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The Effect of Realistic Mathematics Education in Enhancing Indonesian Students' Mathematical Reasoning Ability: A Meta-Analysis

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ABSTRACT

Many researchers have carried out meta-analysis studies related to realistic mathematics education (RME) to enhance mathematical ability. However, their research does not focus on mathematical reasoning ability (MRA). This study aims to estimate and examine the effect of RME implementation in enhancing the MRA of Indonesian students, as well as to explore the moderating factors that influence students' heterogeneous MRA. The meta-analysis examined twenty-five relevant primary research published in national and international journals and sessions between 2010 and 2022. The steps of this research are formulate the problem, inclusion criteria, literature search strategy, study selection, data extraction, statistics analysis, interpretation and reporting. To calculate the effect size, the analytical tool employed the Comprehensive Meta-Analysis (CMA) program using the Hedge formula. Based on the random effect model, the total RME implementation had a very high effect (g = 1,064; p<0,05), significantly enhancing the MRA of Indonesian students. Furthermore, class capacity, educational level, and technological assistance did not influence students' heterogeneous MRA in the RME. These findings imply that Indonesian math educators should consider RME as one of the best ways to implement mathematics learning in the classroom to enhance students' MRA.

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A. INTRODUCTION

According to the NCTM (National Council of Mathematics Teachers), one of the standard abilities that students must know is mathematical reasoning (NCTM, 2014). The reasoning is an essential ability that must be applied and developed in students (Siallagan et al., 2021). In other literature, it is revealed that for students involved in mathematical reasoning, it will provide a strong foundation for understanding mathematical ideas and materials (Lestari & Jailani, 2018). Mathematical content will be frequently accomplished if reasoning abilities are developed, and reasoning skills may be developed by studying mathematics (Bragg et al., 2016). Therefore, teachers must pay close attention to their students' reasoning abilities in teaching and learning mathematics. Conceptual understanding, procedural fluency, and adaptive reasoning are part of mathematical abilities that must be developed when students are learning mathematics in addition to strategic competence or problem-solving and productive disposition (Kilpatrick et al., 2001). Mathematical reasoning involves several activities, such as specializing (making) experiments, determining patterns/relationships, generalizing guesses, and convincing (Barnes, 2019).

Scientists who work with mathematics educators chose the Realistic Mathematics Education (RME) method as one alternative for developing and enhancing mathematical reasoning abilities that are still low. RME approach was chosen as one solution because it provides students with a comprehensive and practical knowledge of the link maths and everyday life, as well as the mathematics' wide relevance to people, so that students are more motivated and understand better since learning is connected to ordinary life, even if the learning results of each sample differ (Wajdih et al., 2020). As a result, many schools use RME paradigm to teach mathematics at all levels of formal education for improvement and enhance students' mathematical reasoning abilities.

Until now, researchers in Indonesia and other countries have extensively examined the mathematical reasoning ability supported by RME approach. However, according to multiple studies reported in various journals, RME method has a considerable significant impact on boosting MRA of students (Fajriani et al., 2020; Merina et al., 2019; Septianawati & Abdillah, 2020; Triyani, 2017). Other researchers, on the other hand, contend that RME has no substantial influence on students' mathematical thinking ability (Alvira, 2021; Zaini & Marsigit, 2014). Inconsistent findings from this research give ambiguous and erroneous information regarding the RME's method efficiency on students' MRA. In contrast, policymakers in the educational field, particularly maths teacher, require clear and exact information for example: at what educational level, what class capacity, and whether or not the approach is technological assistance, which affects the effect size heterogeneity of the RME approach in improving students' reasoning abilities.

Based on this, it is necessary to organize data from several articles found and reviewed to obtain as much information as possible, especially how much effect the RME approach has on mathematical reasoning abilities with meta-analysis studies. Meta-analysis is an overall and empirical review of quantitative studies by summarizing effect sizes based on measures of central tendency and evaluating representations of research error or bias (Siddaway et al., 2019). The effect size is an index that measures the relationship between two variables or the difference between two groups (Borenstein, 2009).

Previous meta-analysis research on the efficiency of the RME method have been conducted, such as the Tamur et al. (2020), which assessed RME's application influence on students' MRA. This discovery also demonstrates that RME may be used at many levels of schooling. Tamur et al. (2020) did not precisely investigate the mathematical skills that RME applies. Widana (2021) performed the following study, which looked at the impact of RME on learners' mathematical problem-solving abilities in Indonesia. Each article's effect size and interval values varied substantially in this study, with a medium effect size of 0.42. Widana (2021) study solely looks at the effect of RME on problem-solving abilities from 2016 to 2021 and does not look at other moderator factors. As a result, researchers are eager to investigate the impact of RME on mathematical reasoning abilities from 2010 to 2022, as well as features such as educational level, class capacity, and technological assistance, using Comprehensive Meta-Analysis Software (CMA).

The next similar research is the research conducted by Juandi dkk. (2022) who examined a meta-analysis of the last two decades of realistic mathematics education approaches. This study examined 54 effect sizes from 38 individual studies conducted in the last two decades with the databases ERIC, Sage Publications, Springer Publications, Semantic Scholars, and Google scholars. The results of this study are the overall effect size of 0.97 using the estimated random effects model. This shows that the application of RME has a significant positive effect on students' mathematical abilities. The moderator variables analyzed in this study were sample size, treatment duration, learning mix, and education level. The difference between this research and the study that the author conducted is that this study is devoted to discussing mathematical abilities in terms of reasoning and solving mathematical problems of students, the range of years of study increases, there is an increase in the number of articles, in previous studies there was no moderator variable for technological assistance status, so the authors added a variable moderator in the form of technological assistance status.

This research will give detailed information on the impact of RME on student MRA in Indonesia. This research attempts to estimate and examine the effect of RME implementation in enhancing the MRA of Indonesian students, as well as to explore the moderating factors that influence students' heterogeneous MRA. As a result, it might be considered for educators to carry out the most effective learning approach to teach and strengthen students' ability to think.

