UJME 13 (1) 2024: 66-80
UNNES JOURNAL OF MATHEMATICS EDUCATION
https://journal.unnes.ac.id/journals/ujme
ISSN: 2252-6927 (print); 2460-5840 (online)

The Effect of Realistic Mathematics Education (RME) Approach on Indonesian Students' Mathematical Ability: A Meta-analysis Study

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ARTICLE INFO

Article history:
Received 9 December 2023
Received in revised form 12 March 2024
Accepted 21 March 2024

Keywords:
Mathematics education; RME; Realistic Mathematics Education; Mathematical abilities; Meta-mar; Meta-analysis

Abstract

Numerous research on the application of the Realistic Mathematics Education (RME) method on students' mathematical ability have been carried out during the last 10 years. However, the impact of study characteristics on the level of variation among studies has not been fully explained in previous primary studies. The purpose of this study was to quantify the impact of RME on Indonesian students' mathematical proficiency. The research method used in that study was meta-analysis. Data collection was done by identifying articles published in national journals and proceedings. 36 articles were examined using the meta-mar website and the random effects model for estimation in accordance with the inclusion criteria. The application of RME has an overall effect size of 0.95 on students' mathematical abilities, which corresponds to into the category of a high effect, according to the random effects model, according to this study.

1. Introduction

Around 1998, the world of mathematics education in Indonesia began to be introduced to an innovation in mathematics learning known as *Realistic Mathematics Education* (RME), which originated from the Netherlands (Sembiring et al., 2010). In Indonesia, the term RME is translated into *Indonesian Realistic Mathematics Education* (PMRI) (Zulkardi et al., 2020). The word "to imagine" in Dutch, "zich REALISEren," is where RME gets its start. Thus, the term "realistic" can refer to one of three contexts: (1) a real-world setting associated with daily life; (2) a formal mathematical context found in the field of mathematics; or (3) an imaginary setting that does not exist in reality but can be imagined. These three meanings are considered to be appropriate meanings for the term "realistic" as long as these contexts can be thought of by students who are learning mathematics (Freudenthal, 1991; Van Den Heuvel-Panhuizen, 2003; Van den Heuvel-Panhuizen & Drijvers, 2020).

According to Hendriana & Soemarmo (2019), the capacity to solve problems in both mathematics and real life is a measure of a student's mathematical ability. Mathematical abilities include understanding concepts and procedural knowledge, problem solving skills, recognizing the relationship of mathematical procedures of a representation topics and links outside of mathematics, and using mathematics in everyday life. Several learning strategies, including the RME approach, can be employed to enhance students' abilities in mathematics, (Rizkiani & Septian, 2019). The results of primary research on the effect of RME implementation on mathematical ability have been published in various scientific articles listed in Table 2. However, these studies have not thoroughly explained the influence of study characteristics, such as education level, sample size, research location, and students' mathematical ability. The government and educational practitioners need in dept and comprehensive information in choosing the right alternative

To cite this article:
Isnaintri, E., Syamsuri, S., Nindiasari, H., & Yuhana, Y. (2024). The Effect of Realistic Mathematics Education (RME) Approach on Indonesian Students' Mathematical Ability: A Meta-analysis Study. *Unnes Journal of Mathematics Education*, *13*(1), 66-80. https://doi.org/10.15294/p8ra2p86

learning model or approach to improve students’ mathematical ability. Higgins & Katsipataki (2015) stated the importance of combining quantitative findings to obtain accurate effect of the primary research is called meta-analysis.

Therefore, the purpose of this study is to investigate the effect of RME on mathematical ability by comparing it with conventional learning models based on the characteristics of education level, sample size, research area, and students’ mathematical ability. It is expected that the results of this study will provide accurate information to teachers regarding the application of RME in mathematical ability.

2. Methods

In this review, the meta examination strategy was utilized. This study followed comparable advances, including setting consideration models; looking through the writing and coding the information; assessing the nature of the examinations; leading measurable examination and creating understandings. This approach was additionally picked on the grounds that the specialist tried to analyze the actions given by each study with respect to the degree to which factors impact different factors. For this purpose, meta-analysis is an analytical method that statistically analyzes the results of relevant studies to determine the combined effect of each study.

In this study, the procedures include: 1) planning the exploration issue; 2) looking for important writing; 3) the study's coding; 4) factual investigation by ascertaining the impact size; 5) making inferences from the translation of the outcomes and checking for distributions inclination; 6) incorporating a report or end (Valentine et al., 2009).

The effect of RME on students' mathematical ability was the initial research problem. The subsequent stage was to look for significant writing by setting consideration models to guarantee similarity with the literature determinations. The examinations engaged with this meta investigation are the consequences of studies that meet the creator's models. The application of RME and its effect on students' mathematical abilities was the subject of this study's meta-analysis, which involved combining and analyzing multiple studies that had been published in journals or proceedings with the same theme.

