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Meta-Analysis of the Effectiveness of Ethnomathematics-Based Learning Models on Students' Mathematical Conceptual Understanding

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ABSTRACT

The growing demand for quality education in the globalization era requires students to develop strong mathematical conceptual understanding alongside essential 21st-century competencies. However, international assessments such as PISA indicate that students' conceptual mastery in several ASEAN countries remains relatively low, partly due to instructional approaches that are less contextual and culturally relevant. In response, ethnomathematics-based learning has been proposed as an alternative model that integrates local cultural contexts into mathematics instruction to enhance meaningful understanding. This study aims to quantitatively synthesize empirical evidence regarding the effectiveness of ethnomathematics-based learning models in improving students' mathematical conceptual understanding and to examine the influence of moderator variables. A meta-analysis was conducted on 26 eligible studies published between 2018 and 2025, selected through purposive sampling from the Google Scholar database. Effect sizes were calculated using Hedges' g under a random-effects model, followed by outlier detection, heterogeneity testing, moderator analysis, and publication bias assessment. The results reveal a statistically significant and very high pooled effect size ($g = 1.21$, $p < 0.0001$) after outlier removal, indicating strong effectiveness compared to conventional instruction. Despite substantial heterogeneity, moderator analyses highlight variations across educational levels, mathematical topics, cultural contexts, and learning models. Overall, ethnomathematics-based learning demonstrates robust empirical support as an effective approach to strengthening students' mathematical conceptual understanding.

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1. INTRODUCTION

In the current era of globalization, the demand for high-quality education has increased significantly. Students are not only required to master academic knowledge but also to possess 21st-century skills, namely critical thinking, creativity, collaboration, and communication [1].

In the context of mathematics learning, the National Council of Teachers of Mathematics (NCTM, 2000) states that there are five core skills that students must develop: communication skills, problem-solving skills, reasoning skills, connection skills, and representation skills [2]. These skills support holistic mathematical thinking, in which students do not merely memorize procedures but understand the meaning, relationships, and applications of mathematical concepts. Students with strong conceptual understanding are able to grasp abstract mathematical ideas more deeply and build a foundation for constructing new knowledge, which can then be applied to solving novel problems [3].

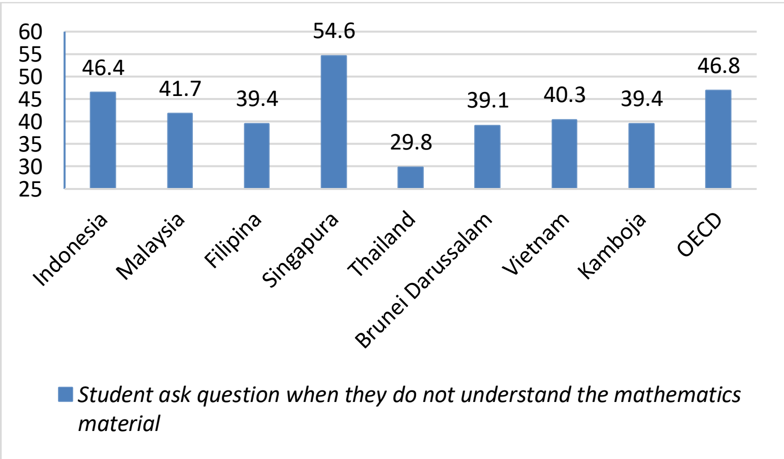


Figure 1. Percentage of Students Who Ask Questions When They Do Not Understand Mathematics (Source: PISA, 2022)

Based on Figure 1, the percentage of students who ask questions when they do not understand mathematics gives information. The diagram above illustrates students' learning strategies across ASEAN countries based on the PISA 2022 survey, showing that more than half of students ask questions when they do not understand mathematics [4]. Singapore records the highest percentage at 54.6% and is the only country above the OECD average of 46.8%. This reflects that students in Singapore have developed a classroom culture that supports active participation, which can be seen as one of the factors contributing to Singapore's consistent top performance in PISA. In contrast, ASEAN countries such as Indonesia, Malaysia, and Vietnam show lower percentages, particularly Thailand, indicating a tendency for students to be less active in expressing confusion or lack of understanding during learning. This limited habit of questioning may negatively affect students' mathematical conceptual understanding, resulting in difficulties in solving internationally standardized problems [5]. PISA items do not merely assess the ability to apply concepts but emphasize how concepts can be used across various contexts [6]. Research by Nusantara et al. (2021) indicates that students with moderate and low abilities do not meet the indicators of conceptual understanding when applying concepts or algorithms to problem-solving tasks assessed through PISA-type items with *space and shape* content [7]. In line with this, Wahyuningsih et al. (2019) argue that the low level of students' mathematical conceptual understanding is caused by a lack of innovation in interactive learning models that are relevant to students' daily lives and cultural contexts [8]. Therefore, there is a need for learning models that encourage students to actively understand and apply mathematical concepts within real-life contexts, including cultural contexts.