B. METHODS

The research methods used in this study was meta-analysis. This study used a meta-analysis to synthesize several relevant primary studies utilizing quantitative methods. There were various advantages to doing a meta-analysis. More openness, identifying and eliminating bias, better-estimating population characteristics, analyzing results in a variety of fields, presenting clear proof of substantial rejection, and offering a methodical approach throughout the synthesis procedure are among the benefits (Litte et al., 2008; Shelby & Vaske, 2008). The population in this study were studies in the form of national and international journal proceedings and journal articles regarding the use of the RME approach to students' mathematical reasoning and problem solving abilities from 2010-2022. The sample taken is a study of the RME approach to reasoning and problem solving abilities with inclusion criteria. The instrument in this study used a coding data sheet which had been validated by two meta-analyst experts to obtain the final schematic on the coding sheet. Bernard et al. (2014); Borenstein (2009); Cooper (2017) indicated in their research that the There were several steps to the meta-analysis investigation, as seen in the flowchart in Figure 1.

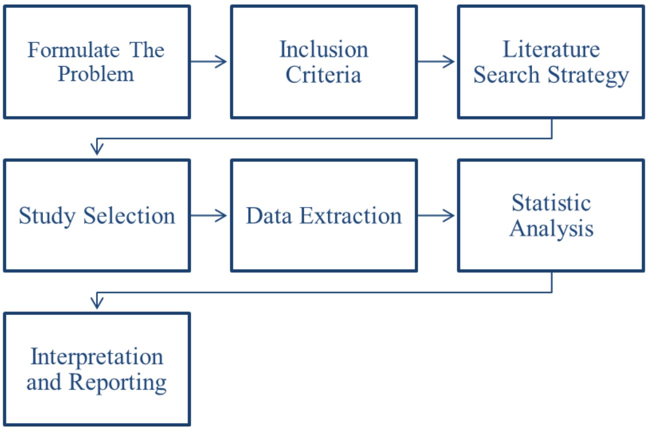

Figure 1. Flowchart showing the steps of a meta-analysis

As a result, these steps were employed in this investigation. In this section, the researchers discuss several phases, considering eligibility criteria and strategies for searching the literature, extraction of data, selection of study, and analysis of statistic. The formulation of the problem in this study is whether the use of the Realistic Mathematics Education Approach has a positive effect on the submission of students' mathematical reasoning abilities and problem solving abilities in terms of the studies analyzed and whether there are differences in the effect size of the application of the Realistic Mathematics Education Approach to marketing reasoning abilities and solving abilities students' mathematical problems in terms of educational level, sample size and based on technology or non-technology. For the interpretation and repotting stages can be seen in the results and discussion section

1. Inclusion Criteria

Preliminary research on the influence of RME adoption on improving MRA was still broad and universal. To narrow the scope of this meta-analysis, the inclusion criteria were defined using the PICOS technique (Population, Interventions, Comparator, Outcomes, and Study Design) (Liberati, et al., 2009), specifically:

a. The primary study's population consisted of students in Indonesia.
b. The preliminary study's intervention was the application of RME.
c. In the primary research, the intervention's comparator applied traditional learning.
d. MRA was the prior study's result.
e. The main research used a quasi-experimental study design using a causal-comparative approach.
f. The preliminary study presented statistical data in the intervention and comparison groups, class capacity, t-value, p-value, mean, standard deviation are some examples.
g. The preliminary study was national and international publications between 2010 and 2022.

The primary studies that did not meet the inclusion criteria in the study selection approach were deleted.

2. Literature Search Strategy

Using internet resources such as Google Scholar, Educational Resources Information Center (ERIC), Semantic Scholar, and Directory Open Access Journal (DOAJ), we searched for RME implementation literature to improve Indonesian students' reasoning ability. Search terms for this type of material included "Realistic Mathematics Education" and "Mathematical Reasoning Ability" or "Mathematical Reasoning Skills." As a result, keywords and databases might help in locating and acquiring some primary research that meets the inclusion requirements.

3. Study Selection

The inclusion criteria were used help guide the selection of primary researches and proposed in their literature that the primary research be selected in four phases directed by PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis), namely: (1) identification; (2) screening; (3) eligibility; and (4) inclusion (Liberati et.al, 2009; Juandi & Tamur, 2020). As a result, these phases were utilized to identify papers for this meta-analysis.

4. Extracting Data

Authors, statistical information, sampling method, research region, year of publication, and type of publication were retrieved from study papers that matched the criteria of inclusion and went as a result of study selection step. The data extraction technique includes two coding specialists in meta-analysis to guarantee that the information or data obtained from the process of extraction was legitimate and reliable (Nugraha & Suparman, 2021). Thus, reliable and credible data increased the likelihood that this meta-analysis would produce outstanding findings.

5. Statistical Analysis

Because the class capacitys in the intervention group (RME) in this meta-analysis were relatively modest, effect sizes were computed using Hedge's g equation (Borenstein, 2009; Harwell, 2020). The collected effect sizes were interpreted using Thalheimer & Cook (2002) classification. The following shows the categorization of effect sizes, as shown in Table 1.

Table 1. The Classification of Effect Size in Thalheimer & Cook's Study

Effect Size (ES)	Interpretation
$-0,15 \leq ES < 0,15$	Ignored
$0,15 \leq ES < 0,40$	Low
$0,40 \leq ES < 0,75$	Medium
$0,75 \leq ES < 1,10$	High
$1,10 \leq ES < 1,45$	Very High
$1,45 \leq ES$	Excellent

Every publishing of study findings was tainted by publication bias. As a result, publication bias and sensitivity analyses were necessary to guarantee that the statistical data contained in each main study was reliable (Furuya-Kanamori & Doi, 2020;Bernard et al., 2014). In this meta-analysis research, funnel plots were employed, and fill and trim tests (Harwell, 2020).

Furthermore, the evidence on effect size stability and normality were tested using analysis of sensitivity in the CMA software's "One study removed" option (Bernard et al., 2014).

Meta-analysis research included two impact models: fixed effect models and random effect models (Borenstein, 2009; Cheung, 2015). This study uses a random effect estimation model, this is due to variations in the effect size and moderator variables to be analyzed (Haidich, 2010; Paloloang et al., 2020). The discovery of heterogeneous effect size data suggested that a study characteristics analysis was necessary to investigate the variables most likely to cause heterogeneity in effect size data (Borenstein, 2009; Siddiq & Scherer, 2019). In addition, in the null hypothesis study, the p-value of Z statistics was utilized to explain the substantial influence of RME deployment on improving Indonesian students' MRA.

C. RESULT AND DISCUSSION

The investigation's search yielded 213 abstracts from Semantic Scholar, Google Scholar, Education Resources Information Center (ERIC), and Directory Open Access Journal databases (DOAJ). 213 main study titles were discovered, including 147 from the Google scholar database, 49 from the Semantic scholar database, eight from the DOAJ database, and nine from the ERIC database. Description of the primary study search and selection results visualization is presented in Figure 2.