The hunt standards were restricted to diary articles accessible in full text. A selection procedure was carried out with inclusion and exclusion criteria to determine the number of samples to be used in this study. Additionally, procedures were carried out to assess the quality and relevance of 118 articles using the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) developed by Moher, Liberati, tetzlaff, and Altman. The PRISMA was used because the number of articles found was quite large (Moher et al., 2009).

Inclusion criteria for articles in the primary study included:

a) The publication years range from January 2013 to May 2023.
b) Articles are research conducted in Indonesia and have been published in Garuda and SINTA registered journals.
c) The article uses quasi-experimental research methods and has a randomized benchmark group pretest posttest configuration, randomized control bunch posttest just plan, nonequivalent gathering pretest posttest plan and nonequivalent gathering posttest just plan.
d) The primary study populations in the article were elementary, junior high and high school/vocational school students.
e) Statistical data on the primary study included sample size, mean and standard deviation.

Exclusion criteria for articles in primary studies in this study include (Priola, 2016):

a) Irrelevant title
b) Full text not accessible
c) Removal of copy articles
d) Irrelevant conceptual
e) Non experimental exploration
f) Required information, for example, test size, mean and standard deviation were not accessible.

The articles to be analyzed were obtained from Google Scholar, Garuda Portal, Sinta Ristekbrin and the national Library’s digital library. These primary studies were searched based on the theme of RME implementation and its effect on students’ mathematical abilities by using keywords such as “Realistic Mathematics Education”, “realistic mathematics learning”, “ PMRI”, “realistic mathematics mathematical understanding”, “realistic mathematics mathematical literacy/ numeracy”, “realistic mathematics mathematical problem solving”, “realistic mathematics mathematical connection”, “realistic mathematics mathematical representation”, “realistic mathematics mathematical communication”, “realistic mathematical creative thinking”, “realistic mathematics mathematical critical thinking”. Based on the inclusion criteria, 118 articles were found in this search. Next, the selection of articles to be excluded from the results was carried out. Based on the exclusion criteria, only 36 articles were retained and used as the main source of the study.

Sources from the essential review were then coded. The coding system was directed through a manual coding instrument utilizing Microsoft excel. The coding system was finished by recording data engaged with the examination interaction, for example, concentrate on code, creator name, distribution year, title, source, research plan, factual data (sample size, mean, and standard deviation of the experimental and control groups). Education level was divided into three categories: 1) SD/MI; 2) SMP/MTs; and 3) SMA/SMK. The number of samples was classified into samples with a size of less than 30 and more than or equal to 30. Based on the articles found, the region where the research was made into two classifications, namely Java Island and outside Java Island. Students’ mathematical ability is classified into nine categories including: 1) mathematical understanding ability, 2) mathematical reasoning ability, 3) mathematical literacy or numeracy ability, 4) problem solving ability, 5) mathematical connection ability, 6) mathematical representation ability, 7) mathematical communication ability, 8) mathematical creative thinking ability and 9) mathematical critical thinking ability.

After the coding process, the next step is to calculate the effect size using the Standardized Mean Difference (SMD), namely Hedges’s g (Fritz et al., 2012). The following Hedges’s g formula is used:

$$Hedges's\ g = \frac{M_1 - M_2}{SD_{pooled}}$$

Description:
$M_1 - M_2$ = difference in means

SD_{pooled} = pooled and weighted standard deviation

Effect size in this meta-analysis was interpreted based on the classification established by (Thalheimer & Cook, 2002), which is presented in Table 1.

Table 1. Effect Size Interpretation

ES	ES Interpretation
$-0.15 \leq ES \leq 0.15$	Ignored
$0.15 < ES \leq 0.40$	Low level
$0.40 < ES \leq 0.75$	Medium level
$0.75 < ES \leq 1.10$	High level
$1.10 < ES \leq 1.45$	Very high level
$ES > 1.45$	Excellent level

Subsequent to working out the impact size, the following stage is to lead a homogeneity test. The homogeneity test means to decide the proper investigation assessment model (Retnawati et al., 2018). Assurance of the investigation model is finished by checking $p - value$. This test's null hypothesis (H_0) states that the primary study's ES is homogeneous for the analysis. On the off chance that the worth of p is under 0.05 then H_0 is dismissed, and that implies that the ES are heterogeneous. Hence, it is concluded that the assessment model utilized is the arbitrary impacts model. The fixed effects model is chosen in this scenario if the $p - value$ is greater than 0.05 indicating that the ES is homogeneous. (Retnawati et al., 2018).

