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The effect of culture-based mathematics learning instruction on mathematical skills: a meta-analytic study

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ABSTRACT

Culture-based mathematics learning (C-bMLI) has emerged as a promising approach to improving students' mathematical skills, yet previous research presents inconsistent findings regarding its efficacy compared to conventional methods. To address this gap, a meta-analytic study is needed to consolidate and present the latest insights regarding the impact of C-bMLI on students' mathematical skills. It also aimed to discern the factors influencing the effectiveness of C-bMLI implementation. Datasets were collected from primary studies published in internationally recognized journals or proceedings. By rigorously adhering to inclusion criteria, a collection of 45 effect sizes from 25 primary studies was identified. The results of this analysis, conducted using the random-effects approach, produced a substantial combined effect size of $g = 0.93$ and $p = 0.00$. The evidence unequivocally substantiated that the employment of C-bMLI significantly contributed to the mathematical process, standing as a superior alternative to conventional learning methodologies. The results of the heterogeneity analysis of the moderator variables showed that factors such as the type of skills, educational tiers, country, publication year, and the variant of C-bMLI contributed to the observed variance, The variable of sample size did not exert a discernible impact on the effectiveness of the learning model.

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1. INTRODUCTION

Learning mathematics is challenging for both students and teachers due to its inherently abstract nature [1], [2]. To enhance understanding, incorporating real-world contexts, such as cultural examples [3], is crucial. Previous studies [4]-[10] highlight culture-based mathematics learning instruction (C-bMLI) as a promising initial approach to teaching mathematics. Other studies also show that C-bMLI is effective in improving various mathematical skills, including understanding mathematical concepts [11], problem-solving [12], [13], communication, and mathematical reasoning [14]-[16], higher-order thinking [17], [18] mathematics learning achievement [19]-[28] metacognition, mathematical retention [20], [21], [29], and mathematical literacy [30]. These essential and complex skills need to be mastered by students, and integrating culture into mathematics learning significantly influences and contributes to their development. It is important to note that some studies report no significant difference between culture-based mathematics learning and traditional approaches [31]-[34]. Despite these diverging results, C-bMLI remains a topic of interest in the ongoing quest to enhance mathematics education.

The disparities in these results may be attributed to moderating factors influencing the effectiveness of C-bMLI. It is essential to acknowledge that individual experiments have limitations concerning time, sample size, and context, thereby accounting for the variations in the results of such investigations [35]. In this regard, conducting a meta-analysis becomes a relevant approach to amalgamate the outcomes of various prior studies and attain a more comprehensive understanding of C-bMLI's impact on mathematics skills. Meta-analysis is a statistical method that allows for the integration of pertinent data and yields more objective conclusions. Through this method, the present study compiles and combines the results of prior investigations on the same subject, allowing for the determination of the collective effect of each utilized approach [36]. Meta-analysis, by combining data from numerous sources, can give more objective and trustworthy results than previous approaches. This technique emphasizes quantifying the impact of empirical results in the research under consideration [37], [38], making it a potent tool for synthesizing existing discoveries and providing an all-encompassing overview of the topic under investigation.

The focus of this study lies in examining the effectiveness of C-bMLI on mathematics skills while investigating moderating factors that influence its efficacy. The anticipated results of this study aim to offer valuable guidance to teachers and educational practitioners in implementing C-bMLI more effectively. More appropriate tactics and ways to improve students' mathematical skills with C-bMLI may be designed with a thorough grasp of the elements influencing its performance. The following research issues are addressed by the meta-analysis in this study:

i) Is C-bMLI more effective in improving mathematical skills than conventional methods?
ii) Does the type of competency influence the efficacy of C-bMLI on students' mathematical skills?
iii) Is the effectiveness of C-bMLI on mathematical skills affected by the tiers of education?
iv) Is the country of origin a factor affecting the effectiveness of C-bMLI on mathematical skills?
v) Does the year of study publication impact the effectiveness of C-bMLI on mathematical skills?
vi) Does the composition of the experimental group affect the effectiveness of C-bMLI on mathematical skills?
vii) Is the type of learning used in the experimental class a factor affecting the effectiveness of C-bMLI on mathematical skills?