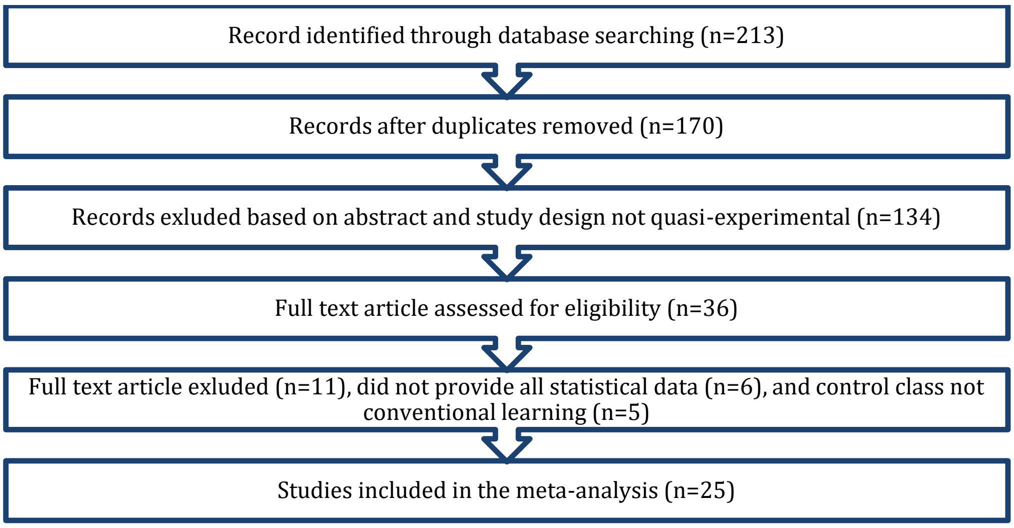

Figure 2. Flowchart for Primary Study Selection

1. Extracting Data Results

The findings of the twenty-five primary studies that met the inclusion criteria as well as the study selection would be obtained. The following shows the findings of data extraction from twenty five preliminary studies, as shown in Figure 2.

Table 2. Extraction of Data from Twenty-Five Primary Studies

Studies	Statistical Data						T-Value	P-Value
	RME			Conventional Learning				
	Mean	SD	SS	Mean	SD	SS		
Merina et al., 2019	52.936	14	31	58.71	16.787	31		
Zaini & Marsigit, 2014	50.09	13.9	32	38.28	16.64	32		
Raharjo et al., 2018	19.97	3.861	33	16.25	2.94	32		
Fajriani et al., 2020	69	11.34	28	60.61	17.468	28		
Alvira, 2021	78.71	12.85	35	83.57	11.73	35		
Pertiwi, 2019	25.49	3.023	35	20.65	5.48	34		
Amir et al., 2021	54.85	18.5	33	20.64	5.48	34		
Kusumaningrum, 2016	14.88	2.91	43	9.37	1.84	41		
Fendrik, 2021	14.3556	2.67272	45	11.3077	2.15399	39		
Hartriani & Veronica, 2015	75.87	5.38	39	72.05	4.13	38		
Putri, 2013	5.78	1.92	41	2.01	5.44	41		
Nurhafizah & Fauzan, 2019	71.25	17.57	30	55.44	16.35	31		
Fauzan et al., 2018	11.52	6.85	29	5.41	3.15	29		
Mendrofa, 2021	77.48	8.46	25	65.92	7.32	25		
Apriani et al., 2019	88.5	8.283	35	82.033	10.788	35		
Dani et al., 2017	7.31	2.2	32	5.69	2.68	32		
Fuadi et al., 2016			36			36	3.771	
Nasution & Dur, 2017			26			25	1.792	
Febrian et al., 2016			32			32	9.32	
A Herwati, 2015			35			34	5.25	
Laurens et al., 2018			25			25	3.32	
Fatmawati & Hasanah, 2018			20			20	2.174	
Ardiniawan et al., 2022			39			39	12.078	
Nuraida, 2018			32			32		0.00
Lestari et al., 2016			36			36		0.04

2. Analysis of Publication Bias and Sensitivity

The following is the Hedge Standard Error Funnel Plot, as shown in Figure 3.

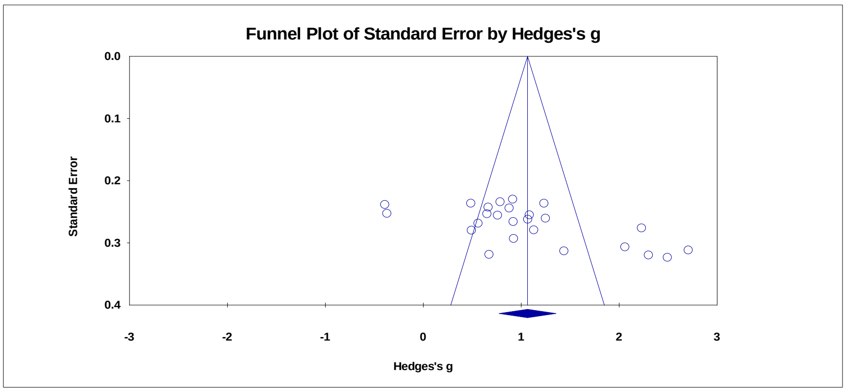

Figure 3. Hedge's Standard Error Funnel Plot

The funnel plot graphic illustrates the distribution data of effect size from the primary studies in this meta-twenty-five analysis. Figure 3 depicts the data on effect size distribution from the twenty-five prior studies included in this investigation. The fill and trim test findings in Table 3 reveal that no impact size data in this meta-analysis research should be added or cut. This conclusion interprets significant evidence from the twenty-five main studies of the distribution symmetry of impact size data. The following shows the results of the fill and trim experiments, as shown in Table 3.

