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Research Article

A Meta-Analysis of the Effects of Realistic Mathematics Education-based Teaching on Mathematical Achievement of Students in Turkey

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Abstract

The aim of the current study is to determine the effect of realistic mathematics education-based teaching on students' mathematics achievement. For this purpose, a meta-analysis method, which allows combining the results of a series of studies on a subject, was used in the study. A total of 40 scientific publications, 27 thesis and 13 articles, which are suitable for the research problem, were included in the sample of the study. The publications conducted on mathematics achievement in 2020 and earlier in Turkey were used in the study. Process effectiveness method of meta-analysis was employed in the analysis of data and Hedges's g was used in the calculation of effect size of the study. In determination of the publication bias of the studies included in the meta-analysis, the funnel plot and Rosenthal's Fail-Safe N-FSN statistics were examined together. In order to determine whether the distribution of the effect sizes is homogenous or not, the results of Q statistic were investigated. As a result, the effect sizes are homogeneously distributed. Therefore, fixed effect model was used. As stated in the fixed effects model, the overall effect size value is 0.760 with a 0.041 level of standard error. As a result of the study, the effect of teaching activities based on realistic mathematics education on mathematical achievement is at a positive medium level.

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Introduction

Considering the fact that mathematics is a part of many areas including daily and academic lives, and careers of individuals, it can be stated that those who are good at mathematics will be successful at life and get opportunities in life (National Council of Teachers of Mathematics [NCTM], 2000; Organization for Economic Co-operation and Development [OECD], 2013). Nevertheless, it is well known that many individuals show the attitude that mathematics is not their cup of tea (Di Martino & Zan, 2011). One of the reasons why individuals have such an attitude may be related to how they learn mathematics. NCTM state that all students need to attain mathematical knowledge, and necessary support and opportunities must be provided for this aim (NCTM, 2000). Consequently, understanding mathematics is closely related to having a teaching process with good quality. It can also be stated that one of the requirements of the teaching process with good quality is to make use of different approaches. Using methods and techniques which are based on different approaches have a positive effect on the learning process of students (Piht & Eisenschmidt, 2008; Soric & Palekcic, 2009). It can be stated that this situation is one of the points to be taken into consideration in the teaching process.

Realistic Mathematics Education

One of the approaches that shape mathematics teaching is realistic mathematics education (RME). RME is a mathematics teaching theory which was created by Dutch mathematician Hans Freudenthal and developed further by Freudenthal Institute (Treffers, 1993). RME emerged as an innovative approach against traditional mathematics teaching (De Corte, 2000). Traditional mathematics teaching can be defined as a teaching process in which mathematics is presented as a ready-made standard system and taught through mechanical means (Van den Heuvel-Panhuizen, 2001). As for Freudenthal (1973), mathematics can be defined as human activity. Freudenthal (1973) asserted that mathematics is not a subject or knowledge to be conveyed. Mathematics starts with real-life problems and formal mathematics is reached through mathematization of the real-life problems (Gravemeijer & Terwel, 2000). The term real expresses real-life situations from an experimental point of view. Problems do need not include only real-life situations; they need to be in a format which the students may experience through actions (Gravemeijer & Doorman, 1999).

Teaching of mathematics needs to be closely related to reality and students' experiences (Van den Heuvel-Panhuizen, 2001). RME advocates that students should be given opportunities that let them rediscover mathematics. The experience of teaching mathematics needs to become fun and beneficial for the students; therefore, a connection must be made between the real world and mathematics (Van den Heuvel-Panhuizen, 2001; 2003). When children realize how mathematics can be used in real life, they will learn better. The informal knowledge that the children possess may be effective in developing their formal knowledge (Treffers, 1991). Students rediscover mathematics while solving real-life problems. Therefore, the teachers relate mathematics teaching with the existing knowledge of the students. Mathematics teaching should be organized as a rediscovering process in a manner that resembles the experience of the process of how mathematicians discovered mathematics (Freudenthal, 1991).

