Article History
Received: 05.01.2022
Received in revised form: 29.09.2022
Accepted: 03.11.2022
Article Type: Research Article

International Journal of Contemporary Educational Research (IJCER)

www.ijcer.net

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To cite this article:

Öksüz, C., Eser, T. M. & Genç, G. (2022). The review of the effects of realistic mathematics education on students' academic achievement in Turkey: A meta-analysis study. *International Journal of Contemporary Educational Research, 9*(4), 662-667. https://doi.org/10.33200/ijcer.1053578

IJCER International Journal of Contemporary Educational Research
Volume 9, Number 4, December 2022, Page 662-677 ISSN: 2148-3868

The Review Of The Effects Of Realistic Mathematics Education On Students' Academic Achievement In Turkey: A Meta-Analysis Study

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Abstract

Realistic Mathematics Education (RME) includes identifying and solving problems. Besides, it is an effort to organize a case, reorganize it according to new ideas, and concretize and rediscover the case to understand it better. This research aims to determine the effect of RME-based teaching against traditional methods, develop a general opinion, and contribute to the literature. In the study, the meta-analysis method was used to synthesize the results of independent experimental studies examining RME's effect on academic achievement. The data set of the research was created in September 2022. Necessary searches were carried out within the ULAKBİM TR Index, YÖK Thesis, ERIC and Web of Science databases. As a result of these searches, 54 studies met the selection criteria to be included in the meta-analysis. The random-effects model was used in the research. As a result of the analysis, the calculated effect sizes were all positive. In the light of this finding, it has been concluded that in all studies, RME-based teaching was more effective than traditional methods on students' academic achievement in mathematics. A moderator analysis was also carried out to determine whether the effect sizes differed statistically significantly according to the variables "publication type, sample size, and educational stage." As a result of the moderator analysis, it was concluded that all moderator variables obtained from the GME-based teaching practices significantly affected the combined effect size.

Keywords: Realistic mathematics education, Meta-analysis, Publication type, Sample size, Level of education

Introduction

The understanding that knowledge has a precise and unchangeable structure and that being knowledgeable means storing and memorizing existing information in the mind has lost its importance today (Özkürkçüler, 2019). Individuals learn by discovering their own knowledge and questioning existing knowledge. Especially in the changing world, there are changes in individuals' education and understanding. According to the Ministry of National Education (MONE) (2018), this change describes individuals who produce knowledge, use it functionally in life, solve problems, and think critically. Suitable education and training programs should be created to raise the desired individuals.

Changes are made in mathematics teaching and curricula according to the changing and developing circumstances of our age. In the 2018 Mathematics Curriculum, the objective of "making sense of the relationships between people and objects and the objects among themselves by using the meaning and language of mathematics" was emphasized (MONE, 2018). According to Çilingir and Artut (2016), some researchers (De Lange, 1987; Gravemeijer, 1994; Treffers, 1987; Streefland, 1990; Van den Heuvel-Panhuizen, 2003) proposed a teaching theory for mathematics education that covered the changed terms and qualities. This theory, which includes identifying and solving a problem, is called Realistic Mathematics Education (RME). Besides, it is an effort to organize a case, reorganize it according to new ideas, and concretize and rediscover the case to understand it better (Freudenthal, 1968; Işık, 2019).

Mathematizing, which is the basic principle of RME, is a level up in mathematics, according to Freudenthal (Ödemiş, 2019). The word "mathematizing" refers to the desire to achieve a level with the help of mathematics taught in students' mathematics lessons (Ödemiş, 2019). In Gravemeijer (1999), contextual problems related to the subject to be covered are given to students at the beginning of the course, and students are focused on the whole subject. Students present their solutions to the problem based on their knowledge of the subject and associate these mathematical concepts with real-life problem cases (Van den Heuvel-Panheuizen 2003; Okuyucu, 2019).

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Treffers (1978, 1987) stated that mathematizing could occur in two ways: horizontally and vertically (Özkürkçüler, 2019). In horizontal mathematizing, students come with mathematical tools that help them understand and solve real-life problems. It includes exploring or defining authentic mathematics, schematizing, formulating, and envisioning a problem from different angles. Besides, converting a real-life problem into a mathematical problem is at the core of horizontal mathematizing. Vertical mathematizing, on the other hand, is a method of rearrangement in the mathematical system. Showing and proving a relationship in a formula, simplifying and organizing models, and using different models, completing and combining models, formulating and generalizing a mathematical model are examples of vertical mathematizing (Zulkardi, 2002; Kan, 2019).

Students use horizontal mathematizing when solving a problem, they have experience with and vertical mathematizing if they encounter an advanced problem. Students gain formal and informal mathematical models with horizontal mathematizing, and they reach vertical mathematizing through problem-solving and similar applications. The students who find the mathematical result interpret the solution they have reached and create a better method for another problem. In this way, students use mathematical knowledge (Demirdöğen, 2007; Gözkaya, 2015). Freudenthal's most convincing argument is that all students will not become mathematicians in the future, but mathematics will be a tool for the vast majority to solve daily life problems (Çakır, 2013). According to Freudenthal (1991), there is no definite line that can distinguish horizontal and vertical mathematizing concepts, that they can participate in all stages of mathematical activities, and that the student must make this decision for himself or herself (Yorulmaz, 2018; Özkürkçüler, 2019).