Table 3. The Fill and Trim Test Result

<table>
<tr><th rowspan="2"></th><th rowspan="2">Studies Trimmed</th><th colspan="2">Random Effect Model</th><th colspan="2">Fixed Effect Model</th><th rowspan="2">Q-Value</th></tr>
<tr><th>Hedge's g</th><th>95% Cl</th><th>Hedge's g</th><th>95% Cl</th></tr>
<tr><td>Observed Values</td><td rowspan="2">0</td><td>1.064</td><td>[0.773;1.354]</td><td>0.981</td><td>[0.876;1.085]</td><td rowspan="2">184.644</td></tr>
<tr><td>Adjusted Values</td><td>1.064</td><td>[0.773;1.354]</td><td>0.981</td><td>[0.876;1.085]</td></tr>
</table>

As a result, examination of multiple publication bias offered significant indication that the data on effect size from the twenty-five meta-analysis comprised primary studies were free of publication bias. Outliers can significantly contribute to the distortion of averages and variation in a collection of effect sizes. As a result, A sensitivity analysis might be used to discover factors that may produce a grouping of aberrant effect sizes (Bernard et al., 2014). The total effect incorporated in the model of random effects was g = 1.064; 95% CI = [0.773;1.354]; n = 25; SE = 0.148, as shown in Table 4. The greatest mean produced by utilizing the tool "One study removed" in CMA software with the random effect model was g = 01.354; n = 25; SE = 0,148, while the lowest average was g = 0,774; n = 25; SE = 0,148. These findings imply that the effect size collection is highly robust and appropriate and that it is unaffected by an unusual combination of effect size and class capacity.

3. Each Primary Study's Overall Effect Size

The following shows the total effect of RME adoption in enhancing each study's MRA of Indonesian students, as shown in Table 4.

Table 4. Each Primary Study's Overall Effect Size

Study Name	Statistic for Each Study						
	Hedge's g	Standard Error	Variance	Lower Limit	Upper Limit	Z-Value	P-Value
Merina et al., 2019	-0.369	0.253	0.064	-0.865	0.127	-1.458	0.145
Zaini & Marsigit, 2014	0.761	0.256	0.066	0.259	1.263	2.973	0.003
Raharjo et al., 2018	1.069	0.262	0.069	0.554	1.583	4.073	0.000
Fajriani et al., 2020	0.562	0.269	0.072	0.035	1.089	2.090	0.037
Alvira, 2021	-0.391	0.239	0.057	-0.858	0.077	-1.637	0.102
Pertiwi, 2019	1.086	0.255	0.065	0.585	1.586	4.251	0.000
Amir et al., 2021	2.495	0.324	0.105	1.860	3.129	7.707	0.000
Kusumaningrum, 2016	2.231	0.276	0.076	1.689	2.773	8.071	0.000
Fendrik, 2021	1.235	0.237	0.056	0.771	1.699	5.214	0.000
Hartriani & Veronica, 2015	0.787	0.234	0.055	0.328	1.247	3.358	0.001
Putri, 2013	0.916	0.230	0.053	0.464	1.367	3.978	0.000
Nurhafizah & Fauzan, 2019	0.920	0.266	0.071	0.398	1.442	3.457	0.001
Fauzan et al., 2018	1.131	0.280	0.078	0.583	1.679	4.045	0.000
Mendrofa, 2021	1.438	0.313	0.098	0.824	2.053	4.590	0.000

Apriani et al., 2019	0.665	0.243	0.059	0.189	1.141	2.737	0.006
Dani et al., 2017	0.653	0.254	0.064	0.156	1.150	2.574	0.010
Fuadi et al., 2016	0.879	0.244	0.060	0.400	1.358	3.598	0.000
Nasution & Dur, 2017	0.494	0.280	0.078	-0.055	1.043	1.764	0.078
Febrian et al., 2016	2.302	0.320	0.102	1.675	2.929	7.194	0.000
A Herwati, 2015	1.250	0.261	0.068	0.739	1.761	4.793	0.000
Laurens et al., 2018	0.924	0.293	0.086	0.349	1.499	3.151	0.002
Fatmawati & Hasanah, 2018	0.674	0.319	0.102	0.049	1.299	2.112	0.035
Ardiniawan et al., 2022	2.708	0.312	0.097	2.097	3.319	8.682	0.000
Nuraida, 2018	2.061	0.307	0.094	1.459	2.662	6.716	0.000
Lestari et al., 2016	0.488	0.237	0.056	0.024	0.952	2.062	0.039
Combine Effect	1.064	0.148	0.022	0.774	1.354	7.187	0.000

According to Table 4, the range of impact sizes of RME implementation in improving MRA of Indonesian students was between -0,391 and 2,708. According to the effect size categorization, there were two studies with insignificant effect sizes, six studies with moderate effect sizes, eight studies with high effect sizes, four studies having extremely high effect sizes, and five research with ideal effect sizes. A null hypothesis study was performed to examine if the deployment of RME significantly improves the MRA of Indonesian students. The following shows the findings of the null hypothesis test, as shown in Table 5.

Table 5. The Random Effect Model based the Null Hypothesis Analysis result

Number Studies	Hedge's g	Standard Error	Variance	95% Cl	Null Hypothesis Test	
					Z-Value	P-Value
25	1.064	0.148	0.022	[0.774; 1.354]	7.187	0.000

According to Table 5 contains an analysis of the null hypothesis test, the application of RME considerably improved the Indonesian students' MRA throughout the twenty-five main studies examined. The twenty-five prior studies' effect size was 1,064, indicating a large impact size. It suggests that the RME application has a pretty favorable influence on improving the MRA of Indonesian students. This finding was in line with meta-analysis performed research by Tamur et al. (2020), which included from 72 research published in national and international publications, 95 effect sizes were calculated or sessions between 2010 and 2019.

The findings of this investigation are as follows: According to Thalheimer & Cook (2002), the total size of the effect is 1.104, which is classed as extremely high. This demonstrates that using RME substantially impacts students' mathematical ability more than the traditional technique. Similarly, Juandi et al. (2022) evaluated 54 impact sizes from 38 separate research completed over the last two decades, including 6140 participants, and discovered that currently uses RME had a considerable significant effect on students' mathematical ability.

Some academics conceptually endorsed the influence of RME deployment on improving students' MRA in Indonesia. Mathematics starts with real-world problems, and formal mathematics is formed by mathematizing real-world problems (Gravemeijer & Terwel, 2000; Laurens et al., 2018; Nasution & Dur, 2017). Teaching mathematics must be closely related to reality and experience (Heuvel-panhuizen, 2003); the knowledge of teaching mathematics must be enjoyable and beneficial for students; thus, connections between reality and math must be made (Heuvel-panhuizen, 2003; Turgut, 2021; Fendrik, 2021).