To ensure that the most likely to be analyzed published studies were representative of all other studies addressing the same issue, the subsequent procedure tested for publication bias. Likewise, this test is utilized to forestall the idea that the examinations remembered for this review are just those with massive impact size results and prohibit those with low impact size results. One method for recognizing and conquer the channel plot technique and Rosenthal's Safeguard N (FSN) (Retnawati et al., 2018). The funnel plot is the first method used to detect publication bias. In the event that the review impact size appropriation isn't balanced or not completely balanced, then, at that point, Rosenthal's FSN strategy is utilized to assist with deciding the presence of distribution predisposition (Tamur, Juandi, & Adem, 2020). If the value of $\frac{FNS}{5k+10} > 1$, with k as the number of studies in the meta-analysis, then this study indicates the presence of publication bias (Paloloang et al., 2020). If there is no publication bias, the analysis can continue. Through this analysis model, the authors can test the null hypothesis (H_0) (Retnawati et al., 2018). If the value $p - value$ is less than 0.05 then H_0 can be accepted. If the analysis model uses random effects, which shows variations between studies, the authors can analyze the characteristics of the study and interpret the results of the analysis (Borenstein et al., 2009).

3. Results & Discussions

This study means to make sense of the effect of learning through the use of the RME move toward on understudies' numerical capacities, by leading an impact size examination that joins different investigations utilized. The table that follows lists the studies that were included because they met the inclusion criteria.

Table 2. Studies Used in The Meta-analysis

Study Code	Journal Name	DOI/ URL
S01	Mosharafa	https://doi.org/10.31980/mosharafa.v8i2.454
S02	Jurnal Ilmiah Sekolah Dasar	https://doi.org/10.23887/jisd.v4i1.21103
S03	Edumatica	https://doi.org/10.22437/edumatica.v3i01.1391
S04	Union	https://doi.org/10.30738/.v5i2.1085
S05	Pena Cendekia	https://ejurnal.univalabuhanbatu.ac.id/index.php/pena/article/view/92
S06	Repository Ar-Raniry	https://repository.ar-raniry.ac.id/id/eprint/24805/1/Ulfa%20Fajrina,%20170205100,%20FTK,%20PMA.pdf
S07	JPMI	https://doi.org/10.22460/jpmi.v5i4.10837
S08	Journal on Mathematics Education Research	https://ejournal.upi.edu/index.php/JMER/article/view/24571
S09	Numeracy	https://doi.org/10.46244/numeracy.v8i2.1611
S10	Repository Universitas Negeri Padang	http://repository.unp.ac.id/23937/1/Jurnal%20NURHAFIZAH%20(15029039)-1.pdf
S11	Unnes journal of Mathematics Education	https://journal.unnes.ac.id/sju/index.php/ujme/article/view/7445/6980
S12	Jurnal Buana Ilmu	https://doi.org/10.36805/bi.v1i1.94
S13	Journal of Physics: Conference Series	10.1088/1742-6596/1776/1/012039
S14	Unnes Journal of Mathematics Education	https://doi.org/10.15294/ujme.v5i3.12015
S15	Jurnal Karya Pendidikan Matematika	https://doi.org/10.26714/jkpm.8.2.2021.45-52
S16	Jurnal Fibonaci	https://doi.org/10.24114/jfi.v2i1.28665
S17	Union	https://doi.org/10.24114/jfi.v2i1.28665
S18	Repository Raden Intan	http://ejournal.radenintan.ac.id/index.php/pspm/article/view/2405/1942

S19	Jurnal Kajian Pendidikan Matematika	http://dx.doi.org/10.30998/jkpm.v3i2.2260
S20	Jurnal Basicedu	https://doi.org/10.31004/basicedu.v6i4.3525
S21	Jurnal ilmiah Sekolah Dasar	https://doi.org/10.23887/jisd.v4i2.25103
S22	Jurnal Profesi Pendidikan (JPP)	https://doi.org/10.22460/jpp.v1i1.10451
S23	Jurnal Prisma	https://doi.org/10.35194/jp.v8i1.395
S24	Madaris	https://jurnalmadaris.org/index.php/md/article/view/308/73
S25	Buana Matematika	https://doi.org/10.36456/buanamatematika.v6i2:.367
S26	Prosiding Semirata	https://jurnal.fmipa.unila.ac.id/semirata/article/view/882/701
S27	Jurnal Pendidikan matematika Raflesia	https://doi.org/10.33369/jpmr.v3i2.6290
S28	Kadikma	https://doi.org/10.19184/kdma.v8i1.5278
S29	James	https://doi.org/10.32665/james.v4i1.172
S30	Jurnal Pendidikan Matematika Rafa	http://dx.doi.org/10.33087/phi.v2i1.25
S31	Buana Matematika	https://doi.org/10.36456/buanamatematika.v6i2:.367
S32	SJME	https://doi.org/10.35706/sjme.v6i1.5761
S33	Jurnal Keguruan dan Ilmu Pengetahuan	https://doi.org/10.25157/j-kip.v3i3.8747
S34	Jurnal Pendidikan Matematika Rafa	http://dx.doi.org/10.33087/phi.v2i1.25
S35	Phi: Jurnal Pendidikan Matematika	http://dx.doi.org/10.33087/phi.v2i1.25
S36	Jurnal Gadang	https://doi.org/10.31629/jg.v3i2.508

Research data for each study was obtained using the meta-mar website, with reference to Hedges'q as listed in Table 3 below.