Regarding the mathematics curriculum in Turkey (2018), using real-life events in the mathematics teaching process is one of the main objectives of mathematics courses. Besides, the program emphasizes that students have to build their own knowledge using their experiences (Tabak, 2019). PISA is an international test based on real-life events. Mathematical literacy is one of the literacy areas covered in the PISA application. Turkey's low achievement in an exam based on real-life situations such as PISA points out how important it is to implement RME-based teaching to build and develop mathematical literacy.

Regarding the results of TIMSS 2015, another international exam, in a general framework, the knowledge, application, and reasoning scores of primary school 4th graders and secondary school 8th graders are below the TIMMS average (Tabak, 2019; Karip, 2017). When the literature is examined, it is observed that the first academic studies on a realistic mathematics education approach in Turkey have started to be carried out since the beginning of the 2000s. On the other hand, it is seen that there has been a great increase in the number of these studies in the last five years. In studies on realistic mathematics education, generally examine students' knowledge creation processes (Deniz, 2014; Dündar, 2019; Uça, 2014), collect student opinions (Okuyucu & Bilgin, 2019 and examine the effect of a realistic mathematics education approach on various variables (Çilingir, 2015; Doluzengin, 2019; Lestari and Surya, 2017; Trisnawati, Pratiwi and Waziana, 2018). However, Tabuk (2019), in his study examining the trends of research on a realistic mathematics education approach in our country, determined that a significant part of these studies focused on the effect of students' academic success and attitudes towards mathematics. Considering the studies conducted on the realistic mathematics education approach, it is noteworthy that the effect of this approach on academic achievement is generally significantly more effective than classical teaching methods. However, another issue that is as important as whether the realistic mathematics education approach is more effective than traditional approaches in mathematics teaching is how effective this approach is. At this point, the effect size value obtained by the meta-analysis method allows an easier evaluation. With the effect size value, an evaluation can be made as "low, medium, or large effective" (Gündüz & Kutluca, 2019).

Considering these facts in Turkey involving RME, this research aims to determine the effect of RME-based teaching against the traditional methods, develop a general opinion, and contribute to the literature. The approaches that provide research opportunities in a wider area are needed to effectively use the studies' results and reliably interpret the analyses. In Turkey, there are many experimental studies examining the impact of RME-based teaching on different groups of students, which reveals the need to conduct a meta-analysis on these studies. Besides, higher-level studies are necessary for being inclusive and reliable in interpreting the cumulative facts created by similar studies (Akgöz, Ercan, & Kan, 2004). Considering all these facts, it was decided to conduct a meta-analysis to be able to make a precise judgment about the effect of RME-based teaching on academic achievement in mathematics compared to traditional teaching methods and make much clearer predictions and generalizations for the future.

Glass (1976) was the first to name meta-analysis as "the analysis of analysis"; this definition is still used today. Meta-analysis is a type of analysis based on the studies' effectiveness, considering their similarities and different aspects (Eser, Yurtçu, & Aksu, 2020). Meta-analysis studies, which also mean combining and re-analyzing the results obtained from different studies, are based on the idea of "analysis of analysis," which is a method that can be used for this purpose (Kaplan et al., 2015).

This research's purpose was to determine the effect of RME-based teaching on students' academic achievement compared to traditional teaching. There are very few studies on RME, which has been mentioned frequently in modern mathematics education, in the related literature. The sample of the meta-analysis performed by Kaplan et al. (2015) was 12 national theses. No moderator analysis has been performed in the mentioned study. In his meta-analysis involving RMA, Tabak (2019) has covered 38 studies conducted in Turkey and used the content analysis method. Tamur, Juandi, and Adem (2020) have conducted a meta-analysis on a sample of 72 studies to examine the effect of RME-based teaching on students' achievement in Indonesia.

According to the purpose of the research, the problem statement of the research was set as follows: "When RME-based teaching is compared to traditional teaching, do the effect sizes of the studies involving the effect of the teaching methods on student academic achievement differ statistically in favor of RME-based teaching?"
The sub-problems of the research are as follows:

1. Does RME-based teaching have a different effect on students' academic achievement compared to traditional teaching?
2. Regarding the studies comparing RME-based teaching with traditional teaching, is there a statistically significant difference between the effect sizes according to publication type?
3. Is there a statistically significant difference between the studies' effect sizes according to the study's sample size ($n < 30$, $n \geq 30$)?
4. Is there a statistically significant difference between the studies' effect sizes according to the educational stage (primary school, middle school, high school) at which RME-based teaching is applied?

Method

This part includes the topics related to the research model, the data collection process, the inclusion criteria, the data coding, and the data analysis.

Research Model

In the study, the meta-analysis method was used to synthesize the results of independent experimental studies examining RME's effect on academic achievement. Meta-analysis is considered the analysis of the analyses performed by reviewing the studies that are independent of each other in order to obtain information on a relevant subject, combining the results obtained after this review process, and interpreting the findings related to the results (Cohen, 1988; Lipsey & Wilson, 2001).