The usage of models aimed at concrete models that progress to abstract models allows pupils to improve mathematical reasoning skills (Zaini & Marsigit, 2014). The average calculation of the twenty-five research examined reveals that the utilization of the RME approach significantly impacts students' mathematical reasoning ability. This is due to the combination of the RME approach's phases with measures of students' mathematical thinking (Fauziyah et al., 2016).

The RME technique can enhance intrinsic motivation, increase perseverance, and help students apply mathematical reasoning skills to the issues they confront (Anita Rahmatunisa, 2020; Ariati & Juandi, 2022a, 2022b; Tamur et al., 2020). The comparatively large effect size of RME implementation in improving the Indonesian students' MRA gives strong evidence that RME may be employed as effective learning in addressing students' poor MRA in studying mathematics. As a result, Indonesian mathematics instructors, particularly mathematics teachers, can use RME as among the most acceptable methods to enhance students' MRA.

4. The Analysis of the Study Characteristics

The study's variable features was the element responsible for the heterogeneous MRA of Indonesian students due to RME adoption. As a result, it was critical to investigate these aspects. The following shows the calculation results from the study characteristics analysis, as shown in Table 6.

Table 6. The Results of the Study Characteristics Analysis

Study Characteristic	Group	Studies Number	Hedges'g	Null Hypothesis Test		Heterogeneity		
				Z-Value	P-Value	Qb	Df (Q)	P-Value
Educational Level	ES	2	1.957	2.657	0.008	2.359	2	0.307
	JHS	20	0.956	5.808	0.000			
	SHS	3	1.180	7.368	0.000			
Class Capacity	≤ 32	12	0.949	4.701	0.000	0.547	1	0.460
	> 32	13	1.169	5.357	0.000			
Technological assistance	Yes	3	0.983	6.300	0.000	0.170	1	0.680
	No	22	1.078	6.406	0.000			

Note: ES (Elementary School), JHS (Junior High School), SHS (Senior High School)

This meta-analysis examined three study characteristics: education level, class capacity, and technology assistance. Table 6 reveals that the p-value of Q statistics was more than 0.05 for all research characteristics. This suggests that the features of education level, class capacity, and technical assistance have no significant influence on the diverse effect size of RME implementation in improving the MRA of Indonesian students. This conclusion is comparable to that of (S. Turgut, 2021), who discovered that RME-based instruction did not demonstrate a significant difference in class capacity. Another meta-analysis investigation indicated a substantial difference between the two groups (Juandi et al., 2022; Turgut, 2021). The amount of primary studies included in the meta-analysis process was what distinguished this study from the previous one (Nugraha & Suparman, 2021).

This meta-analysis study classified education levels into three categories based on their characteristics: elementary, junior high, and senior high schools. The p-value of the three education level groups' Z statistics was less than 0.05. It reveals that RME application greatly improves the MRA of elementary, junior high, and senior high school students. Descriptively, primary school had a more significant impact size than others. Adopting the Realistic Mathematics Education method in elementary school is extremely helpful in enhancing mathematical thinking ability. This is consistent with earlier research that shows the Realistic Mathematics Education method is particularly effective in improving students' mathematical reasoning ability at the primary school level (Shoffa, 2022).

This meta-analysis study was divided into two groups depending on class capacity: less than or equal to 32 participants and more than 32 participants. Table 8 shows that the Z statistics p-value for the two class capacity groups was less than 0.05 for the null hypothesis test. It is interpreted that the use of RME considerably improves the MRA of Indonesian students, regardless of whether the class capacity is less than or equal to 32 participants or greater than 32 participants.

Furthermore, the effect of RME implementation on Indonesian students' MRA with a class capacity of less than or equal to 32 participants is smaller than the effect of performance on Indonesian students' MRA with a class capacity greater than 32 participants. This finding is reinforced by G. İ. Turgut (2022), who found that RME implementation with a class capacity of less than or equal to 32 students has a lower effect than RME implementation with a class capacity greater than 31 students. As a result, this meta-analysis study advises Indonesian mathematics instructors that using RME to improve students' MRA might be used in courses with small class capacity.

This meta-analysis research separated it into two categories based on technology-assisted RME and technology-assisted RME. The p-value of Z statistics for two technology-assisted was less than 0.05 for each group. This suggests that using RME improves the MRA of Indonesian students significantly. Furthermore, this meta-analysis study discovered that technology-assisted RME greatly influenced students' mathematical thinking ability. As a result, these data demonstrate that using technology in mathematics instruction greatly benefits instructors in enhancing students' mathematical reasoning abilities.

D. CONCLUSION AND SUGGESTIONS

The method of summarizing, estimating, and evaluating twenty-five primary research utilizing a meta-analysis study reveals indicates the use of RME has a significant influence on enhancing the MRA of Indonesian students. As a consequence of this meta-analysis study, Indonesian mathematics teachers should consider RME as one of the best approaches to improve students' MRA while applying mathematics teaching. The features of educational level, class capacity, and technological assistance had no significant influence on the varied effect size of RME implementation in improving students' MRA. However, the descriptive assessment of the research features This meta-analysis research indicates to Indonesian mathematics teachers that using RME to improve students' MRA should be limited to classrooms with less than 32 pupils, in primary schools and technologically assisted.

This research recommends that researchers increase the amount of primary investigations they do, main research indexed by Scopus, and databases or literature search engines for future meta-analysis studies that primarily concentrate on the adoption of RME to improve students' MRA. Furthermore, future researchers should explore and assess study features as in treatment length, educational level, and year of study. As a result, these comments and ideas will result in more qualified future meta-analysis research.

REFERENCES

A Herwati. (2015). Efektifitas pendekatan realistik dalam meningkatkan kemampuan penalaran matematika di SMA Negeri 1 Tembilahan Inhil Riau. *Efektiftas Pendidikan*, *4*(1), 13.