2. METHOD

2.1. Study design and inclusion criteria

This study utilized the meta-analysis method to examine other explorations on the effect of C-bMLI on mathematics skills. The stages of meta-analysis encompassed setting inclusion criteria, searching for relevant studies, collecting and coding variable data, as well as conducting statistical analysis [37], [39]. This meta-analysis study established inclusion criteria to facilitate searching and evaluating eligible studies for analysis. These criteria enabled the screening of relevant studies, ensuring the utilization of data of adequate quality and completeness. The following inclusion criteria were established: i) Publication year: studies accepted in the analysis should be published between 2009 to 2023. This time range was chosen to ensure that the studies used are relatively recent and relevant to the current study context; ii) Journal/Proceedings: studies can be published in national and international journals and proceedings. This is carried out to obtain diverse literature sources and includes results from various scientific forums; iii) Methodologies: to provide a clear control setting and demonstrate a cause-and-effect link between the usage of C-bMLI and mathematical skills, only research that uses experimental or quasi-experimental methods will be considered; and iv) Data reporting: for each experimental and control group, the mean, standard deviation, and sample size should be provided by the selected research. When such information is unavailable, the research can publish the sample size together with appropriate statistical metrics (t-value, p-value, or f-value). These requirements ensure that enough data is collected to assess effect estimates and statistically integrate research results.

2.2. Data gathering and coding

To gather relevant research, online resources such as Google Scholar, ERIC, Elsevier, and EBSCO were employed, using keywords, namely "Effectiveness of Culture-based Learning" AND "Mathematics" in Indonesian and English. Out of 110 collected studies, only 25 were considered eligible based on the specified criteria. After obtaining eligible articles, coding was employed to identify the characteristics of the literature, including the type of skill measured, educational tiers, country, year of publication, type of experimental group, and sample size. Table 1 shows summarizes the coding findings.

Table 1. The studies that were considered for inclusion in the meta-analysis

Moderator variable	Frequency	Percentage (%)
Mathematical skill type		
Conceptual-understanding	1	2.2
Creative-thinking-skill	3	6.6
Critical thinking skill	2	4.4
Higher-order thinking skill	4	8.8
Mathematical communication	5	11.1
Mathematical literacy	1	2.2
Mathematical reasoning	3	6.6
Mathematics achievement	15	33.3
Mathematics performance	4	8.8
Mathematics retention	2	4.4
Metacognitive skill	1	2.2
Problem-solving skill	4	8.8
Educational tiers		
Primary school	10	22.2
Junior high school	20	44.4
Senior high school	12	26.6
College	3	6.6
Country		
Alaska	4	8.8
Indonesia	24	53.3
Nigeria	13	28.8
Turkey	1	2.2
Zambia	1	2.2
Zimbabwe	2	4.4
Publication year		
2009-2016	17	37.8
2017-2023	28	62.2
Type C-bMLI in the experimental class		
Contextual learning with ethnomathematics	3	6.6
Culture-based contextual learning (CBCL)	1	2.2
Culture-based contextual learning with GeogGebra (CBCLG)	2	4.4
Ethnomathematics approach	18	40
Ethnomathematics-based e-module	1	2.2
Ethnomathematics-based SAVI	1	2.2
Local culture-based mathematical heuristic-kr	3	6.6
Mathematics in cultural context	4	8.8
Probing-prompting based on ethnomathematics	1	2.2
RME culture-based	2	4.4
RME in a rural context	6	13.3
Ethnomathematics based on the RME model	1	2.2
Sq3r method-based ethnomathematics	1	2.2
Stem model based on local culture	1	2.2
Sample size		
Large	17	37.7
Small	9	20
Medium	19	42.2

2.3. Data analysis

Comprehensive meta-analysis (CMA) version 3 software was used to examine the data, and the Borenstein phases were followed: i) determining the size of each study's influence, ii) carrying out a heterogeneity test and calculating the aggregate effect size, iii) examining moderator factors, and iv) assessing publication bias. The effect size was calculated using the Hedges equation, and its interpretation followed Cohen's classification as shown in Table 2. The Q and I^2 parameters were used in the heterogeneity test, such that when the assumption was met, the random effect was employed to calculate the summary effect. When the heterogeneity assumption was violated, the fixed-effect estimating model was used. A publishing bias test based on the file-safe N (FSN) approach was used to determine how well the existing literature reflected the full range of study findings [40]-[42].