Data Collection

The data set for the research was created in September 2022. Necessary searches were carried out within the ULAKBİM TR Index, YÖK Thesis, ERIC and Web of Science databases using the keywords "mathematics, realistic mathematics, Realistic Mathematics Education," "matematik," "gerçekçi matematik," gerçekçi matematik eğitimi" to find the studies that constitute the research sample. As a result of these searches, 54 study theses (38 master's, 6 doctoral, and 10 articles) involving the effects of RME on Turkish students' academic achievement in mathematics have been reached. Papers compiled from theses were not included in the research.
The presentations and reports of systematic review and meta-analysis studies should be accurate. Accordingly, in the international literature, it is recommended to use the flow chart suggested by the PRISMA statement in systematic reviews and meta-analysis studies (The PRISMA Group, 2009). The flowchart showing the data collection process through literature search is given in Figure 1.

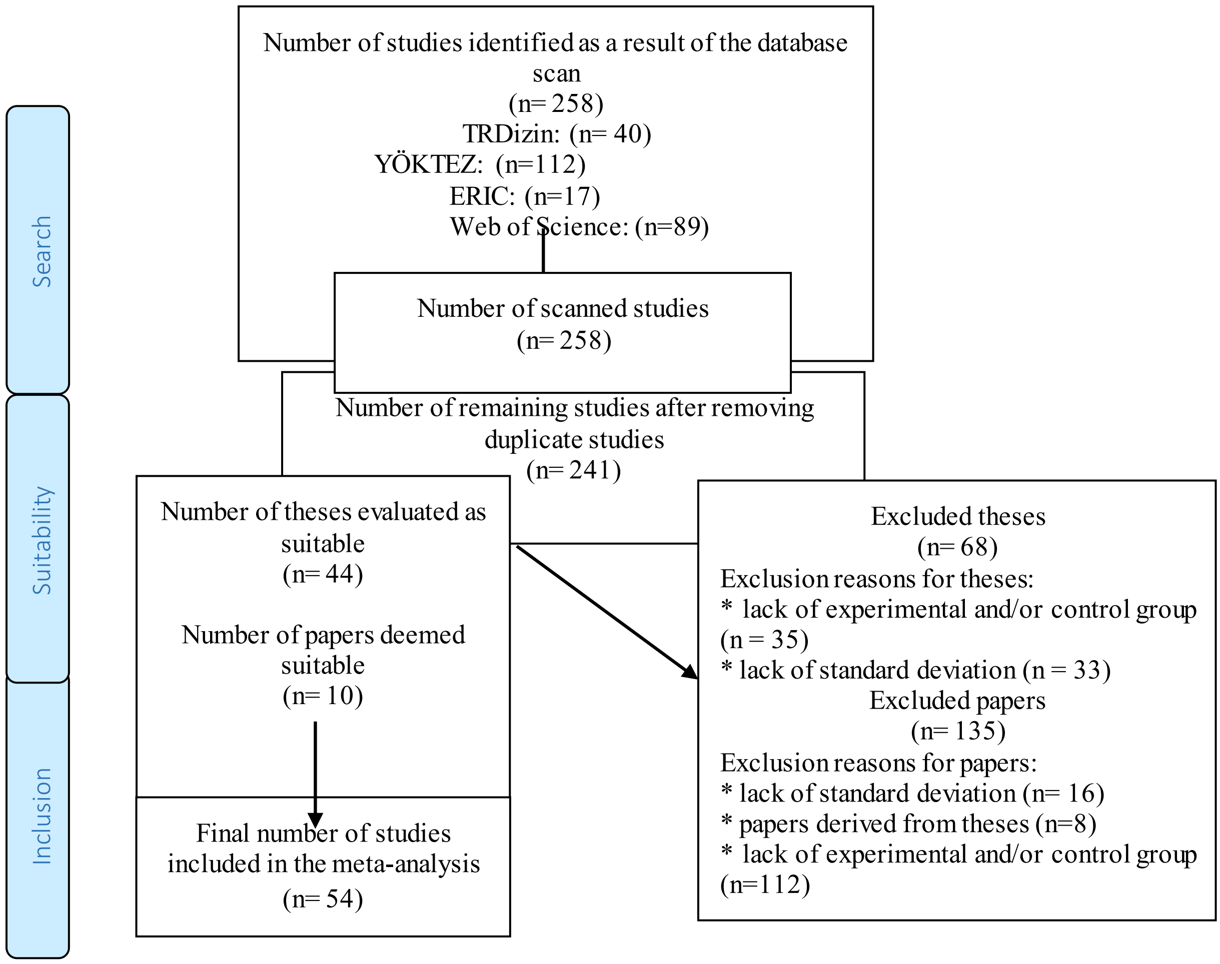

Figure 1. Data collection flowchart

Inclusion Criteria

The following criteria were considered while determining the studies to be included in the research:

1. Studies should have been published between 2000-2022.
2. Studies should be either a master's thesis, a doctoral thesis, or articles published in peer-reviewed scientific journals.
3. Studies should have been performed using an experimental design.
4. Studies should have been carried out with pre-school, elementary, middle, high school, and university students studying in Turkey.
5. In the studies, RME-based teaching should have been applied to the experimental group and traditional teaching approaches to the control group.
6. The mean, standard deviation, and number of participants in both groups of the study should be given for both the experimental and control groups.