Culture-based learning models are among the approaches that can be developed to promote active student engagement in learning, as students do not merely imitate or receive information from teachers but instead gain contextual learning experiences and prior knowledge to understand scientific concepts within local culture [9]. Culture-based mathematics, also known as ethnomathematics, is an approach used to explain the role of mathematics in societies with diverse cultural backgrounds [10]. Ethnomathematics utilizes local culture and traditions to develop students' abilities, particularly their capacity to understand mathematical concepts [11].

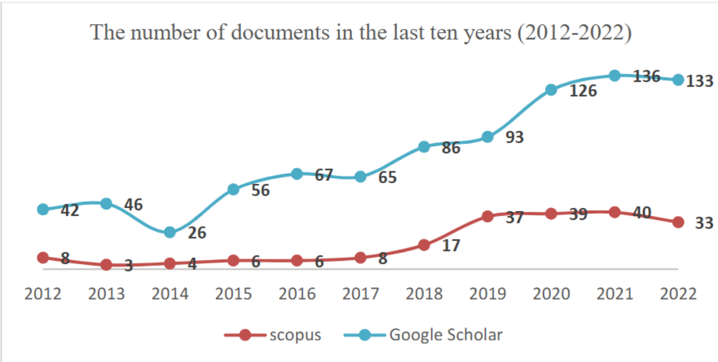


Figure 2. Publication Trends in Ethnomathematics Research Indexed in Scopus and Google Scholar (Source: Yohanis et al., 2024)

Figure 2 illustrates trends in the number of ethnomathematics studies over the past decade (2012–2022) based on Google Scholar and Scopus databases. The data show a significant year-by-year increase in the number of studies indexed in Google Scholar, rising from 42 studies in 2012 to a peak of 133 studies in 2022, with Indonesia being one of the countries contributing a relatively high volume of ethnomathematics research. Meanwhile, the number of studies indexed in Scopus has also increased, although not as markedly [12]. This trend reflects growing scholarly attention and interest in ethnomathematics as a means of enhancing students' understanding of mathematical concepts.

Ethnomathematics is a research program that focuses on the relationship between mathematics and culture [13]. It does not merely emphasize computational or measurement techniques but also encompasses language, knowledge systems, ways of thinking, and values underlying mathematical practices within specific cultural contexts [14]. Ethnomathematics can serve both as an alternative approach and as an implicit philosophy in school mathematics instruction, as it is closely aligned with contextual learning [15]. By studying ethnomathematics, students can gain broader and deeper perspectives on mathematical concepts and how these concepts are applied in diverse cultural and social contexts [16].

Consequently, the ethnomathematics approach offers a compelling alternative by connecting mathematics learning with students' culture, traditions, and lived experiences, thereby providing a foundation for developing students' mathematical conceptual understanding [17].

Several studies agree that culture-based mathematics learning is able to enhance students' mathematical abilities, as summarized in the following table.

Table 1. Key Findings of Studies on Ethnomathematics-Based Learning

Key Finding	Reference
The Auditory Intellectually Repetition (AIR) learning model with an ethnomathematical nuance was found to be superior to conventional learning conducted via WhatsApp groups in improving mathematical communication and understanding in probability topics, as indicated by a significance value of 0.000 and an F-value of 66.517.	Afrida (2020) [18]
The implementation of the ethnomathematics-based Contextual Teaching and Learning (CTL) model grounded in Sundanese culture was significantly more effective (62.29%) than conventional models in improving fourth-grade elementary students' mathematical conceptual understanding of basic quadrilateral geometry concepts.	Nugraha et al. (2020) [19]
The application of the ethnomathematics-based Contextual Teaching and Learning (CTL) model improved students' mathematical conceptual understanding, with an average percentage score of 80.36%, classified as very high.	Ega Amara et al. (2024) [20]
The use of ethnomathematics modules in teaching specific geometry topics to Teduray students at SMA Nasional Mangudadatu–Villamonte Annex, Philippines. The mean n-gain scores indicated that the Teduray module group outperformed the conventional module group, with $t = 1.658$ and $p = 0.192$.	Fransisco et al. (2023) [21]

Table 1 summarizes key empirical findings from previous studies on ethnomathematics-based learning. Overall, the studies consistently report positive effects on students' mathematical conceptual understanding and related skills. Various learning models, such as Auditory-Intellectual Repetition (AIR) and Contextual Teaching and Learning (CTL), when integrated with cultural elements, demonstrate higher effectiveness compared to conventional instruction. The reported results include significant statistical values, high percentage gains, and improved n-gain scores, particularly in topics such as probability and geometry. The table indicates that incorporating local cultural contexts into mathematics instruction contributes to more meaningful learning experiences and measurable improvements in students' conceptual understanding.

