in the learning process. Ningsih & Bambang (2012) also noted that POGIL allows students to learn independently according to their abilities while enhancing critical thinking skills. By engaging in structured, inquiry-based activities, students using the POGIL model actively solve problems, collaborate with peers, and explore new concepts through guided questioning.

The POGIL model emphasizes critical reasoning, problem-solving, and a deeper understanding of mathematical concepts rather than rote memorization. Additionally, it promotes social interaction among students, fostering a cooperative learning environment where peer discussions and group work enhance understanding (Purnama & Rahayu, 2023; Sanggara et al., 2019; Restanti et al., 2023). In this approach, teachers act as facilitators, guiding students through the learning process with carefully designed worksheets that stimulate critical thinking, exploration, and discussion (Septianti & Indrowati, 2022). Consequently, students not only gain a better grasp of mathematical concepts but also improve their social, communication, and teamwork skills, as supported by findings from Idul & Caro (2022).

One of POGIL's key advantages is its ability to help students build a deep understanding of concepts. Through active engagement, students not only recall information but also connect new knowledge to existing frameworks, allowing them to see relationships between concepts and apply them in various contexts (Nurmasari et al., 2017; Wang, 2023). Additionally, POGIL fosters social and collaborative skills by encouraging group work, where students share ideas, listen to others, and develop better understanding through discussion and teamwork (Rumain & Geliebter, 2020; Udu et al., 2020). These skills are not only vital for academic success but also crucial for future career development. As noted by Rice et al. (2022), POGIL is not merely about mastering subject matter; it is about shaping students into independent, critical, and collaborative learners capable of thriving in both academic and professional settings. Thus, POGIL serves as a transformative approach to mathematics education, providing both cognitive and interpersonal benefits.

CONCLUSION

The findings of this meta-analysis demonstrate that Process-Oriented Guided Inquiry Learning (POGIL) is highly effective in enhancing the mathematical reasoning abilities of students in Indonesia. Based on 25 effect sizes analyzed, the summary effect size value was rRE = 1.14; $p < 0.001$; 95% CI: 0.512–1.35, categorizing it as a very high effect size. These results highlight the significant positive impact of the POGIL model in fostering students' mathematical reasoning skills. By engaging students in active and creative learning processes, the POGIL model effectively supports the development of critical thinking and problem-solving abilities, making it a powerful instructional approach for improving mathematical reasoning in educational settings.

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