Table 2. Effect size group type (g)

Type	Interval
Disregarded	$0.00 < g \leq 0.19$
Small	$0.19 < g \leq 0.49$
Medium	$0.49 < g \leq 0.79$
Large	$0.79 < g \leq 1.29$
Very large	$g > 1.29$

3. RESULTS AND DISCUSSION

3.1. Effect size of each study

Data were collected from 25 main studies that evaluated the use of local culture-based learning with standard approaches in mathematics learning contexts to assess the effect size of each research. Figure 1 summarizes the impact size results for each research. Upon examining Figure 1, it became evident that among the total of 45 analyzed effect sizes, the smallest had been -1.310, while the largest had reached 9.409.

Study name	Statistics for each study						
	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Gembong et. al (2022)	0.862	0.152	0.023	0.565	1.159	5.686	0.000
Palinussa (2013) a	0.687	0.221	0.049	0.254	1.119	3.113	0.002
Palinussa (2013) b	0.588	0.554	0.307	-0.497	1.674	1.063	0.288
Palinussa et al (2021) a	2.510	0.294	0.086	1.935	3.086	8.545	0.000
Palinussa et al (2021) b	2.023	0.292	0.086	1.450	2.597	6.918	0.000
Palinussa et al (2021) c	1.288	0.213	0.046	0.870	1.706	6.036	0.000
Palinussa et al (2021) d	0.428	0.221	0.049	-0.006	0.862	1.932	0.053
Palinussa et al (2021) e	0.814	0.246	0.060	0.332	1.295	3.313	0.001
Palinussa et al (2021) f	0.735	0.191	0.036	0.361	1.109	3.848	0.000
Kisker et al (2012) a	0.758	0.083	0.007	0.595	0.920	9.148	0.000
Kisker et al (2012) b	0.694	0.082	0.007	0.532	0.855	8.414	0.000
Kisker et al (2012) c	0.288	0.080	0.006	0.131	0.455	3.590	0.000
Kisker et al (2012) d	0.364	0.080	0.006	0.207	0.522	4.534	0.000
Sudarsono (et.al, 2022)	1.815	0.332	0.110	1.163	2.466	5.461	0.000
Samo et al (2019) a	0.592	0.267	0.071	0.068	1.116	2.216	0.027
Samo et al (2019) b	0.642	0.268	0.072	0.116	1.167	2.393	0.017
Samo et al (2019) c	0.009	0.259	0.067	-0.499	0.517	0.034	0.973
Hartinah et al (2019)	0.747	0.286	0.082	0.188	1.307	2.617	0.009
Achor et al (2009) a	1.846	0.150	0.022	1.552	2.140	12.316	0.000
Achor et al (2009) b	3.882	0.213	0.046	3.463	4.300	18.195	0.000
Agusdianita et al (2020)	0.787	0.257	0.066	0.284	1.290	3.067	0.002
Suherman et al (2021)	2.007	0.314	0.099	1.392	2.622	6.394	0.000
Kara (2010)	0.163	0.285	0.081	-0.395	0.721	0.572	0.567
Sunzuma et al (2021) a	0.815	0.219	0.048	0.386	1.244	3.721	0.000
Sunzuma et al (2021) b	0.785	0.218	0.048	0.357	1.213	3.597	0.000
Oraneto et al (2021)	0.968	0.210	0.044	0.556	1.380	4.603	0.000
Abiam et al (2015)	1.034	0.106	0.011	0.826	1.242	9.752	0.000
Farokhah et al (2017)	0.614	0.232	0.054	0.158	1.070	2.641	0.008
Ozofor&Onos (2018)	0.521	0.220	0.048	0.089	0.952	2.365	0.018
Omere&Ogedengbe (2022)	1.281	0.110	0.012	1.066	1.495	11.684	0.000
Milambo&Sakala (2019)	0.840	0.188	0.035	0.472	1.209	4.468	0.000
James et al (2021) a	4.649	0.328	0.108	4.005	5.292	14.157	0.000
James et al (2021) b	9.409	0.593	0.352	8.246	10.572	15.858	0.000
Nur et al (2020) a	0.822	0.448	0.200	-0.055	1.700	1.837	0.066
Nur et al (2020) b	0.222	0.397	0.157	-0.556	1.000	0.560	0.576
Nur et al (2020) c	0.981	0.507	0.257	-0.013	1.975	1.935	0.053
Tandiseru (2015) a	-0.239	0.475	0.225	-1.169	0.691	-0.503	0.615
Tandiseru (2015) b	-0.239	0.475	0.225	-1.169	0.691	-0.503	0.615
Tandiseru (2015) c	0.219	0.489	0.239	-0.739	1.177	0.449	0.654
Unodiaku (2013) a	-0.974	0.176	0.031	-1.319	-0.630	-5.540	0.000
Unodiaku (2013) b	-1.310	0.173	0.030	-1.649	-0.970	-7.562	0.000
Clement et al (2014) a	0.456	0.228	0.052	0.009	0.902	2.000	0.046
Clement et al (2014) b	-0.273	0.258	0.067	-0.799	0.233	-1.059	0.290
Tudunkaya&Muawiya (2019)	2.299	0.254	0.064	1.802	2.796	9.062	0.000
Sutarto et al (2022)	1.285	0.281	0.079	0.735	1.835	4.580	0.000