Tabel 3. Effect size, Effect Size Interpretation, Standard Error and Trust Interval

Study Code	Author Name and Year	Effect Size	Interpretation of Effect Size	Standard Error (SE)	Trust Interval	
					Lower Limit	Upper Limit
S01	(Jeheman et al., 2019)	0.5867	Medium	0.2556	0.0858	1.0876
S02	(Hidayat et al., 2020)	0.8989	High	0.2914	0.3277	1.4701
S03	(Putri, 2013)	0.1714	Low	0.2213	-0.2623	0.6050
S04	(Nursiddik et al., 2017)	0.2545	Low	0.3176	-0.3679	0.8769
S05	(Pasaribu et al., 2019)	1.2331	Very high	0.2823	0.6798	1.7863
S06	(Ulfa Fajrina, 2022)	0.0382	Ignored	0.2949	-0.5398	0.6162
S07	(Firdaus et al., 2022)	2.2377	Very good	0.3707	1.5112	2.9641
S08	(Fajriani et al., 2020)	0.5617	Medium	0.2726	0.0274	1.0961
S09	(Fendrik, 2021)	1.9313	Very good	0.3114	1.3210	2.5416
S10	(Nurhafizah & Fauzan, 2019)	0.9203	High	0.2697	0.3917	1.4488
S11	(Hartriani & Veronica, 2015)	0.7872	High	0.2368	0.3231	1.2512

S12	(Kusumaningrum, 2016)	2.2309	Very good	0.2790	1.6841	2.7776
S13	(Zubaidah Amir et al., 2021)	0.5911	Medium	0.2516	0.0979	1.0843
S14	(Kusuma et al., 2016)	0.5705	Medium	0.2816	0.0185	1.1224
S15	(Herutomo & Masrianingsih _, 2021)	0.7181	Medium	0.2581	0.2122	1.2240
S16	(Syafitri & Fauzi, 2021)	0.1810	Low	0.2566	-0.3220	0.6840
S17	(Istiana et al., 2020)	1.1959	Very high	0.3283	0.5525	1.8393
S18	(Noviyana & Fitriani, 2018)	2.3046	Very good	0.3750	1.5695	3.0396
S19	(Susanti & Nurfitriyanti, 2018)	0.8867	High	0.3320	0.2360	1.5374
S20	(Herdiansyah & Purwanto, 2022)	1.7896	Very good	0.3067	1.1885	2.3908
S21	(N. P. R. Wulandari et al., 2020)	3.7003	Very good	0.4705	2.7783	4.6224
S22	(Lugina & Artiani, 2022)	1.2259	Very high	0.2521	0.7318	1.7201
S23	(N. Y. Wulandari, 2019)	0.6323	Medium	0.2647	0.1134	1.1512
S24	(Fauzana, 2022)	0.9930	High	0.3882	0.2322	1.7539
S25	(Ariyanti, 2016)	1.1138	Very high	0.2691	0.5863	1.6413
S26	(Rahmawati, 2013)	0.1209	Ignored	0.2428	-0.3549	0.5967
S27	(Heryan, 2018)	0.5645	Medium	0.2634	0.0482	1.0808
S28	(Melati et al., 2017)	0.4095	Medium	0.2334	-0.0480	0.8670
S29	(Yuliyanti et al., 2021)	1.0182	High	0.2748	0.4795	1.5568
S30	(Muslimahayati, 2019)	1.0398	High	0.2668	0.5170	1.5626
S31	(Ariyanti, 2016)	1.5892	Very good	0.2876	1.0255	2.1529
S32	(Asmara et al., 2022)	0.1836	Low	0.2241	-0.2556	0.6228
S33	(Imanisa & Effendi, 2022)	0.9290	High	0.2656	0.4085	1.4495
S34	(Lestari et al, 2018)	0.8176	High	0.2669	0.2946	1.3406
S35	(Oktaviani et al., 2018)	0.4213	Medium	0.2528	-0.0742	0.9168
S36	(Meirisa et al., 2018)	0.7802	High	0.2751	0.2410	1.3194

Based on Table 3, each of the 36 primary studies had an effect size that varied from 0.0382 to 3.7003. according to Thalheimer & Cook (2002), the data in Table 3 shows that seven studies had excellent effect sizes, which means that the application of the RME approach in those seven studies affected students' mathematical abilities very well. In addition, four studies had very high effect sizes and ten studies had high effect sizes, this means that the RME approach in fourteen studies had very high and high effects on Indonesian students' mathematical ability. In addition, nine studies had medium sized effect sizes and two studies were ignored.