Data Coding

Before this meta-analysis-based study is carried out, a coding form was created to address the studies involving RME from a general perspective and identify the studies to include in the meta-analysis. The following information is entered in the coding form:

1. Name of the study; author(s) of the study
2. Publication type (1 = master’s thesis, 2 = doctoral thesis, 3 = article)

3. Sample size, arithmetic mean, and standard deviation of the experimental and control groups included in the study
4. The experimental group's sample size is less than 30, equal to, or greater than 30 (0 = n <30, 1 = ≥30)
5. The educational level of the student population on which the study was conducted (0 = primary school, 1 = middle school, 2 = high school)

To ensure the content validity of the coding form, four experts with a doctorate in educational sciences were given detailed information about the research process steps, and expert opinions were obtained for this purpose. The studies to be included in the meta-analysis process should be coded by at least two coders to ensure coding reliability (Cooper, 2016). Thus, the coding of the research was carried out by three experts (with a doctorate in mathematics education) to ensure the research's reliability. These three experts then came together, and the necessary consensus was achieved on the codings that did not overlap with each other. In this way, errors caused by the data entry process were minimized. The reliability of the coding was calculated using the formula "Reliability = Consensus/(Consensus + Disagreement) x 100" (Miles & Huberman, 1994) and was found to be 85%. In terms of coding reliability, values obtained by this formula of 70% or higher are considered sufficient (Yıldırım & Şimşek, 2011). In light of this information, the coding is reliable in terms of the coding reliability (85%) obtained for the research. It was concluded that the measurement results made on the coding form were valid and reliable when considered holistically.

Data Analysis

Fixed and random effect models are used in meta-analysis to calculate the effect sizes. It is necessary to be very careful in deciding the model to be used in the meta-analysis. In the research, the independent experimental studies examining the effect of RME on academic achievement, which had been reached by a literature scan, have formed the research sample. In determining the research's sampling frame, a universe was specified, and the actual effect size of each study in this universe has been assumed to be different. Specifying a universe, assuming that each study's actual effect size in the universe is different, and the generalizability of the analysis results to the universe and all cases included in the sampling frame are the indicators for choosing the random-effects model. All these issues were considered, and the random-effects model was used in the research (Borenstein et al., 2009; Borenstein, 2019).

Jamovi and R programs were used in the analysis of the research. Jamovi is free software built on the R programming language that performs statistical analysis using popular R packages (Eser, Yurtçu & Aksu, 2020). Both programs made use of the metaphor package (Viechtbauer, 2010). The effect sizes of the studies included in the meta-analysis should met the normal distribution assumption (Rosenberg, Adams, & Gurevitch, 2000). First of all, it was checked whether the studies' effect sizes included in the meta-analysis meet the normal distribution assumption. The normal distribution chart obtained from the studies' effect sizes was analyzed, and it was concluded that the normal distribution assumption was met.

Regarding the variance estimation, the Hartung-Knapp-Sidik-Jonkman (HKSJ) method, which is known to perform significantly better than the DerSimonian-Laird method, which is frequently used in the literature, was preferred (Viechtbauer, 2005; Sidik and Jonkman, 2007; IntHout, Ioannidis, and Borm, 2014). Considering that different achievement tests were used in the studies included in the meta-analysis, the *standardized mean difference* was used as the model's effect size measurement. Regarding heterogeneity, Tau^2, Q, I^2, and confidence interval values were used to obtain prediction information even though they do not give information about the amount of heterogeneity (Borenstein, 2019). Fail-Safe N was used to assess the study's strength and reliability, and the outputs obtained from p-curve and p-uniform analysis were taken into account for publication bias.

Considering the different subgroups of the studies that constitute the meta-analysis sample, moderator analyses were conducted to compare the calculated effect size values The publication type, the experimental group's sample size being less than or equal to 30, and the educational stage were used as moderators. The confidence level was taken as 95% in all calculations related to effect size. The Hedge's g was taken as the difference between the means in units of the pooled standard deviation. While interpreting the importance of the calculated effect sizes, the following criteria were used (Cohen, Manion, & Morrison, 2011):

0 ≤ Effect size ≤ 0.20 (Weak Effect),
0.21 ≤ Effect size ≤ 0.50 (Low Effect),
0.51 ≤ Effect size ≤ 1.00 (Moderate Effect)
1.00> Effect size (Strong Effect)

Results

In this part of the research, the average effect sizes of the studies included in the meta-analysis were calculated, and the first sub-problem, "How does RME-based teaching affect students' academic achievement compared to traditional teaching?" was addressed.

Findings Regarding the Effect of RME-Based Instruction on Academic Achievement

Regarding the recent studies on publication bias, it was mostly due to significance levels and p-hacking. Therefore, it is recommended to interpret the outputs of p-curve, and p-uniform analyses in the process of collecting evidence for publication bias (Simonsohn, Nelson, & Simmons, 2014a; Harrer et al., 2019). Before calculating the average effect size, evidence of publication bias was sought in the studies included in the meta-analysis. For this purpose, first, p-uniform analysis outputs were interpreted, followed by p-curve analysis outputs. Table 1 contains p-uniform publication bias statistics. The p-value for the p-uniform publication bias test in Table 1 is greater than 0.05. This does not mean that the null hypothesis is true; it indicates that there is not enough evidence to reject the null hypothesis. As a result, the p-value obtained from the p-uniform analysis means that there is not enough evidence for the existence of publication bias (p = 0.088>.0.05).

Table 1. P-uniform publication bias test statistics

Test statistics	p-value
1.354	0.088

The p-uniform analysis gave the effect size and the confidence intervals. Table 2 contains the effect size statistics resulting from the p-uniform analysis.