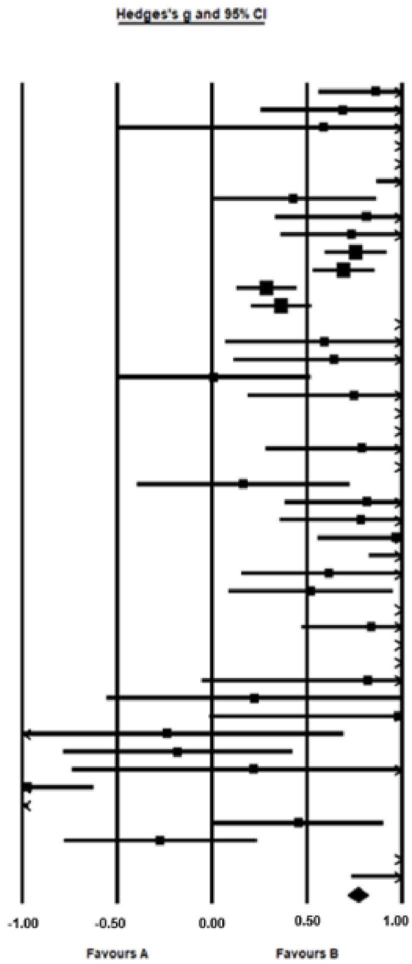

Figure 1. Forest plot for effect size

According to the classification of Cohen [36], the results revealed nine studies ($n = 9$) with very large effects, eleven ($n = 11$) with large effects, twelve ($n = 12$) with medium effects, six ($n = 6$) with small effects, and seven ($n = 7$) with negligible effects that had been disregarded. These results underscored the significant variability in the impact of C-bMLI on the effect size of mathematical skills. Consequently, to attain a more precise conclusion, calculating a combined effect size has become imperative.

3.2. Heterogeneity test and combined effect size

The Q and I^2 statistical tests were used in this investigation to examine heterogeneity among the included studies. The heterogeneity test findings were used to choose the best estimate model for calculating the pooled effect size. The heterogeneity test, as well as the random-effects and fixed-effects estimating models, are shown in Table 3.