Alvira, L. D. (2021). Perbedaan Pendekatan Konstruktivis Dan Pendekatan Matematika Realistik Terhadap Kemampuan Berpikir Logis Siswa Smp Muhammadiyah 01 Medan. *Duconomics Sci-Meet (Education & Economics Science Meet)*, *1*, 137–143. https://doi.org/10.37010/duconomics.v1.5430

Anita, F. D. (2020). Penerapan Pendekatan Realistic Mathematics Education (Rme) Melalui Perangkat Pembelajaran Terhadap Motivasi Belajar Matematika Siswa. *Jurnal PEKA (Pendidikan Matematika)*, *3*(2), 54–59. https://doi.org/10.37150/jp.v3i2.787

Apriani, D., Mujib, M., & Pratiwi, D. D. (2019). The Influence of Realistic Mathemathic Education Model on Mathematical Reasoning Ability Viewed from Student Learning Styles. *ZERO: Jurnal Sains, Matematika Dan Terapan*, *3*(1), 12. https://doi.org/10.30829/zero.v3i1.5885

Ardiniawan, D. Y., Subiyantoro, S., & Kurniawan, S. B. (2022). Peningkatan Kemampuan Penalaran Matematis Siswa Sekolah Dasar Melalui Pendekatan Realistic Mathematics Education (RME) Siswa SD Se-Kecamatan Pacitan. *Seminar Nasional Hasil Riset Dan Pengabdian*, *4*(April), 607–613.

Ariati, C., & Juandi, D. (2022a). Kemampuan Penalaran Matematis: Systematic Literature Review. *LEMMA: Letters of Mathematics Education*, *8*(2), 61–75. https://ejournal.upgrisba.ac.id/index.php/jurnal-lemma/article/view/5745

Ariati, C., & Juandi, D. (2022b). *Pengaruh Pendekatan Realistic Mathematics Education terhadap Penalaran Matematis: Systematic Literatur Review*. *5*(5), 1535–1550. https://doi.org/10.22460/jpmi.v5i5.1535-1550

Barnes, A. (2019). Perseverance in mathematical reasoning: the role of children’s conative focus in the productive interplay between cognition and affect. *Research in Mathematics Education*, *21*(3), 271–294. https://doi.org/10.1080/14794802.2019.1590229

Bernard, R. M., Borokhovski, E., Schmid, R. F., Tamim, R. M., & Abrami, P. C. (2014). A meta-analysis of blended learning and technology use in higher education: From the general to the applied. *Journal of Computing in Higher Education*, *26*(1), 87–122. https://doi.org/10.1007/s12528-013-9077-3

Borenstein. (2009). Introduction to Meta-Analysis. In *International Statistical Review* (Vol. 77, Issue 3). https://doi.org/10.1111/j.1751-5823.2009.00095_15.x

Bragg, L. A., Herbert, S., Loong, E. Y. K., Vale, C., & Widjaja, W. (2016). Primary teachers notice the impact of language on children’s mathematical reasoning. *Mathematics Education Research Journal*, *28*(4), 523–544. https://doi.org/10.1007/s13394-016-0178-y

Cheung, M. W. . (2015). *Meta-Analysis: A Structural Equation Modeling Approach*. John Wiley & Sons, Ltd.

Cooper, H. (2017). *Research Synthesis and Meta-Analysis A Step-by-Step Approach*.

Dani, S., Pujiastuti, H., & Sudiana, R. (2017). Pendekatan Realistic Mathematics Education Untuk Meningkatkan Kemampuan Generalisasi Matematis Siswa. *Jurnal Penelitian Dan Pembelajaran Matematika*, *10*(2), 182–193. https://doi.org/10.30870/jppm.v10i2.2043

Fajriani, A. N., Dahlan, J. A., & Usdiyana, D. (2020). Penerapan Pendekatan Pendidikan Matematika Realistik Indonesia untuk Pencapaian Kemampuan Penalaran Induktif Matematis Siswa. *Journal on Mathematics Education*, *1*(1), 20–27.

Fajriani, A. N., Dahlan, J. A., Usdiyana, D., Matematika, D. P., & Indonesia, U. P. (2020). Indonesia Untuk Pencapaian Kemampuan Penalaran Induktif. *Journal on Mathematics Education*, *1*(1), 20–27.

Fatmawati, F., & Hasanah, K. A. (2018). Pengaruh Pendekatan Pendidikan Matematika Realistik terhadap Kemampuan Penalaran Spasial pada Materi Volume dan Luas Permukaan. *Jurnal Penelitian Pendidikan Matematika*, *2*(2), 102–111.

Fauzan, S., Rika, D. A. N., & Mustika, M. (2018). Upaya Meningkatkan Kemampuan Penalaran Matematis Dengan Pendekatan Realistic Mathematic Education Pada Siswa Kelas VII SMPN 1 Karawang Barat. *Prosiding Seminar Nasional Matematika Dan Pendidikan Matematika*, 383–394. https://journal.unsika.ac.id/index.php/sesiomadika/article/view/2117

Fauziyah, F., Zulkardi, Z., & Putri, R. I. I. (2016). Desain Pembelajaran Materi Belah Ketupat Menggunakan Kain Jumputan Palembang untuk Siswa Kelas VII. *Kreano, Jurnal Matematika Kreatif-Inovatif*, *7*(1), 31–40. https://doi.org/10.15294/kreano.v7i1.4829

Febrian, H. (1386). *Pendekatan Matematika Realistik terhadap Penalaran Matematis pada Materi Perbandingan SMP*. 1–10.

Febrian, H., Hartoyo, A., & Suratman, D. (2016). Pendekatan Matematika Realistik terhadap Penalaran Matematis pada Materi Perbandingan SMP. *Khatulistiwa: Jurnal Pendidikan Dan Pembelajaran*, *5*(7), 1–10.

Fendrik, M. (2021). Pengaruh Pendekatan Realistic Mathematics Education Terhadap Kemampuan Penalaran Matematis Siswa SD Ditinjau Dari Kemampuan Siswa Dan Level Sekolah. *Numeracy*, *8*(2), 102–112. https://doi.org/10.46244/numeracy.v8i2.1611

Fuadi, R., Johar, R., & Munzir, S. (2016). Peningkatkan Kemampuan Pemahaman dan Penalaran Matematis melalui Pendekatan Kontekstual. *Jurnal Didaktik Matematika*, *3*(1), 47–54.

Furuya-Kanamori, L., & Doi, S. A. R. (2020). *Meta-analysis: Methods for Health and Experimental Studies (p.293)*. Springer Nature Singapore Pte LTD.

Gravemeijer, K., & Terwel, J. (2000). Hans Freudenthal: A mathematician on didactics and curriculum theory. *Journal of Curriculum Studies*, *32*(6), 777–796. https://doi.org/10.1080/00220270050167170

Haidich, A. B. (2010). Meta-Analysis in Medical Research. *Hippokratia*, *14*((Supp 1)), 29–37. https://pubmed.ncbi.nlm.nih.gov/21487488/

Hartriani, N., & Veronica, R. . (2015). Keefektifan Model Pembelajaran Two Stay Two Stray Berbasis Realistic Mathematics Education Terhadap Kemampuan Penalaran Matematik. *Unnes Journal of Mathematics Education.*, *4*(1), 69–76.