Despite empirical evidence supporting the effectiveness of ethnomathematics-based learning and study results that generally demonstrate positive impacts on students, this issue remains a concern. Field data indicate that the abilities of most students in ASEAN countries, particularly Indonesia, still lag considerably behind neighboring countries such as Singapore, as evidenced by PISA scores [22]. This raises an important question: *why does an approach proven effective in classroom settings fail to yield significant impacts on a broader scale?* This situation suggests the presence of more complex and diverse implementation challenges in real-world contexts, leading to a gap between the theoretical effectiveness of the approach in classrooms and practical realities in the field.

Several studies emphasize that the implementation of ethnomathematics requires a deeper evaluation of factors influencing the success of its integration into education, as summarized in the following table.

Table 2. Challenges and Limitations in the Implementation of Ethnomathematics

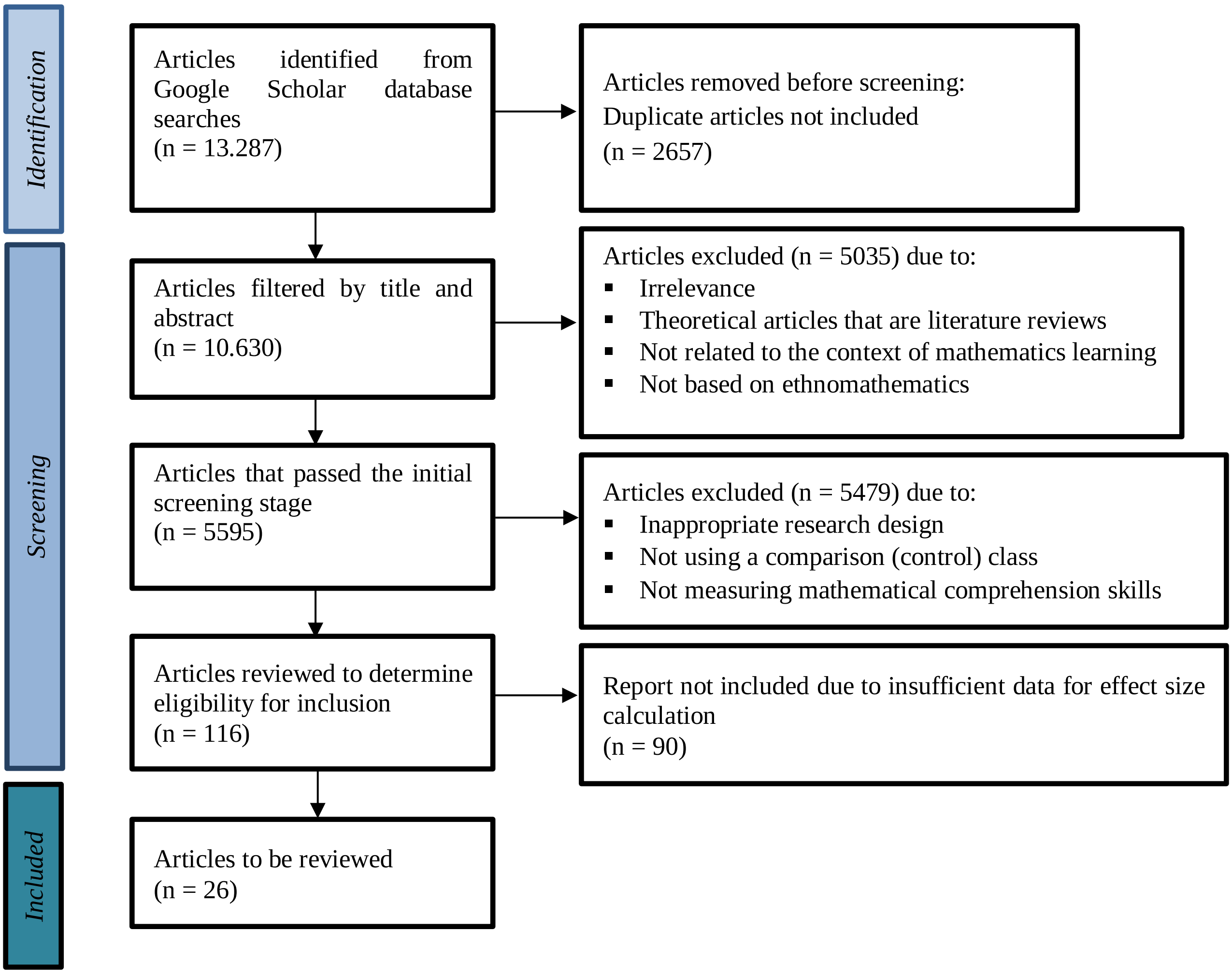
Key finding	Reference
Existing applications of ethnomathematics are often limited to local contexts or small samples, resulting in findings that are not always generalizable.	Pranowo (2020) [23]
The effectiveness of ethnomathematics-based learning depends on the alignment between the selected mathematics topics and students' cultural backgrounds and learning environments.	Supriadi (2018) [24]
Geometry is the most dominant topic in ethnomathematics-based learning and is the easiest to relate to various cultural contexts.	Astanti et al. (2022) [25]
Ethnomathematics-based learning applied to geometry, curves, and probability shows significant results in improving mathematical conceptual understanding, whereas its application to systems of linear equations in two variables (SPLDV) yields less substantial effects.	Nisrina et al. (2021) [26]