Table 2. Effect size statistics regarding the p-uniform analysis

Effect size	Confidence Interval Lower Limit	Confidence Interval Upper Limit	Z	p-value	Number of Statistically Significant Studies
0.682	0.498	0.854	-5.315	.	46

Regarding the effect size and confidence intervals of the p-uniform analysis outputs in Table 2, the effect size (0.682) is in the range of 0.51-1.00, indicating a moderate effect. As a result, the effect size of the p-uniform analysis was determined to be moderate.

After the p-uniform analysis, the outputs of the p-curve analysis were interpreted. Figure 2 shows the p-curve publication bias analysis result. The observed p-curve includes 46 studies at a p<0.05 significance level, and 33 of these 46 studies are at a p<0.025 significance level. Since the p-value of the remaining nine studies is greater than 0.05, these studies were not evaluated within the scope of the p-curve. The blue line represents the observed p-curve, and the power estimate for the observed p-curve is 84% at a confidence interval of 74- 90%.

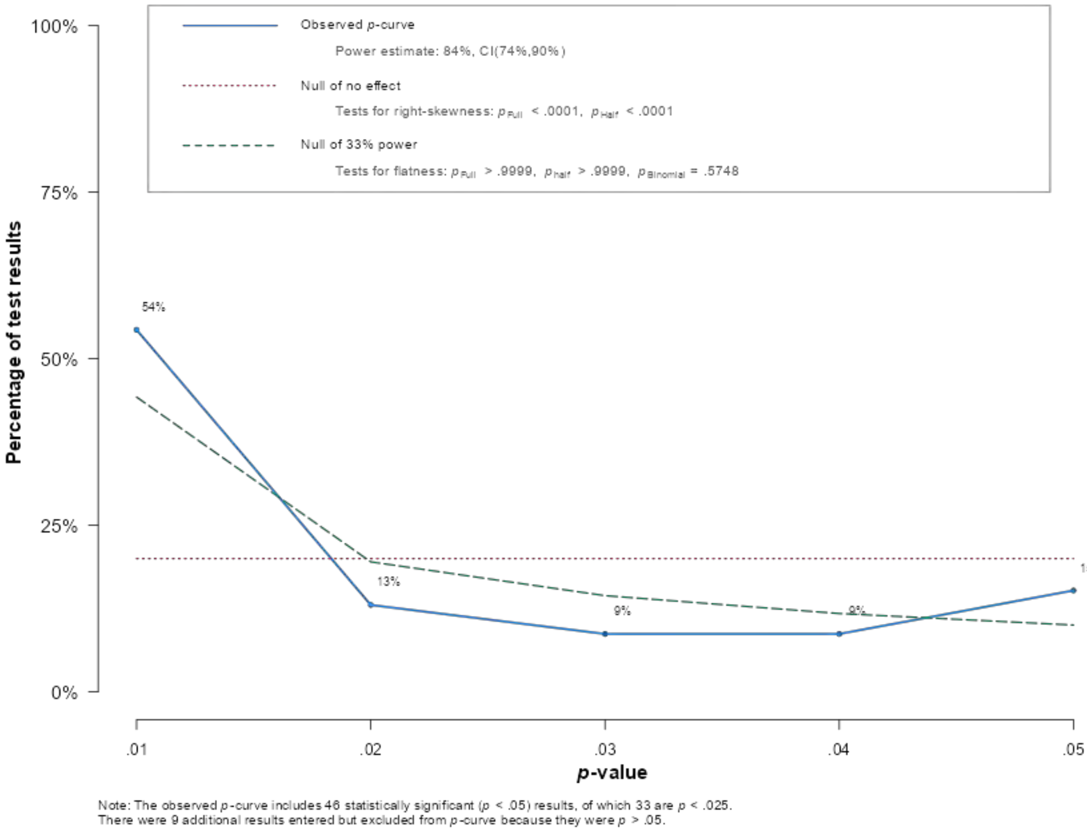

Figure 2. P-Curve

Mullen, Muellerleile, and Bryant (2001) stated that the results of meta-analysis studies have resistance against future studies, but only when the value calculated from the N/(5k+10) formula is greater than 1. This value was calculated for the experimental group (n=1530), the control group (n=1520), and the whole sample (n=3050) using the relevant formula. All of them were found to be greater than 1, which can be interpreted as very low publication bias. As a result of the holistic evaluation of the relevant values and the outputs of p-uniform and p-curve analyses, it is concluded that there is no evidence for publication bias.

Fail-Safe N, which is another way of defining the p-value obtained from the meta-analysis, was also examined. If the p-value of Fail-Safe N is lower than alpha ($p < 0.05$), the analysis is considered powerful and highly reliable. *Fail-Safe N* does not give information about the presence or absence of publication bias in any case (Borenstein, 2019). The p-value for Fail-Safe N was found to be less than alpha (0.05) (FSN = 10.221, $p < .05$), therefore it can be said that the research is powerful and highly reliable.

Following the evidence search for publication bias for the studies included in the sample, the average effect size under the preferred random effects model should be calculated considering the sampling frame. Table 2 shows the average effect size and the lower and upper values of the confidence interval.

Regarding Table 3, the average effect size was 0.905 with a standard error of 0.0891. The confidence interval's lower and upper limits are 0.726 and 1.084, respectively (95% confidence interval). Regarding the point estimation value of 1.90 and the confidence interval's lower and upper limits according to the effect size range suggested by Cohen et al. (2011), it can be said that RME-based teaching has a moderate effect on increasing academic achievement in mathematics courses. The point estimation value of the average effect size is positive, indicating that the result is in favor of the experimental group.