The above results show that the review was not impacted or liberated from distribution predisposition. This intends that there is no distribution inclination; all in all, the examinations associated with the exploration are illustrative of other comparable investigations so there is compelling reason need to add extra examinations because of the shortfall of distribution predisposition (Paloloang et al., 2020). To work out the joined impact size of every essential review, the creators expected to make an assessment model through homogeneity testing, all things considered. Table 4 provides details on the homogeneity testing of all primary studies.

Table 4. Homogeneity of Effect Size Distribution

Chi-Squared	Heterogeneity		I-Squared	σ^2
	Df	P-value		
181.42	35	< 0.01	81 %	0.3975

Tabel 4 shows that $p - value < 0.05$. This test's null hypothesis is therefore rejected, indicating that the effect size is variable. The combined effect size was then calculated using the random effects model's estimation model. In addition, the following figure provides a funnel plot.

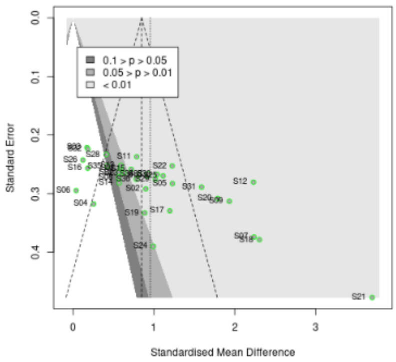

Figure 1. Funnel Plot

In light of Figure 1, it was found that the impact size circulation was not even to the upward line. The authors the detected publication bias with Rosenthal's Fail-Safe N (FSN) from the 36 primary studies studied (k). from the calculation, it was found that the value of $FNS = 5054$. By using the formula $\frac{FNS}{5k+10} = \frac{5054}{5(36)+1} = \frac{5054}{181} = 27.92 > 1$. This shows that if the studied in this meta-analysis are moderately tolerant of publication bias, then the publication bias will be reduced (Tamur, Juandi, & Kusumah, 2020). The results of the meta-analysis of primary studies using random effects models and fixed effect models are then displayed in Tabel 5.

Table 5. Meta-analysis Results Based on Estimation Model

Model	n	Effect Size and 95% Confidence Interval				Test of null (2-tall)	
		ES	SE	Lower Limit	Upper Limit	Z- value	P-value
Fixed Effect Model	36	0.85	0.09	0.76	0.94	18.41	< 0.0001
Random Effect Model	36	0.95	0.24	0.71	1.20	7.92	< 0.0001

By utilizing an irregular impacts model, it is gotten that the $p - value < 0.0001$ atau $p - value < 0.05$. In view of the speculation testing rules, one might say that in general, the RME approach fundamentally affects numerical capacity contrasted with the standard learning model. This end is in accordance with different examinations, for example, research led by (Afsari et al., 2021). The review presumed that the utilization of the RME approach has the viability to further develop learning results and can likewise work on different understudies' numerical capacities. In view of these outcomes, it very well may be seen that RME an option for educators to work on understudies' numerical capacities and understudies' numerical learning results. In light of the irregular impacts model, with a certainty level of 95%, the joined impact size of all reviews is 0.95, which is as per the translation by (Thalheimer & Cook, 2002), this impact size is delegated a high impact. In this manner, it tends to be presumed that ethnomathematics based learning models have a high impact in further developing understudies' numerical capacities contrasted with normal learning models. As per Coe (2002), the consolidated impact size of 0.95 shows that the numerical capacity of understudies in the trial bunch is higher that the numerical capacity of 82% of understudies in the benchmark group.

In the past homogeneity test, data was gotten that the essential review impact size information followed a heterogeneous dissemination. The subsequent stage was to dissect the review attributes that were thought to de the reason for the inhomogeneity of the impact size information in numerical capacity. Therefore, the study characteristic, such as education level, sample size, research area and mathematical ability, were analyzed. The results of the analysis of these characteristics are in Tabel 6 below.