Table 2 outlines several challenges and limitations in implementing ethnomathematics-based learning. The studies indicate that many applications are confined to specific local contexts and small samples, limiting generalizability. Effectiveness also depends on the alignment between mathematical topics and students' cultural backgrounds. Geometry is identified as the most frequently and easily integrated topic, while other topics, such as systems of linear equations, show less consistent results. Overall, the table highlights that although ethnomathematics has strong potential, its success is influenced by contextual suitability, topic selection, and implementation conditions.

Variations in research findings regarding the effectiveness of ethnomathematics indicate inconsistencies across studies, particularly concerning its impact on different mathematical topics. This condition underscores the need for further investigation to identify the effects and additional factors influencing the effectiveness of ethnomathematics-based learning models on students' mathematical conceptual understanding, especially in ASEAN countries characterized by rich cultural diversity.

2. METHOD

This study is a meta-analysis conducted since January 2025, utilizing the Google Scholar electronic database as the primary data source due to its broad coverage and high credibility. The research adopts a descriptive quantitative approach through meta-research, which involves statistically integrating and analyzing the findings of relevant primary studies. The study population consists of scholarly articles on ethnomathematics-based learning models in mathematics education indexed in Google Scholar from 2018 to 2025, while the sample is selected using purposive sampling based on specific criteria, including the availability of effect size data, educational level, and English-language abstracts. Data collection is carried out through documentation by classifying experimental and control group data and extracting the statistical information required to calculate effect sizes. The research instrument is a coding sheet used to record study characteristics and empirical findings, including authors, year of publication, learning model, cultural context, instructional content, research design, sample size, and effect size values, to support a systematic synthesis and analysis of the data.



1. Effect Size Calculation and Statistical Models

   Data analysis is the process of organizing and grouping data to identify specific patterns or themes, allowing for a deeper understanding of their meaning. This activity includes the process of classifying data into themes, patterns, or categories relevant to the research objectives. If data is not well organized, the discussion process in research, theses, or articles will be hampered. Through this grouping process, researchers then interpret the findings to give meaning to the findings, explain the patterns or categories formed, and identify relationships between concepts [27].

   Meta-analysis is a statistical method that combines the results of various quantitative studies addressing the same problem, using effect size as the basic unit of analysis. By combining the effect sizes from each study, the meta-analysis calculates the average effect size to obtain more accurate and credible conclusions than conclusions from a single study [28].

In this study, the Hedges'g parameter, also known as the standardized mean difference (SMD), was used to determine effect size. The Hedge's parameter was developed by Hedges in 1985 as a standard measure for measuring the impact of a treatment [29]. This calculation will examine the effectiveness of an ethnomathematics-based learning model on the overall understanding of mathematical concepts from the sample of articles taken. Furthermore, it will examine the extent of ethnomathematics' effectiveness based on educational level, the mathematics topic taught, and the cultural context used.

In performing the Hedges'g calculation, the initial step is to assume that K studies (study outcomes) present two treatment groups: a control group (index 1) and an experimental group (index 2). For each study, from 1 to K, it is assumed that there are n_1 in the control group and n_2 in the experimental group. Where n_1 and n_2 Are the sample sizes of the two groups.