Table 3. Heterogeneity test summary and combined effect size

Model	k	Effect size (g)	Std. Error	Lower limit	Upper limit	p	df	Heterogeneity Q	P	I^2
Random-effect	45	0.93	0.13	0.68	1.18	0.00	44	972.09	0.00	95.47%
Fixed-effect	45	0.74	0.03	0.69	0.79	0.00	44			

The outcomes of the heterogeneity test, as shown in Table 3, yielded a Q value of 972.09, $df = 44$, $p = 0.00$, and I^2 of 95.47%. These results affirmed substantial heterogeneity among the analyzed studies, leading to the adoption of the random-effects model for calculating the pooled effect size. Based on this model, the pooled effect size stood at $(g = 0.93;\ p < 0.01)$, placing it within the category of a large effect. Therefore, it could be inferred that the employment of C-bMLI had significantly impacted the mathematical skills of students, proving more efficacious compared to conventional approaches. This consistency aligned with the results of prior studies [43], which corroborated the significant positive effect of C-bMLI on student learning achievement. These results lent robustness and uniformity to the recommendation of utilizing C-bMLI as an effective learning approach for enhancing mathematical skills.

3.3. Moderator variable analysis

The meta-analysis conducted on the 45 effect sizes yielded conclusive results. This study also conducted a moderator variable analysis to identify potential factors influencing the effectiveness of local wisdom-based learning on the mathematical skills of students. The moderator variable analysis is shown in Table 4.

The C-bMLI learning approach offered students a more authentic and meaningful learning experience, allowing them to perceive the practical applications of mathematical concepts in real-world contexts. This cultivated heightened motivation and interest in learning mathematics, fostering a deeper comprehension of mathematical principles. Furthermore, C-bMLI learning promoted active engagement and participation among students. By employing relatable examples and real-life scenarios familiar to students, educators were able to illustrate mathematical concepts, thereby encouraging greater involvement and heightened enthusiasm for learning [44]. The incorporation of local wisdom culture into learning emerged as a potent avenue for bolstering student outcomes in mathematics education. In this educational context, such integration facilitated the alignment of mathematics learning with daily life, enhancing the pertinence and practicality of mathematical concepts. By weaving local wisdom culture into mathematics education, students were able to establish meaningful connections between mathematical concepts and their everyday experiences, ultimately rendering these concepts more comprehensible and applicable [45]. This study also investigated heterogeneity to examine the factors influencing the effectiveness of C-bMLI on mathematical proficiency. The findings of this meta-analysis revealed that various moderator factors substantially affected the efficiency of C-bMLI on the mathematical skills including the type of mathematical proficiency, educational level, country, publication year, type of learning in the experimental class, and sample size.

First, the study found that the moderator variable of mathematical skill type had a significant impact on the effectiveness of C-bMLI. The average learning effectiveness of C-bMLI varied depending on the observed type, as indicated by the value of $Qb = 481.7;\ p < 0.05$. This discovery was congruent with previous studies, indicating that the type of skill under investigation could impact the effect size of a learning model [46], [47]. It was observed that C-bMLI significantly improved various types of mathematical skills, encompassing conceptual understanding, critical thinking, higher-order thinking skills, mathematical communication, literacy, reasoning, achievement, performance, retention, metacognitive, and problem-solving. On the other hand, C-bMLI had no substantial effect on creative thinking skills $(g = -0.11;\ p > 0.01)$. This suggested that this learning method may prioritize other aspects of mathematical learning rather than specifically targeting the enhancement of creative thinking skills. However, the method did not diminish the value and relevance of C-bMLI as an effective approach for advancing mathematical skills. Among the various types of mathematical skills, C-bMLI demonstrated the greatest influence on three specific types, namely mathematical retention $(g = 4.48;\ p < 0.01)$, conceptual understanding $(g = 2.01;\ p < 0.01)$, and reasoning $(g = 1.79;\ p < 0.01)$.

Second, the moderator variable of educational level significantly affected the effectiveness of C-bMLI on mathematical skills. These results paralleled previous studies [48]-[50], which also highlighted how moderator variables like educational level could impact the effect size of a learning model. The average effectiveness of the model exhibited variations based on the level of education $(Qb = 59.53;\ p < 0.05)$. The analysis demonstrated that the use of C-bMLI had a notable impact on improving proficiency across all educational tiers, encompassing primary school (PS), junior high school (JHS), senior high school (SHS), and College. Based on the results, the learning approach yielded significant benefits in enhancing mathematical skills across diverse educational stages. While significant differences existed between the groups, the utilization of the model continued to exert a significant effect across all levels of education. These results underscored the potential of this learning method to be implemented at various educational tiers, thereby enriching the mathematical skills of students from primary school through tertiary education.