Table 6. Analysis Results Based on Study Characteristics

Study Characteristics	Category	n	Hedges'g	I-Squared	P-Value	95% CI	
						Lower Limit	Upper Limit
Education Level	SD/ MI	9	1.3645	87%	< 0.01	0.6109	2.1181
	SMP/ MTs	24	0.8427	79%	< 0.01	0.5736	1.1119
	SMA/ SMK/ MA	3	0.7311	0%	0.64	0.2932	1.1690
Sample Quantity	≤ 30	13	1.2508	87%	< 0.01	0.6361	1.8656
	> 30	23	0.8039	71%	< 0.01	0.5897	1.0180
Research Area	Java Island	14	0.9952	82%	< 0.01	0.6028	1.3877
	Outside Java Island	22	0.9313	80%	< 0.01	0.5904	1.2723
Mathematical Ability	Mathematical Understanding	7	0.7501	82%	< 0.01	0.0546	1.4457
	Mathematical Reasoning	6	1.1588	85%	< 0.01	0.4031	1.9145
	Mathematical Literacy/ Numeracy	4	0.6361	51%	0.10	−0.0135	1.2857
	Problem Solving	4	2.1355	88%	< 0.01	0.2868	3.9843
	Mathematical Connection	2	0.9344	62%	0.11	−2.8363	4.7052
	Mathematical Representation	2	1.0747	0%	0.80	0.3565	1.7929
	Mathematical Communication	6	0.7747	75%	< 0.01	0.2225	1.3269
	Creative Thinking	3	0.6244	65%	0.06	−0.3926	1.6414
	Critical Thinking	2	0.5854	0%	0.34	−1.6861	2.8570

3.1. Education Level Study Characteristics

Based on the data listed in Table 6, the education levels in this meta-analysis study can be grouped into three categories, namely SD/ MI, SMP/ MTs, and SMA/ SMK/ MA. The effect size measurement results show that the SD/MI category has a value of 1.3645, which is included in the very high effect category. Meanwhile, the SMP/ MTs category has an effect size value of 0.8427, which is included in the high effect category. For the SMA/SMK/MA category, the effect size value found is 0.7311, which is included in the medium effect category. Based on the analysis $p - value$ analysis, the value of $p < 0.05$ was seen in the SD/MI and SMP/MTs categories. This indicates that the SD/MI and SMP/MTs categories have a significant effect in improving mathematical abilities with the RME approach.

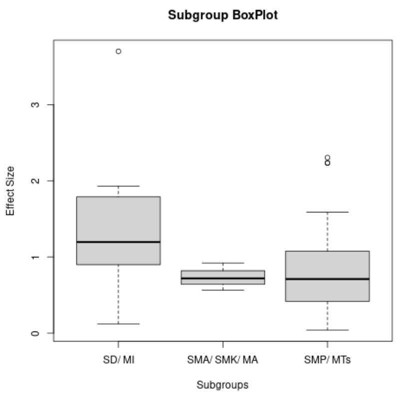

Figure 2. Subgroup Box Plot of Education Level Study Category

Furthermore, the value of $I\ Squared$ in the SD/ MI and SMP/MTs categories are 87% and 79%, respectively. According to J. P. T. Higgins et al (2003), this indicates a high level of heterogeneity between research studies. However, in the SMA/SMK/MA category, the value was 0%, indicating to heterogeneity between research studies. $I\ Squared$ was 0%, indicating no significant heterogeneity between research studies in this meta-analysis. By looking at the upper and lower bound intervals for each education level, namely SD/MI (0.61-2.12), SMP/MTs (0.57-1.11) and SMA/SMK/MA (0.29-1.17), it can be concluded that there is a gap or intersection between the upper and lower bound intervals in the characteristics of SMP/MTs and SMA/SMK/MA. Subsequently, the two gatherings meaningfully affect the use of learning with RME way to deal with work on understudies' numerical capacities. It tends to be presumed that understudies' numerical capacities through the utilization of RME approach are impacted by the degree of training and are generally reasonable for use at the SD/MI level with an avery high impact, this is as per the consequences of the review (Nur & Angriani, 2021). This data can likewise be seen outwardly in Figure 2.

3.2. Study Characteristics Sample Size

Based on the findings presented in Table 6, the sample characteristics in this meta-analysis study can be divided into two groups, namely the number of samples ≤ 30 and sample size > 30. Based on the analysis in Table 6, the number of samples ≤ 30 there are 13 studies and the number of samples > 30 there are 23 studies. The effect size value on the number of samples ≤ 30 is 1.2508 including the very high effect category and the number of samples is 0.8039 with a high effect category > 30 is 0.8039 with a high effect category. Furthermore, it can be observed for the value of $p - value$ in each category of sample size shows a value of $p < 0.05$ which means that each category of sample size has a significant effect in improving mathematical abilities with the RME approach. The value of $I\ Squared$ in the sample size category ≤ 30 and > 30 are 87% and 71% respectively, this indicates a high and medium level of heterogeneity between research studies.

Taking into account the upper and lower limit intervals for each sample size, namely $\leq 30(0.63 - 1.87)$ and $> 30(0.59 - 1.02)$, it can be concluded that thaere is no intersection between the upper and lower bounds of the interval on the characteristics of the number of samples, namely ≤ 30 and > 30. This suggests that the impact of the RME approach on enhancing students' mathematical abilities varies between the two groups based on the characteristics of the sample size under study. This aligns with the viewpoint of Tamur, Juandi, & Adem (2020) who posit that the effectiveness of implementing RME in Indonesia is notably high in enhancing students' mathematical abilities, particularly when accounting for the size of the study sample.