The measured outcomes in the study are $\overline{X_1}$ for *i* from 1 to n_1 for the control group and $\overline{X_2}$ for *i* from 1 to n_2 for the experimental group. Then, assume the values for the control group $\overline{X_1}$ are sampled from a normal distribution with mean μ_1 and standard deviation (SD) σ_1 and for the experimental group $\overline{X_2}$ with mean μ_2 and standard deviation (SD) σ_2. The standard sampling estimators for μ_1 and μ_2 are their respective sample means are as follows:

$$\overline{X_1} = \frac{\sum_{i=1}^{n_1} X_{1i}}{n_1}$$

$$\overline{X_2} = \frac{\sum_{i=1}^{n_2} X_{2i}}{n_2}$$

And the standard sampling estimators for σ_1 and σ_2 are their respective standard deviations are as follows:

$$\overline{SD_1} = \sqrt{\frac{\sum_{i=1}^{n_1} (X_{1i} - \overline{X_1})^2}{n_1 - 1}}$$

$$\overline{SD_2} = \sqrt{\frac{\sum_{i=1}^{n_2} (X_{2i} - \overline{X_2})^2}{n_2 - 1}}$$

If it is assumed that the standard deviation of the control and intervention groups is the same in the study $\sigma_1 - \sigma_2 = \sigma$, then:

$$\overline{SD_2} = \sqrt{\frac{(n_1 - 1)SD_1^2 + (n_2)SD_2^2}{n_1 + n_2 - 2}}$$

This estimate allows for an estimate of the difference between the means of the experimental and control studies in each study, expressed in standard deviation (SD) units. Hedges proposed the γ index as a population parameter used to describe the size in statistical power analysis, known as **g.** The symbol used for the effect size parameter is γ, while for the in-sample estimate, it uses the symbol **g.**

$$\gamma = \frac{\mu_1 - \mu_2}{\sigma}$$

The estimates used for the Hedges'g study sample are as follows:

$$g = \frac{\overline{X_1} - \overline{X_2}}{SD}$$

For funnel plots or heterogeneous tests, it is necessary to apply the standard error formula. Assuming that the experimental and control groups have equal variances, then each group will have a standard error calculated as follows:

$$SE_{(g)} = \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}$$

Referring to the standard theory of variance equality in linear regression, this standard error is used to determine the confidence interval and p-value for γ, using the t-distribution and degrees of freedom of $n_1 + n_2 - 2$. In meta-analysis, the main goal is to estimate the weighted mean of γ, which will be equal to the general value if all γs are identical. In general, this meta-population parameter is defined as the weighted sum of γ using the weight ω, where the weight is a combination of the sample sizes of the experimental and control groups $n = n_1 + n_2$.

$$\bar{\gamma} = \frac{\sum_{i=1}^{K} \omega\gamma}{\sum_{i=1}^{K} \omega}$$

The estimator for the meta-population γ is obtained by summing with weights ω, which can be estimated using the consistent estimator W.

$$\bar{g} = \frac{\sum_{i=1}^{K} \omega\gamma}{\sum_{i=1}^{K} \omega}$$

In the case where ω is a collection of n, then W is also n.

2. Detection Outlier

   In meta-analysis, a random effects model is commonly applied to handle variation that cannot be explained solely by differences within individual studies. However, this approach is sometimes less than optimal when there are studies that act as outliers. Therefore, the process of identifying outliers is a crucial step, considering that these studies have extreme effect sizes and deviate significantly from the overall effect [30]. In this study, R software version 4.5.1 was used to detect outliers, utilizing the 'metafor' and 'dmetar' features. The 'dmetar' feature includes the 'find.outliers' function that implements an algorithm to remove outliers [31]. In addition, the 'gosh.diagnostic' function was also used, which utilizes various clustering algorithms to identify data patterns. Of the several available algorithms, the k-means algorithm was specifically selected for this analysis [32].