Table 3. Output of the random effects model

Model	Effect size	Standard Error	Z	p	Confidence Interval Lower Limit	Confidence Interval Upper Limit
Random Effects	0.905	0.0891	10.2	< .001	0.726	1.084

Another output of the meta-analysis is the forest plot, which is shown in Figure 3. Regarding the effect sizes of the studies included in the research, the smallest effect size is 0.14 (Uskun, Çil, & Kuzu, 2021), and the highest one is 4.25 (Kavuran, 2019). The holistic review of the studies' statistical results related to the effect size shows that all 54 studies that form the sample have positive effects. In Figure 3, the studies are located on the right side of the no-effect line, represented by the dashed line passing through zero. All studies show a benefit to the experimental group that received RME-based instruction.

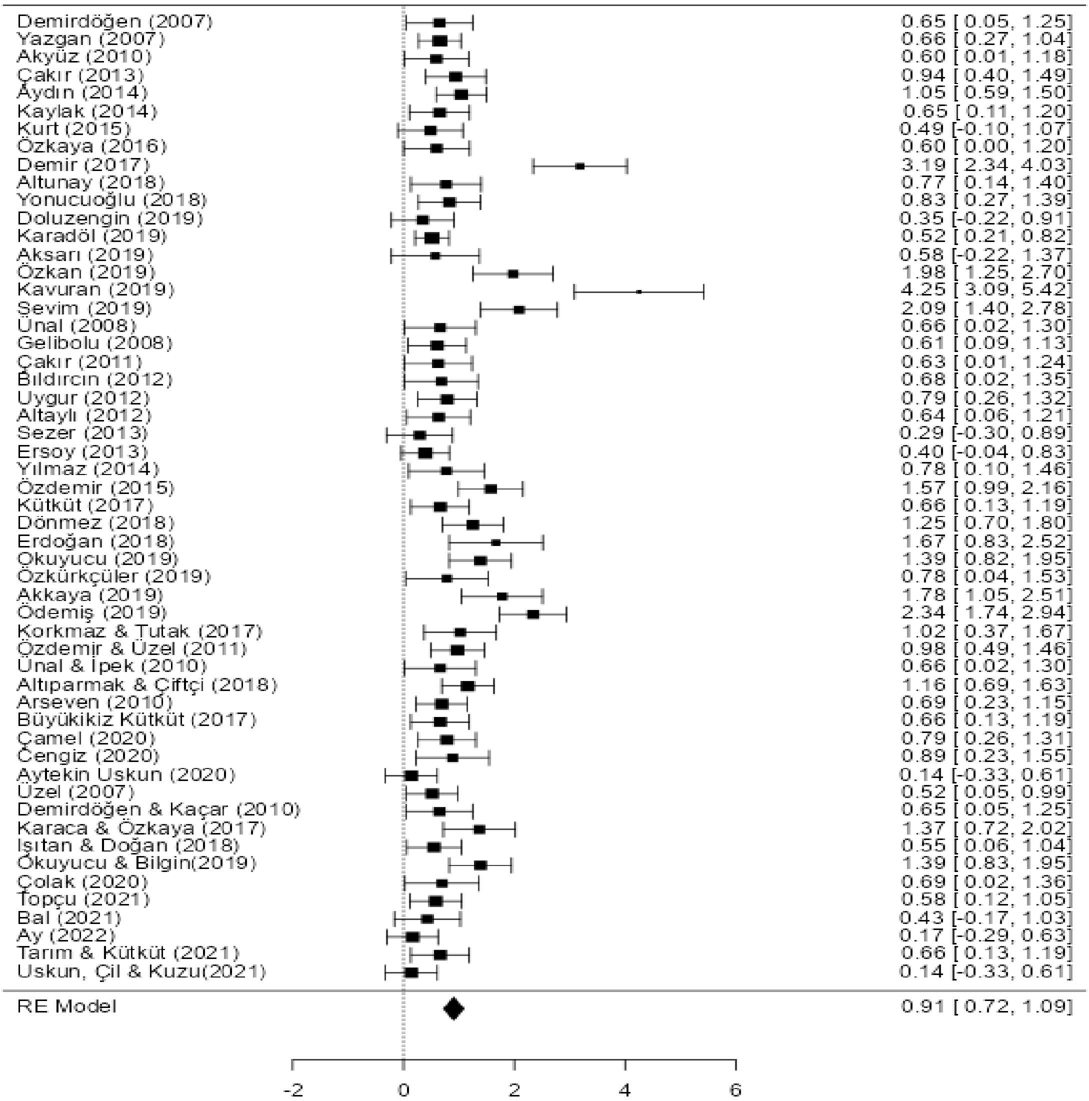

Figure 3. Forest Plot

After the forest plot, the heterogeneity statistics in Table 4. have been examined. The Q test result of Cochran is statistically significant (Q ~ (df = 53) ~ = 194.846, p = <.001). That is, the change in effect size is larger than the expected sampling error. According to this result, it can be said that the actual effect size varies according to the studies. The I^2 statistic, another statistic that provides information on heterogeneity, shows the rate of change in the observed effect size attributed to sampling error. In table 3, I^2= %83.09. It should be kept in mind that the I^2