Third, the moderator variable of the country significantly influenced the effectiveness of C-bMLI on mathematical skills. The average effectiveness of C-bMLI demonstrated distinct values depending on the country under analysis ($Qb = 59.34$; $p < 0.05$). The application of C-bMLI exerted a substantial effect on enhancing this proficiency in diverse countries, including Alaska, Indonesia, Nigeria, Zambia, and Zimbabwe. These results showed that the learning method yielded considerable benefits in enhancing mathematical skills across the aforementioned countries. However, C-bMLI learning had no significant effect on competency in Turkey ($g = 0.16$; $p = 0.57$). This suggested that there were country-specific factors that may influence the effectiveness of the learning method. These results contributed to a deeper comprehension of how the effectiveness of the learning approach may be impacted by facets such as culture, curriculum, and educational context [51]. Therefore, to optimize the efficacy of C-bMLI learning, it was imperative to consider the distinctive context and attributes of each country.

Fourth, there was a significant influence of the publication year on the utilization of C-bMLI in enhancing mathematical skills. The efficacy of employing the model exhibited variability contingent upon the temporal span of the publication ($Qb = 74.14$; $p < 0.05$). The application of the learning approach demonstrated higher efficacy within the 2017-2023 timeframe ($g = 1.04$; $p < 0.01$) when compared to the period spanning 2009-2016 ($g = 0.57$; $p < 0.01$). This discrepancy implied a discernible shift in the potency of C-bMLI over time, aligning with a prior study that underscored the impact of publication year as a determinant of effect size [52], [53]. It was crucial to acknowledge that despite the observable disparities in effectiveness across publication year groups, the utilization of the model continued to exert a substantial influence within all periods under scrutiny. This underscored the sustained pertinence and utility of this pedagogical approach in bolstering mathematical prowess, regardless of whether the studies were conducted pre or post-2017. Consequently, these results accentuated the necessity of accounting for temporal dynamics when employing C-bMLI. This supported the argument that shifts in curricular paradigms, technological advancements, and the educational milieu over time could potentially shape the efficacy of this instructional modality. In light of this, educators and scholars were urged to maintain vigilance over the evolving landscape of C-bMLI and explore avenues for its optimization to enhance mathematical proficiency.

Fifthly, there was a profound impact of C-bMLI type within the experimental classroom setting on the application of C-bMLI in augmenting mathematical skills. The average effectiveness of the model utilization evinced variability based on the specific C-bMLI variant employed within the experimental cohort ($Qb = 108.5$; $p < 0.05$). An in-depth scrutiny of the outcomes indicated a marked positive influence of the learning approach on mathematical aptitude across various categories within the experimental group. Notable instances encompassed contextual learning with ethnomathematics; culture-based contextual learning; culture-based contextual learning with GeoGebra; ethnomathematics approach; ethnomathematics-based e-module; Ethnomathematics-based somatic, auditory, visualization, intellectually (SAVI); Mathematics in cultural context; probing-prompting based on ethnomathematics; realistic mathematics education (RME) culture-based; RME in rural context; RME model-based ethnomathematics; survey, question, read, recite and review (SQ3R) method-based ethnomathematics; and Science, technology, engineering, and mathematics (STEM) model based on local culture. However, the integration of local wisdom-based learning exhibited negligible efficacy when applied to the local culture-based mathematical heuristic-KR variant within the experimental class (-0.11; $p = 0.64$). This particular observation underscored the limited potency of this experimental class in enhancing mathematical skills through the implementation of C-bMLI. Consequently, this insight held pivotal significance for educators and analysts, elucidating the types of experimental classes that were more likely to yield favorable outcomes. Selecting an appropriate pedagogical approach could undoubtedly amplify the impact of the approach and yield greater dividends for the advancement of mathematical education.