3. Moderator Variable Analysis

   Moderator variable analysis is a crucial aspect of meta-analysis, as it allows researchers to identify factors contributing to differences in effect sizes between studies. Furthermore, this analysis provides a basis for assessing the effectiveness of interventions and assists in the development of more optimal interventions and impacts future research [33]. In this study, the moderator variables analyzed included cultural context, mathematics topic, educational level, and the learning model used. The heterogeneity of research findings across studies was explored using a Q test. A key finding from the Q statistic indicates the likelihood that each study draws from the same population. In particular, the significant variation in the collective impact of each element on the moderator variable, as indicated by a significant Q value, underscores the importance of moderator variable analysis. Analysis of all moderator variables in this study was conducted using a model approach, such as ANOVA. This model displays the mean effect size (g) in each group, its 95% confidence interval (CI), and intergroup heterogeneity (Qb). A significant Qb value indicates a meaningful difference in the aggregate effect size among the components of the moderator variable. All analyses were conducted using R software version 5.4.1 with the help of the 'meta' feature [34].

4. Publication Bias Assessment

The publication bias assessment aims to identify potential bias in the analyzed literature and its impact on the overall conclusions of the meta-analysis. To assess publication bias in this meta-analysis, a three-stage approach was used. The first step was performed using a funnel plot and Egger's regression test. Visual inspection of the funnel plot was used as an initial step to detect possible asymmetry. A symmetrical distribution in a funnel plot is considered an indication of the absence of publication bias [35]. This graphical representation also facilitates the identification of potential outliers and provides an overview of the potential publication bias. Next, the Egger's regression test, known as a quantitative approach to assessing asymmetry in funnel plots, was performed. This test measures the extent of funnel plot asymmetry, providing a quantitative dimension for evaluating potential publication bias. This evaluation aims to determine whether there is a systematic relationship between a study's effect size and precision, which could indicate publication bias.

In addition to these two methods, the Trim and Fill method was also used to strengthen the publication bias analysis. This method is a common technique for correcting asymmetry in funnel plots [36]. Through this method, suspected missing studies are identified from the funnel plot, and then the meta-analysis results are adjusted to include these studies in the estimation, resulting in a more accurate effect size estimate. This comprehensive approach allows researchers to more robustly address potential publication bias and enhance the credibility of the meta-analysis findings. To conduct the publication bias analysis, R software version 5.4.1 was used, with the assistance of the statistical packages 'meta' and 'metafor' [37]. The integration of these various statistical tools allows for a comprehensive exploration of publication bias, thereby strengthening the analysis's robustness and increasing the reliability of the meta-analysis's findings in explaining the influence of ethnomathematics-based learning models on mathematical concept understanding.

3. RESULTS AND DISCUSSION

3.1. Result

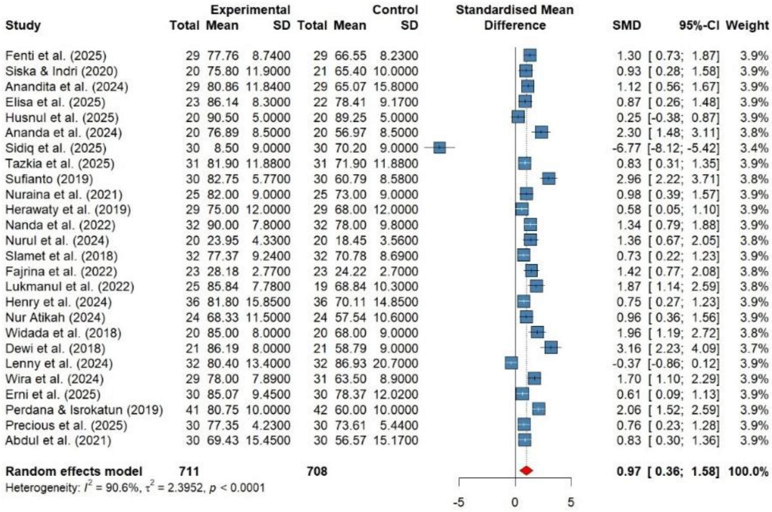


Figure 3. Forest Plot for 31 Studies (Pre-Outlier Detection)

The meta-analysis using a random-effects model indicates that the mean effect size (SMD) from the 26 analyzed studies is 0.97 ($p < 0.0001$), demonstrating that the integration of ethnomathematics into mathematics learning models has a statistically significant effect on improving students' mathematical conceptual understanding. The 95% confidence interval ranges from [0.36; 1.58] (Figure 1), suggesting that the findings can be generalized with a high level of confidence. According to the effect size classification proposed by Thalheimer and Cook (2002), this effect size falls within the "high" category ($0.75 \leq ES < 1.10$), indicating that the application of ethnomathematics exerts a strong influence on enhancing students' mathematical abilities compared to non-culture-based instruction. In addition, the analysis reveals very high variability in effect sizes across studies, as indicated by $Q = 287.6$ and $df = 27$ ($p < 0.0001$), which signifies a very high level of heterogeneity. This finding reflects substantial variation in effect sizes among the included studies.