Harwell, M. (2020). Growth in the amount of literature reviewed in a meta-analysis and reviewer resources. *Mid-Western Educational Researcher*, *32*(1), 31–47.

Heuvel-panhuizen, M. Van Den. (2003). The Didactical Use of Models in Realistic Mathematics Education: An Example from a Longitudinal Trajectory on Percentage. *Educational Studies in Mathematics*, *54*(1), 9–35. http://www.ncbi.nlm.nih.gov/pubmed/2499633

Hunter, J. E., & Schmidt, F. L. (2004). *Methods of Meta-Analysis*. SAGE Publications Inc.

Juandi, D., Kusumah, Y. S., & Tamur, M. (2022). A Meta-Analysis of the last two decades of realistic mathematics education approaches. *International Journal of Instruction*, *15*(1), 381–400. https://doi.org/10.29333/iji.2022.15122a

Juandi, D., & Tamur, M. (2020). *Pengantar Analisis Meta*. UPI PRESS.

Kilpatrick, J., Swafford, J., & Findell, B. (2001). *Adding it Up*. National Academy Press.

Kusumaningrum, D. S. (2016). Peningkatan kemampuan penalaran dan kemandirian belajar matematik melalui pendidikan matematika realistik indonesia (PMRI) [Improving reasoning ability and self-regulated in learning mathematics through Indonesian realistic mathematics education]. *Jurnal Buana Ilmu*, *1*(1), 10–20. https://journal.ubpkarawang.ac.id/index.php/BuanaIlmu/article/view/94

Laurens, T., Batlolona, F. A., Batlolona, J. R., & Leasa, M. (2018). How does realistic mathematics education (RME) improve students' mathematics cognitive achievement? *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(2), 569–578. https://doi.org/10.12973/ejmste/76959

Lestari, Prahmana, & Wiyanti. (2016). Peningkatan Kemampuan Penalaran Matematis Siswa Menggunakan Pendekatan Pendidikan Matematika Realistik. *Jurnal Inovasi Pendidikan Dasar*, *1*(2), 25–30. https://www.researchgate.net/profile/Rully_Prahmana/publication/304022469_PENINGKATAN_KEMAMPUAN_PENALARAN_MATEMATIS_SISWA_MENGGUNAKAN_PENDEKATAN_PENDIDIKA

N_MATEMATIKA_REALISTIK/links/5763a4e508ae192f513e458e.pdf

Lestari, W., & Jailani. (2018). Enhancing an Ability Mathematical Reasoning through Metacognitive Strategies. *Journal of Physics: Conference Series*, *1097*(1). https://doi.org/10.1088/1742-6596/1097/1/012117

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P. A., Clarke, M., Devereaux, P. J., Kleijnen, J., & Moher, D. (2009a). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *BMJ (Clinical Research Ed.)*, *339*. https://doi.org/10.1136/bmj.b2700

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P. A., Clarke, M., Devereaux, P. J., Kleijnen, J., & Moher, D. (2009b). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *BMJ (Clinical Research Ed.)*, *339*. https://doi.org/10.1136/bmj.b2700

Litte, J. H., Corcoran, J., & Pillai, V. (2008). *Systematic Review and Data Analysis*. Oxford University Press. https://doi.org/https//doi.org/10.1016/j.medine.2017.10.012

Mendrofa, R. N. (2021). Pengaruh Metode Pembelajaran Realistic Mathematics Education (RME) Terhadap Kemampuan Nalar Siswa Pada Kelas X SMK Negeri 1 Gunung Sitoli Alooa. *Warta Dharmawangsa*, *15*(1), 104–113. https://doi.org/10.46576/wdw.v15i1.1053

Merina, M., Imswatama, A., & Lukman, H. S. (2019). Penerapan Pendekatan Pendidikan Matematika Realistik terhadap Kemampuan Pemahaman Konsep dan Penalaran Matematis Siswa. *Jurnal Tadris Matematika*, *2*(1), 23–30. https://doi.org/10.21274/jtm.2019.2.1.23-30

Nasution, S. A., & Dur, S. (2017a). Pengaruh Pendekatan Matematika Realistik terhadap Kemampuan Penalaran Matematika Siswa di Kelas VII SMP Yayasan Pendidikan Islam Deli Tua TA. 2016/2017. *AXIOM : Jurnal Pendidikan Dan Matematika*, *13*(3), 1576–1580.

Nasution, S. A., & Dur, S. (2017b). Pengaruh Pendekatan Matematika Realistik terhadap Kemampuan Penalaran Matematika Siswa di Kelas VII SMP Yayasan Pendidikan Islam Deli Tua TA. 2016/2017. *AXIOM : Jurnal Pendidikan Dan Matematika*, *6*(2), 1–12. https://doi.org/10.1016/j.addr.2018.07.012%0Ahttp://www.capsulae.com/media/Microencapsulation - Capsulae.pdf%0Ahttps://doi.org/10.1016/j.jaerosci.2019.05.001

Navel Oktaviandy Mangelep, D. F. K. (2018). Penerapan Pembelajaran Matematika Realistik untuk Meningkatkan Kemampuan Adaptive Reasoning Siswa. *Jurnal Pendidikan Matematika*, *7*(3), 455–466. https://scholar.google.co.id/citations?view_op=view_citation&hl=id&user=_G_bSGAAAAAJ&citation_for_view=_G_bSGAAAAAJ:9yKSN-GCB0IC

NCTM. (2014). Six Principles for School Mathematics. *National Council of Teachers of Mathematics*, 1–6. http://www.nctm.org/uploadedFiles/Math_Standards/12752_exec_pssm.pdf

Nugraha, T., & Suparman, S. (2021). Heterogeneity of Indonesian primary school students' mathematical critical thinking skills through problem-based learning: A meta-analysis. *Al-Jabar : Jurnal Pendidikan Matematika*, *12*(2), 315–328. https://doi.org/10.24042/ajpm.v12i2.9645

Nuraida, I. (2018). Penerapan Pembelajaran Matematika Realistik untuk Meningkatkan Kemampuan Adaptive Reasoning Siswa. *Mosharafa Jurnal Pendidikan MatematikaJurnal Pendidikan Matematika*, *7*(1), 25–32.