The sixth discovery of this study unveiled the moderator variable of sample size, which comprised three distinct groups, namely large, small, and medium. Analysis results according to Table 4 showed an absence of significant differentiation in the average effect size among the three sample groups ($Qb = 5.19, p > 0.05$). Therefore, it was established that the sample size held no sway over the utilization of C-bMLI for enhancing mathematical skills. The efficacy of employing the model exhibited uniform influence across all examined sample sizes, irrespective of the specific scale employed. In essence, whether the study engaged a small cohort ($e.g. \leq 50$), a medium-sized ($50 - 100$), or a large assembly ($e.g. > 100$), the impact of C-bMLI on mathematical skills remained consistently noteworthy. These results imparted crucial insights and reinforced the soundness of conclusions pertaining to the effectiveness of the model in elevating mathematical proficiency. This underscored the adaptability of the approach across diverse educational contexts, rendering it independent of the scale of samples under investigation.

Table 4. Moderator variable analysis results

Moderator variable	k	g	Std. Error	Test of null (2-Tail)		Heterogeneity		
				Z	P	Q	P	I^2
Mathematical skill type								
Conceptual understanding	1	2.01	0.31	6.39	0.00	0.00	0	1.00
Creative thinking-skill	3	-0.11	0.23	-0.47	0.64	0.58	2	0.75
Critical thinking skill	2	0.67	0.20	3.29	0.00	0.03	1	0.87
Higher-order thinking skill	4	0.64	0.11	5.90	0.00	8.10	3	0.04
Mathematical communication	5	0.66	0.10	6.45	0.00	1.78	4	0.78
Mathematical literacy	1	0.79	0.26	3.07	0.00	0.00	0	1.00
Mathematical reasoning	3	1.79	0.15	12.05	0.00	12.19	2	0.00
Mathematics achievement	15	0.73	0.05	16.17	0.00	383.47	14	0.00
Mathematics performance	4	0.52	0.04	12.77	0.00	24.82	3	0.00
Mathematics retention	2	4.48	0.20	22.87	0.00	49.50	1	0.00
Metacognitive skill	1	1.28	0.28	4.58	0.00	0.00	0	1.00
Problem-solving skill	4	1.06	0.20	5.23	0.00	9.92	3	0.02
Qw						490.40	33	0.00
Qb						481.70	11	0.00
Educational tiers								
Primary school	10	0.58	0.04	16.19	0.00	63.53	9	0.00
Junior high school	20	1.04	0.05	20.00	0.00	281.76	19	0.00
Senior high school	12	0.84	0.06	13.69	0.00	563.67	11	0.00
College	3	0.41	0.15	2.65	0.01	3.61	2	0.16
Qw						912.57	41	0.00
Qb						59.53	3	0.00
Country								
Alaska	4	0.52	0.04	12.77	0.00	24.82	3	0.00
Indonesia	24	0.86	0.05	15.76	0.00	115.50	23	0.00
Nigeria	13	0.96	0.05	19.94	0.00	772.42	12	0.00
Turkey	1	0.16	0.28	0.57	0.57	0.00	0	1.00
Zambia	1	0.84	0.19	4.47	0.00	0.00	0	1.00
Zimbabwe	2	0.80	0.15	5.17	0.00	0.01	1	0.92
Qw						912.75	39	0.00
Qb						59.34	5	0.00
Year of Publication								
2009-2016	17	0.57	0.03	17.15	0.00	576.51	16	0.00
2017-2023	28	1.04	0.04	24.02	0.00	321.44	27	0.00
Qw						897.96	43	0.00
Qb						74.14	1	0.00
Type C-bMLI in the experimental class								
Contextual learning with ethnomathematics	3	0.61	0.26	2.39	0.02	1.72	2	0.42
Culture-based contextual learning	1	0.59	0.27	2.22	0.03	0.00	0	1.00
Culture-based contextual learning with Geogebra	2	0.31	0.19	1.69	0.09	2.88	1	0.09
Ethnomathematics approach	18	0.92	0.04	20.89	0.00	780.88	16	0.00
Ethnomathematics-based e-module	1	1.28	0.28	4.58	0.00	0.00	0	1.00
Ethnomathematics-based SAVI	1	0.61	0.23	2.64	0.01	0.00	0	1.00
Local culture-based mathematical heuristic KR	3	-0.11	0.23	-0.47	0.64	0.58	2	0.75
Mathematics in cultural context	4	0.54	0.04	13.81	0.00	29.56	4	0.00
Probing-prompting based on ethnomathematics	1	0.75	0.29	2.62	0.01	0.00	0	1.00
RME culture-based	2	0.67	0.20	3.29	0.00	0.03	1	0.87
RME in a rural context	6	1.13	0.10	11.78	0.00	47.95	5	0.00
Ethnomathematics based on RME Model	1	0.79	0.26	3.07	0.00	0.00	0	1.00
SQ3R method-based ethnomathematics	1	2.01	0.31	6.39	0.00	0.00	0	1.00
STEM model based on local culture	1	1.81	0.33	5.46	0.00	0.00	0	1.00
Qw						863.60	31	0.00
Qb						108.50	13	0.00
Sample size								
Large	17	0.74	0.03	24.38	0.00	835.28	16	0.00
Small	9	0.47	0.13	3.59	0.00	26.62	8	0.00
Medium	19	0.79	0.06	13.95	0.00	105.00	18	0.00
Qw						966.90	42	0.00
Qb						5.19	2	0.07