Outlier Detection

To identify outlier data points that deviate markedly from the overall pattern, an analysis using the K-Means Clustering method was conducted on standardized residual values (Figure 4.2). The plot shows that one study deviates conspicuously from the majority of the data, lying outside the ±2 tolerance limits on the standardized residual scale. One study exhibits an extremely large residual value of approximately −7 (Study 7), indicating a very strong deviation from the general data pattern. Accordingly, it can be concluded that one study is a potential outlier, namely Sidiq et al. (2025).

Figure 4. K-Means Plot for Detecting Outliers

Combined Effect Analysis After Outlier Detection

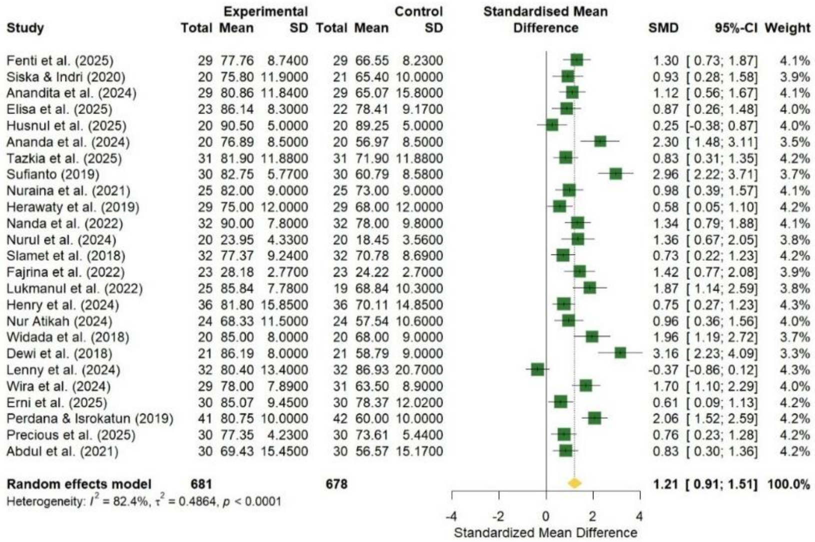


Figure 5. Forest Plot for 25 Studies (Post-Outlier Detection)

After removing the study identified as an outlier, the collective impact of the remaining 25 studies was reassessed. The effect sizes (ES) across these studies range from −0.37 to 2.96 (Figure 5). Among them, one study (3.23%) reports a negative effect size, indicating that the ethnomathematics-based learning model was not more effective than conventional instruction in the control group. In contrast, 24 studies (96.77%) report positive effect sizes, implying that students in the experimental groups employing ethnomathematics-based learning achieved higher levels of mathematical conceptual understanding than those in the control groups.

Overall, the meta-analysis yields a positive and statistically significant pooled effect size of $g = 1.21$ ($p < 0.0001$, 95% CI = [0.91; 1.51]), which is higher than the original effect size estimated prior to the removal of the outlier. This result underscores the importance of outlier detection in meta-analytic procedures (Viechtbauer & Cheung, 2010). The exclusion of the outlier increased the effect size to the “very high” category (Thalheimer & Cook, 2002), indicating that the presence of an extreme study in the initial analysis exerted a

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disproportionate influence on the overall effect estimate. Figure 4.3 presents the forest plot illustrating the effect sizes and confidence intervals for each study. Furthermore, heterogeneity testing reveals significant results (Q = 130.68, df = 23, $p < 0.0001$) with I^2 = 82.4%, indicating substantial variability among the studies. According to Higgins et al. (2003), an I^2 value above 75% reflects high heterogeneity, meaning that most of the observed variance represents real differences in effect sizes rather than sampling error alone.