Nurhafizah, & Fauzan, A. (2019). Pengaruh Penerapan Pendekatan Realistic Mathematics Education Terhadap Kemampuan Penalaran Matematis Peserta Didik Di Kelas XII IPA SMA Pertiwi 1 Padang. *Jurnal Edukasi Dan Penelitian Matematika*, *8*(4), 96–102.

Paloloang, M. F. B., Juandi, D., Tamur, M., Paloloang, B., & Adem, A. M. G. (2020). Meta Analisis : Pengaruh Problem-Based Learning Terhadap Kemampuan Literasi Matematis Siswa Di Indonesia Tujuh Tahun Terakhir Universitas Pendidikan Indonesia , Bandung , Indonesia Universitas Katolik Indonesia Santu Paulus Ruteng , Indonesia Universitas. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *9*(4), 851–864.

Pertiwi, C. M. (2019). Enhancing mathematical reasoning ability and self confidence students' through realistic mathematics education approach with geogebra. *National Conference on Mathematics Education*, *1*(1), 30–37.

Putri, F. M. (2013). Pengaruh Pembelajaran Matematika Realistik Terhadap Kemampuan Penalaran Matematis Siswa Smp. *Edumatica: Jurnal Pendidikan Matematika*, *3*(1), 19–26.

Raharjo, M. S., Azhar, E., & Faradillah, A. (2018). Pengaruh Model Pembelajaran Realistic Mathematics Education (Rme) Terhadap Kemampuan Penalaran Matematis Siswa. *Seminar Nasional Pendidikan Matematika 2018*, *01*, 19–29.

Septianawati, E., & Abdillah, E. (2020). Efektivitas Pendekatan Realistik Terhadap Kemampuan Penalaran Matematis Mahasiswa. *Sainsteknopak*, *2015*, 49–53. http://ejournal.unhasy.ac.id/index.php/SAINSTEKNOPAK/article/view/1360

Shelby, L. B., & Vaske, J. (2008). Understanding meta-analysis: A review of the methodological literature. *Leisure Sciences*, *30*(2), 96–110. https://doi.org/10.1080/01490400701881366

Shoffa, S. (2022). Meta Analisis Pendekatan Realistic Mathematic Education Terhadap Kemampuan Berpikir Kritis Siswa. *Vygotsky: Jurnal Pendidikan Matematika Dan Matematika*, *4*(2), 105–116. https://doi.org/https://doi.org/10.30736/voj.v4i2.571

Siallagan, F., Sinaga, B., & Rajagukguk, W. (2021). Analisis Kemampuan Penalaran dan Berpikir Kreatif Matematis Siswa dalam Pembelajaran Penemuan Terbimbing. *Paradikma Jurnal Pendidikan Matematika*, *14*(1), 68–74.

Siddaway, A. P., Wood, A. M., & Hedges, L. V. (2019). How to Do a Systematic Review: A Best Practice Guide for Conducting and Reporting Narrative Reviews, Meta-Analyses, and Meta-Syntheses. *Annual Review of Psychology*, *70*(July), 747–770. https://doi.org/10.1146/annurev-psych-010418-102803

Siddiq, F., & Scherer, R. (2019). Is there a gender gap? A meta-analysis of the gender differences in students' ICT literacy. *Educational Research Review*, *27*(June 2018), 205–217. https://doi.org/10.1016/j.edurev.2019.03.007

Tamur, M., Juandi, D., & Adem, A. M. G. (2020). Realistic Mathematics Education in Indonesia and Recommendations for Future Implementation: A Meta-Analysis Study. *JTAM | Jurnal Teori Dan Aplikasi Matematika*, *4*(1), 17. https://doi.org/10.31764/jtam.v4i1.1786

Thalheimer, W., & Cook, S. (2002). How to calculate effect sizes from published research. *Work-Learning Research*, *1*(August), 1–9.

Triyani, M. (2017). *Pengaruh Pendekatan Pendidikan Matematika Realistik Indonesia (PMRI) Terhadap Kemampuan Penalaran Matematis MTs Negeri 1 Model Palembang*. http://repository.radenfatah.ac.id/id/eprint/3221

Turgut, G. İ. (2022). Gerçekçi Matematik Eğitiminin Türk Öğrencilerin Matematik Tutumlarına Etkisi: Bir Meta-Analiz. *Bartın University Journal of Faculty of Education*, *11*(2), 446–460. https://doi.org/10.14686/buefad.987649

Turgut, S. (2021). A Meta-Analysis of the Effects of Realistic Mathematics Education-based Teaching on Mathematical Achievement of Students in Turkey. *Journal of Computer and Education Research*, *9*(17), 300–326. https://doi.org/10.18009/jcer.844906

Wajdih, M. F., Kusumayanti, A., Latuconsina, N. K., & Nursalam, N. (2020). Meta-Analisis Pembelajaran Realistic Mathematics Education (Rme) Terhadap Hasil Belajar Matematika. *Al Asma : Journal of Islamic Education*, *2*(2), 285. https://doi.org/10.24252/asma.v2i2.17340

Widana, I. W. (2021). Realistic Mathematics Education (RME) untuk Meningkatkan Kemampuan Pemecahan Masalah Matematis Siswa di Indonesia. *Jurnal Elemen*, *7*(2), 450–462. https://doi.org/10.29408/jel.v7i2.3744

Zaini, A., & Marsigit. (2014a). Perbandingan Keefektifan Pembelajaran Matematika dengan Pendekatan Matematika Realistik dan Konvensional Ditinjau dari Kemampuan Penalaran dan Komunikasi Matematik Siswa. *Riset Pendidikan Matematika*, *1*(2), 284–296.

Zaini, A., & Marsigit, M. (2014b). Perbandingan Keefektifan Pembelajaran Matematika Dengan Pendekatan Matematika Realistik Dan Konvensional Ditinjau Dari Kemampuan Penalaran Dan Komunikasi Matematik Siswa. *Jurnal Riset Pendidikan Matematika*, *1*(2), 152. https://doi.org/10.21831/jrpm.v1i2.2672

Zubaidah Amir, M. Z., Urrohmah, A., & Andriani, L. (2021). The effect of application of realistic mathematics education (RME) approach to mathematical reasoning ability based on mathematics self efficacy of junior high school students in Pekanbaru. *Journal of Physics: Conference Series*, *1776*(1). https://doi.org/10.1088/1742-6596/1776/1/012039