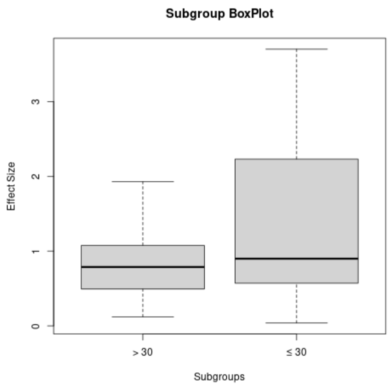

Figure 3. Subgroup Box Plot of Sample Size Category

3.3. Characteristics of The Study Area

The characteristics of the study areas in this meta-analysis were categorized into two categories, namely Java Island and Outer Java Island. Based on the analysis results from Table 6, there were 14 studies conducted in Java Island and 22 studies conducted outside Java Island. The effect size value in the Java Island category is 0.9952 and outside Java Island is 0.9313 with each having a high effect category. The value of $I\ Squared$ in the category of research in Java and outside Java were 82% and 80% respectively, indicating a high level of heterogeneity between research studies. When viewed from the value of $p - value$ based on the characteristics of the study area in Java Island and outside java Island has a value of $p - value < 0.05$ so that the characteristics of the study area have an influence in improving mathematical abilities through the application of the RME approach.

By identifying the upper and lower bound intervals for the research areas in Java and Outside Java, respectively (0.60-1.39) and (0.59-1.27), it can be concluded that there is no intersection between the upper and lower bound intervals on the characteristics of the research areas, namely Jaa and outside java. This implies that the application of the RME approach to enhance students' mathematical abilities yields varying effects in the two groups. Consequently, one can infer that the effectiveness of implementing the RME approach to improve students' mathematical abilities is contingent upon the characteristics of the research area being investigated. Research conducted in Java Island has a more effective influence that the group outside Java Island which is visualized in Figure 4 below.

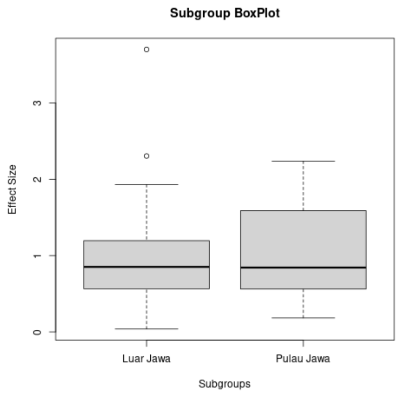

Figure 4. Subgroup Box Plot of Research Area Category

3.4. Characteristics of Mathematical Ability Studies

For the characteristics of mathematical ability studies, it can be seen from the effect size of the studies on students' mathematical abilities. Four studies on mathematical problem solving ability had the highest effect size of 2.1355 with a very good effect category. Meanwhile, studies on mathematical reasoning ability, totalling 6 studies, had an effect size of 1.1588 with a very high effect category. In additional, studies on mathematical representation ability amounted to 2 studies had an effect size of 1.0747, studies on mathematical connection ability amounted to 2 studies had an effect size of 0.9344, studies on mathematical communication ability amounted to 6 studies had an effect size of 0.7747, all three had a high effect category. Whereas for studies on mathematical understanding, 7 studies have an effect size of 0.7501, studies on mathematical literacy skills, 4 studies have an effect size of 0.6361, studies on creative thinking skills, 3 studies have an effect size of 0.6244 and studies on critical thinking skills, 2 studies have an effect size of 0.5854, the four each have a medium effect category.

If analyzed from the value of $I\ Squared$ the studies that have a high level of heterogeneity between research studies are in problem solving ability (88%), mathematical reasoning ability (85%), mathematical understanding ability (82%) and mathematical communication ability (75%). In additional, studies that have a moderate level of heterogeneity between research studies are found in creative thinking ability (65%), mathematical connection ability (62%) and mathematical literacy ability (51%). Meanwhile, studies that did not have significant heterogeneity between research studies in this meta-analysis were studies on mathematical representation ability and critical thinking ability. Meanwhile, in terms of the value of $p-value$, studies that have $p < 0.05$ so that the characteristics of the research study have an influence in improving mathematical abilities through the application of the RME approach are studies on research on mathematical understanding, mathematical reasoning, problem solving, and mathematical communication skills.