Evaluation of Publication Bias

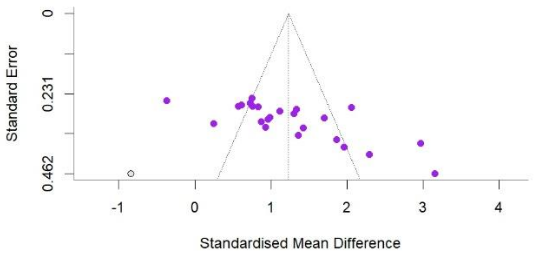

Figure 6. Funnel Plot Using the Trim-and-Fill Method

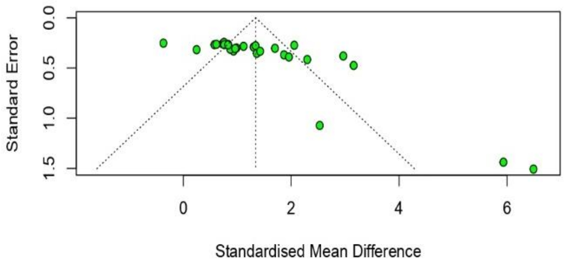

Figure 7. Funnel Plot Using Egger's Method

The funnel plot in Figure 6 illustrates the results of publication bias analysis using the Trim-and-Fill method (Duval & Tweedie, 2000). Several studies appear on the left side of the plot at a considerable distance from the central point, suggesting the possible absence of unpublished studies with negative or non-significant results. This asymmetric pattern indicates a tendency for studies reporting positive effects to be published more frequently than those reporting small or null effects. The imbalance was subsequently adjusted using the Trim-and-Fill procedure by statistically imputing the "missing" studies, thereby producing a more balanced overall effect estimate. This adjustment suggests that some of the initially observed positive effects may be inflated due to publication bias; therefore, the meta-analysis results should be interpreted with caution. This finding aligns with the literature, noting that educational research is often affected by the file-drawer problem, wherein studies with non-significant results remain unpublished (Rothstein, 2005; Pigott et al., 2013).

In contrast to the Trim-and-Fill approach, the funnel plot in Figure 7 presents the results of Egger's regression test (Egger et al., 1997), which detects publication bias based on the relationship between effect size and standard error. Visually, this plot appears more symmetric, particularly around the center of the funnel, suggesting that publication bias may be less pronounced than indicated by the Trim-and-Fill method. The absence of a strong skewed pattern or small-study effects implies that heterogeneity or natural variation among studies may be the primary source of dispersion rather than publication bias alone. Discrepancies between the results of Egger's test and the Trim-and-Fill method are common in meta-analyses and highlight the importance of employing multiple approaches to assess publication bias (Sutton et al., 2000). Consequently, the interpretation of the meta-analysis findings should consider both methods in a complementary manner to obtain a more accurate assessment of the overall validity of the results.

3.2. Discussion

Based on the results of the meta-analysis, overall, the implementation of an ethnomathematics-based learning model has a very strong positive effect on students' mathematical conceptual understanding, with a very high score. This indicates that ethnomathematics-based learning is not only statistically effective but also has a significant practical impact in improving the quality of students' mathematical conceptual understanding.

This large effect size indicates that integrating local culture into mathematics learning can create a more meaningful and contextual learning experience [38]. Through a cultural context close to students' daily lives, abstract mathematical concepts can be presented more concretely, through the use of local cultural ornaments in exploring the area of a rhombus [39], songket cloth motifs or traditional house designs as learning media [40], and the integration of traditional games such as congklak into learning activities [41], thus encouraging student engagement and strengthening conceptual understanding.

Theoretically, these findings align with D'Ambrosio's view of ethnomathematics, which emphasizes that cultural practices contain mathematical activities that can be used as a bridge between formal mathematics and students' social experiences. The integration of cultural elements into learning provides students with the opportunity to connect new knowledge with existing cognitive schemas, enabling optimal assimilation and accommodation. This also aligns with Piaget's constructivist theory, which asserts that conceptual understanding is formed through the active interaction between experience and an individual's cognitive structure.

Furthermore, the results of this study support the National Council of Teachers of Mathematics (NCTM, 2000) framework, which emphasizes the importance of connecting students' real-life experiences with abstract mathematical concepts. Learning grounded in a cultural context allows students to build mathematical connections, both between concepts and between mathematics and everyday life, resulting in deeper and more sustainable conceptual understanding.

The findings of this study are also consistent with previous research demonstrating the effectiveness of the ethnomathematics approach in mathematics learning. For example, Fadhliyah reported that the implementation of an ethnomathematics-based cooperative learning model produced an effect size of 0.39, which is considered a large effect size. Although the effect size values in these studies are lower than those in this meta-analysis, the difference is understandable because this study integrates and synthesizes various studies with diverse characteristics, thus providing a more comprehensive and generalizable estimate of the effect. Thus, the results of this meta-analysis not only strengthen previous empirical findings but also provide stronger evidence regarding the effectiveness of ethnomathematics-based learning models in improving students' mathematical conceptual understanding.

4. CONCLUSION

Based on the research findings, the following conclusions can be drawn:

Ethnomathematics-based learning models are overall proven to be effective, as indicated by the meta-analysis results showing a very high and statistically significant effect size in improving students' mathematical conceptual understanding.

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