Note. g = effect size; Qw = total within; and Qb = total between

3.4. Publication bias

An evaluation of potential publication bias within the encompassed analysis was carried out. By employing the FSN methodology, the assessment of publication bias was unfolded. Table 5 shows the outcomes derived from diagnosing the FSN value.

Table 5. FSN analysis

Value	Results
z-value	27.80
p-value	0.00
Alpha	0.05
Z for Alpha	1.96
N	45
P > Number of missing studies	9007

Based on the analysis results shown in Table 5, it became apparent that the obtained p-value fell below the predetermined alpha threshold, signifying the credibility and validity of this study [39]. Additionally, the FS N analysis estimated the requisite number of undisclosed studies necessary to alter the p-value to exceed alpha=0.05, arriving at a staggering 9007. In line with the substantial volume of studies, these results solidified the reliability of this analysis and negated indications of significant publication bias.

4. CONCLUSION

In conclusion, the comprehensive examination of this meta-analysis yielded definitive insights. Specifically, the utilization of C-bMLI emerged as a potent catalyst for the advancement of mathematical skills, decisively surpassing conventional pedagogical approaches. The analytical exploration revealed nuanced variations in effect sizes. However, at a macroscopic level, the model decisively exerted a pronounced positive influence on mathematical proficiency. The heterogeneity analysis uncovered several pivotal determinants namely the skill category assessed, educational level, geographical context, publication year, and experimental group categorization that collectively modulated the impact of the approach on mathematical skills. This underscored the imperative of judiciously considering these variables in the implementation of local wisdom-based learning, aiming to extract maximal efficacy.

The results cascaded into profound implications for curriculum refinement and the pedagogical landscape of mathematics. The strategic integration of C-bMLI emerged as a potent avenue for heightening mathematical acumen. However, the judicious assimilation of diverse facets, such as the specific skill domain under scrutiny, educational tier, regional context, publication timeline, and experimental subgroup classification, proved pivotal in amplifying its influence. The study corpus gained enrichment from this endeavor, seamlessly integrating and dissecting prior outcomes of investigations. It should be noted that the scope of this study encountered certain constraints, encompassing limited primary data, the inherent heterogeneity of primary studies, plausible publication bias, generalized skill limitations, and the absence of quality assessment. Based on these results, future scholarly inquiries were strongly advocated, delineating an expansive trajectory. The horizon of primary study incorporation could be broadened, enabling a deeper dissection of heterogeneity facets. A rigorous evaluation of primary study quality could be interwoven into the analysis, while also accommodating the integration of novel variables potentially shaping the efficacy of C-bMLI deployment. These results were poised to illuminate the course for educational practitioners and research analysts, steering them toward the strategic evolution of efficacious mathematics pedagogy.

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