Studies that have $p > 0.05$ so that the characteristics of these research studies do not have an influence in improving mathematical abilities through the application of the RME approach are studies on research studies of mathematical literacy, mathematical connections, mathematical representation, creative thinking and critical thinking. Upon examining the upper and lower bounds intervals for each study focusing on the comprehension of mathematical abilities, it was observed that there were intersections between the upper bound interval and the boundary related to the characteristics of the study aiming to enhance mathematical abilities. This suggests a consistent effect on mathematical ability, indicating that the RME approach has a uniform impact on mathematical abilities. The analysis of study characteristics regarding mathematical ability leads to the conclusion that the application of the RME approach to enhance students' mathematical abilities is influenced by the specific characteristics of the study. Notably, the most significant effect was observed in the study of mathematical problem-solving ability, displaying a substantial effect size. This outcome aligns with the findings of (Negara et al., 2021) and is visually represented in Figure 5 below.

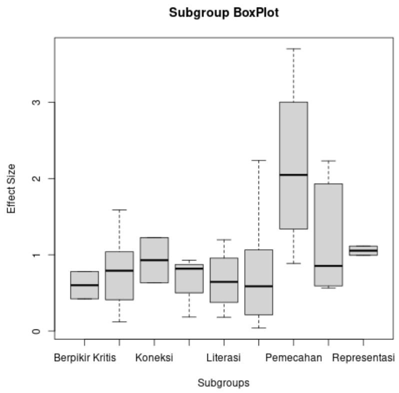

Figure 5. Subgroup Box Plot of Mathematical Ability Category

Based on the aforementioned findings, it can be asserted that the RME approach serves as a viable alternative learning method for enhancing students' mathematical abilities, regardless of whether the sample size is less than or equal to 30 individuals or exceeds 30. The suggested areas of mathematical improvement through the implementation of the RME approach encompass mathematical understanding, reasoning, problem-solving, and communication skills. Analyzing the educational level characteristics, it is evident that the SD/MI education level is particularly well-suited for the application of the RME approach in fostering students' mathematical abilities. Moreover, the effectiveness of the RME approach in enhancing mathematical skills is also influenced by the characteristics of the study area. The magnitude of the effect size values obtained for each study characteristic indicates that the RME approach exerts the most significant impact when employed at the SD/MI education level, involving sample sizes of less than or equal to 30 students, conducted in the Java Island region, and focusing on the improvement of mathematical problem-solving abilities.

Based on the findings above, several recommendations for further research and the implementation of the Realistic Mathematics Education (RME) approach in various aspects can be outlined. Firstly, there is a need for further investigation into the effectiveness of applying RME at different educational levels, such as junior and senior high school. Additionally, exploring the adaptability of RME for higher education levels and understanding the potential sustainability of its implementation is crucial. Researchers should also delve into the effectiveness of RME across various mathematical topics to ascertain the extent to which this approach can be comprehensively applied, including adapting strategies for challenging topics like algebra, geometry, or statistics.

Innovation in RME learning models is encouraged, including the integration of technology in mathematical education. Investigating combinations of the RME approach with other teaching methods to enhance overall learning effectiveness is another avenue for exploration. Analysing the influence of local contextual characteristics on RME implementation and understanding how adjustments can be made to align with local needs are vital aspects for consideration. Moreover, researchers should examine the relationship between RME implementation and students' numeracy literacy. Identifying RME strategies that specifically support the development of numeracy literacy skills, including comprehension, reasoning, problems solving, and mathematical communication, is essential. Additionally, investigating the impact of regional characteristics on RME implementation and understanding how these factors affect mathematical learning outcomes is crucial.

Finally, longitudinal research should be conducted to comprehend the trends in the development of students' mathematical abilities over time with the implementation of RME. Continuous monitoring is recommended to evaluate the long-term impact of RME on mathematical learning outcomes. Through careful research and implementation, it is hoped that the RME approach will continue to evolve and positively contribute to the enhancement of students' mathematical abilities across various educational levels.

4. Conclusion

The outcomes of a meta-analysis encompassing 36 significant studies, which investigated the impact of the *Realistic Mathematics Education* (RME) approach on students' mathematical abilities, revealed a combined effect size of 0.95. According to the interpretation by Thalheimer & Cook (2002), this effect size is categorized as high, indicating a substantial positive influence of the RME approach on improving students' mathematical abilities. Not only does this approach foster greater creativity, but it also proves to be more effective when compared to the implementation of conventional learning models. Upon scrutinizing the characteristics of the primary studies, it can be deduced that the educational levels of Junior High School and Senior High School exert distinct effects on the application of the Realistic Mathematics Education RME approach.

Put differently, the enhancement of mathematical problem-solving skills through the RME approach is impacted by the attributes of the educational level. The varied outcomes in this meta-analysis lead to the conclusion that the application of the RME approach serves as an effective means to improve mathematical problem-solving abilities, offering an alternative model in the realm of mathematics learning. Additionally, it is advisable for future researchers to incorporate a more diverse range of study characteristics to conduct more comprehensive investigations and unveil additional intriguing insights.

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