statistic is a ratio, not an absolute measure of heterogeneity. It is recommended not to use the draft percentage ranges (Higgins & Green, 2011) in the literature when interpreting the I^2 value (Borenstein, 2019). I^2 provides information on the degree of inconsistency of the studies' findings within the meta-analysis. It reflects the extent to which confidence intervals obtained from different studies overlap (Borenstein et al., 2009). The I^2 value obtained from the meta-analysis is relatively high, which means that the studies' effect sizes have significantly changed. Besides Q and I^2 statistics, the lower and upper confidence limits of the effect sizes (0.726 and 1.084, respectively) provides information on how widely (based on the standard deviation) the effect sizes vary between populations. Considering the statistically significant result of the Q statistic, the relatively high I^2 value, and the estimation range's relative width, it can be said that there is heterogeneity that needs further analysis. Moderator analysis was used to explain the heterogeneity.

Table 4. Heterogeneity Statistics

I^2	sd	Q	p
83.09%	53	194.846	<0.001

Findings Regarding the Differentiation of Effect Sizes According to Publication Type

Table 6 displays the output of the moderator analysis carried out to address the second sub-problem of the research: "Regarding the studies comparing RME-based teaching with traditional teaching, is there a statistically significant difference between the effect sizes according to publication type?"

When Table 6 was examined, it was concluded that the effect sizes of the studies differed statistically significantly according to the type of study (Q=177.767, p<0.05). Accordingly, it can be said that whether the study type is a master's thesis, a doctoral thesis, or an article, it causes a change in the effect size. When the effect sizes in Table 6 are examined, it can be said that the publication (being master's thesis, doctoral thesis, or article) causes a difference in the effect size in favor of RME in terms of academic achievement. When the effect sizes of the categories in Table 6 are examined, it is striking that the publication type that causes the most variation in the effect size in favor of RME is a master's thesis.

Table 6. Moderator Analysis Results for the Publication Type

	Category	N	Effect size	Confidence Interval	df	Q_B	p
Publication Type	Master's Thesis	38	0.522	[0.149,0.896]	2	177.767*	<0.05
	Doctoral Thesis	6	0.371	[-0.034;0.776]			
	Article	10	0.392	[-0.074,0.820]			

Findings Regarding the Differentiation of Effect Sizes According to Sample Size

Table 7 displays the output of the moderator analysis carried out to address the third sub-problem of the research: "Is there a statistically significant difference between the studies' effect sizes according to the study's sample size (n <30, n≥30)?"

When Table 7 was examined, it was concluded that the effect sizes of the studies differed statistically significantly according to the sample size (n<30, n≥30) (Q=194.087, p<0.05). In other words, it can be said that the sample size being n<30 or n≥30 causes a difference in effect size in favor of RME in terms of academic achievement. When the effect sizes of the categories in Table 7 are examined, it is striking that the sample size of less than 30 causes more variation in the effect size in favor of RME than being n≥30.

Table 7. Moderator analysis results for the sample size

	Category	N	Effect size	Confidence Interval	df	Q_B	p
Sample size	n<30	19	0.610	[0.3428,0.8777]	1	194.087*	<0.05
	n≥30	35	0.255	[0.3154;0.8254]			

Findings Regarding the Differentiation of Effect Sizes According to the Level of Education

Table 8 displays the output of the moderator analysis carried out to address the fourth sub-problem of the research: "Is there a statistically significant difference between the studies' effect sizes according to the educational stage (primary school, middle school, high school) at which RME-based teaching is applied?"

When Table 8 was examined, it was concluded that the effect sizes of the studies differed statistically significantly according to the level of education ($n<30$, $n\geq30$) ($Q=157.563$, $p<0.05$). In other words, it can be said that the sample size being $n<30$ or $n\geq30$ causes a difference in effect size in favor of RME in terms of level of education. When the effect sizes of the categories in Table 8 are examined, it is striking that the middle school level causes more variation in the effect size in favor of RME than the primary school level and high school level.

Table 8. Moderator analysis results for the level of education

	Category	N	Effect size	Confidence Interval	df	Q_B	p
	Primary School	8	0.338	[0.3428,0.8777]			
Sample size	Middle School	35	0.610	[-0.3154;0.8254]	2	157.563*	<0.05
	High School	11	0.379	[0.3775,0.8254]			

Discussion and Conclusion

In this study, examining the effect of RMA-based teaching on the students' mathematics achievement in Turkey, 54 effect sizes were calculated for the meta-analysis sample. The calculated effect sizes were all positive. In the light of this finding, it has been concluded that in all studies, RME-based teaching was more effective than traditional methods in raising students' academic achievement in mathematics. These effect sizes varied between 0.14 and 4.25, and based on the random-effects model, the average effect size of 54 studies was 0.90, and the lower and upper limits of the confidence interval were 0.72-1.08. Regarding the holistic review of the effect sizes and the average effect size, it has been concluded that the studies have a moderate effect according to the classification of Cohen et al. (2011). Based on the findings of the effect size, it has been concluded that RME-based teaching has a moderate effect on students' academic achievement in mathematics compared to traditional methods.

In the meta-analysis study by Tamur, Juandi, and Adem (2020) in which they combined 95 effect sizes from 72 studies on realistic mathematics education in Indonesia, the combined effect size was calculated to be larger (1.104) than the combined effect size of this study. It is thought that the reason for the difference in the combined effect sizes obtained as a result of this research and the research of Tamur, Juandi, and Adem (2020) is due to the difference in internal and external criteria. Özdemir (2020), on the other hand, brought together the effect sizes obtained from 23 studies on realistic mathematics teaching and calculated the combined effect size as 1.048. Özdemir (2020) did not include articles published in scientific journals in the scope of his meta-analysis study, instead calculating effect sizes from postgraduate theses. This situation is thought to be the reason why the combined effect size obtained within the scope of this research is different from the study of Özdemir (2020). In another study, Kaplan et al. (2015) combined 12 effect sizes in their study in which they examined the effect of realistic mathematics education-supported instruction on mathematics achievement, and the overall effect size was calculated as 0.607. The combined effect sizes obtained by Kaplan et al. (2015) and the combined effect sizes obtained within the scope of this study show a "moderate level of effect. In the light of all these explanations, it can be concluded that the realistic mathematics education approach in mathematics teaching is effective in increasing the academic success of students.

When the literature is examined, it is striking that Eade and Dickinson (2006) concluded that mathematics teaching with realistic mathematics education acts in favor of students' mathematical development. Wubbels, Korthagen, and Broekman (1997) stated that teaching based on realistic mathematics education is a very effective method for students to achieve success.

In this study, based on the finding that teaching based on realistic mathematics education moderately affects mathematics achievement, teaching toward realistic mathematics education in the learning process should be encouraged, and guidance should be given to enable students to define and make sense of the problem situations they encounter in accordance with daily life, and to feel responsible for the solution of the problem.

A moderator analysis was also carried out to determine whether the effect sizes differed statistically significantly according to the variables "publication type, sample size, and level of education." As a result of Analog ANOVA and meta-regression performed within the scope of moderator analysis, it was concluded that all variables considered moderator variables within the scope of the study had an effect on the combined effect size.

As a result of the moderator analyses carried out within the scope of the study, it was concluded that the type of publication had a statistically significant effect on the effect size in favor of the master's theses. As a result of the meta-analysis study, in which Özdemir (2020) examined the effect of realistic mathematics education on mathematics achievement, he found the effect size to be medium for master's theses and high for doctoral theses. The fact that the samples of the studies within the scope of the research carried out by Özdemir (2020) are only those of Turkey can be considered the reason for the difference between the findings of the two studies. The absence of any other finding with which this result can be compared reveals the necessity of conducting more meta-analysis studies on the same subject within the scope of the relevant variable.

As a result of the meta-analysis study conducted by Tamur, Juandi, and Adem (2020), they concluded that "the combined effect size of the small sample group (30 or less) is significantly different from the combined effect size of the large sample group (31 or more). At the same time, this result overlaps with similar studies in the literature, including the sample size as a moderator variable in the meta-analysis (Turgut & Temur, 2017; Tumankeng, Yusmin, & Hartoyo, 2018). According to these studies, the effect of a small study group on a small sample is stronger than the effect of a large sample, and the relevant results obtained by the researchers are in line with the results of this study.

As a result of the moderator analyses carried out, it was concluded that the education level of the individuals forming the sample played a role in the change in the combined effect size. Turgut (2022) investigated the effect of realistic Mathematics Education on the mathematics attitudes of students studying in Turkey through meta-analysis and concluded that the education level did not cause a statistically significant difference between the groups. Turgut (2022) irestricted the meta-analysis to studies involving a Turkey sample. It is thought that this situation plays a role in the difference in the results of the relevant research. Chen, Shih, & Law (2020) and Juandi, Tamur & Kusumah (2022) concluded that the effect size of the samples formed by individuals with low education level is relatively higher than the groups with higher education level. Considering that students are confronted with problem situations that they can imagine within the framework of RME, it can be thought that this conclusion is possible (Van den Heuvel-Panhuizen & Drijvers, 2014). Students studying at higher levels, such as high school and university, may no longer need such a framework. More studies are needed to support this result.

Recommendations

In this study, based on the finding that teaching based on realistic mathematics education moderately affects mathematics achievement, teaching toward realistic mathematics education in the learning process should be encouraged, and guidance should be given to enable students to define and make sense of the problem situations they encounter in accordance with daily life, and to feel responsible for the solution of the problem.

Based on the findings of this study, which show that RME-based teaching has a significant impact on students' mathematics achievement, it is recommended that RME-based teaching be implemented in learning processes at all levels of education. Besides, support should be provided to ensure that students correctly define the problem situations they face in the learning process and that they will be responsible for the solutions they find.

RME-based teaching is a type of teaching that fits the constructivist education philosophy. The results of this study also support this view. In this context, it may be suggested to adopt RME-based teaching at all levels of education.

Considering the findings obtained as a result of the moderator's analysis, it can be suggested that education practitioners consider the variables of publication year, sample size, and education level.

Reporting the statistics required to calculate the effect size in all experimental and quasi-experimental studies examining the effects of RME-based teaching on students' mathematics achievement will allow future studies on similar subjects to be more valid and reliable.

In addition to this, it is recommended for meta-analysis studies to examine the effect of RME-based teaching on different variables such as students' anxiety, attitude, and motivation, in addition to their mathematics achievement.

Author (s) Contribution Rate

All authors contributed equally to the article.

Conflicts of Interest

There is no conflict of interest.

Ethical Approval

This metaanalysis study not need ethical approval in terms of the subject.

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