Mathematization

Mathematics is an activity of looking for and solving problems and organizing the solution of a problem. This activity may be a real problem that needs to be organized and solved in accordance with mathematical patterns (Freudenthal, 1971). This organizational activity is called mathematization (Gravemeijer, 1994; Treffers, 1991). Mathematization is a key process in mathematics teaching since dealing with mathematics teaches students to deal with daily life situations with a mathematical approach. When the students deal with mathematical knowledge with a mathematical perspective, they will have a true understanding of concepts and the implementation of these concepts. According to RME, the students need to reach mathematical knowledge by discovering through experiences (Gravemeijer & Doorman, 1999).

Treffers (1987) takes on the mathematization in two processes, namely, horizontal process and vertical process. The students use mathematical tools in organizing problems regarding real-life situations in the horizontal mathematization process (Gravemeijer & Doorman, 1999; Van den Heuvel-Panhuizen, 2003; Van den Heuvel-Panhuizen & Drijvers, 2014). The horizontal mathematization process enables students to reach mathematical symbols through their real-life situations (Freudenthal, 1991). Expressing a real-life problem in a mathematical manner is a product of the horizontal mathematization process. On the other hand, the vertical mathematization process is formulizing mathematics in various ways through mathematical rules and reorganizing the mathematical system (Van den Heuvel-Panhuizen, 2003; Van den Heuvel-Panhuizen & Drijvers, 2014). Transforming a real-life problem into a mathematical problem is a product of the vertical mathematization process. Since abstract mathematical symbols are used in this process, it will occur more often in a classroom environment (Gravemeijer & Terwel, 2000). In the vertical mathematization process, the students can make mathematical formulizations of relationships, make explanations with various examples, and reach conclusions.

Freudenthal (1991) stated that horizontal mathematization is going from realistic to symbolic situations, and vertical mathematization is moving through symbolic situations; however, no strict distinction between the two. The most significant way to describe the distinction between horizontal and vertical mathematics is to give examples at various levels (Freudenthal, 1991). Transferring a realistic problem to a mathematical problem, exploring patterns and relationships, schematizing, formulizing in various methods, and visualization activities are examples of horizontal mathematization. Representing relationships with formulas, developing models, integrating various methods, and generalization activities are among the examples for vertical mathematization (De Lange, 1987). Therefore, vertical and horizontal mathematization processes are closely related to each other. There is no superior process between the two; only, emphasizing real-life situations may put the vertical mathematizing process in the background (Van den Heuvel-Panhuizen & Drijvers, 2014). Based on these facts, vertical and horizontal mathematizing processes need to be considered hand-in-hand within the process of mathematics teaching.

Principles of Realistic Mathematics Education

RME has a dynamic structure; yet, it has fundamental principles. These principles, which were stated firstly by Treffers (1978) and has gone through reformations in time, and explained by Van den Heuvel-Panhuizen and Drijvers (2014) are as follows:

Activity principle: The students are active participants in the learning process. Mathematics is best learned by dealing with practice.

Reality principle: Mathematics teaching should begin with meaningful problem situations. Students develop mathematical understanding and tools which they produced while solving real-life problems. Teaching does not start with abstract and definitions, it starts with a contextual problem which requires mathematical organizations.

Level principle: Students go through various levels of comprehension while learning mathematics. In this process, models are important in filling in the blanks between informal and formal mathematics.

Intertwinement principle: Learning mathematics is a social activity. The students can share their strategies and discoveries through in-class discussions and group activities. Thus, they may acquire ideas that enable them to develop strategies and reach a higher level of comprehension.

Guidance principle: The teachers have a proactive role in the learning process of the students.

Teachers need to consider the aforementioned principles while preparing teaching activities based on RME. In RME, mathematical knowledge must be constructed or reconstructed by the student. Under no circumstance, mathematical knowledge is readily available and transferred in a top-down manner. Even in a perfect lesson, the mathematical knowledge offered to students can only become meaningful through actively reconstructing the knowledge by every student. Students must re-discover mathematics by starting from fundamental experiences under the appropriate guidance (Freudenthal, 1971). Teaching must start with meaningful real-life problems rather than rules and abstract concepts. The role of teaching must not be directly conveying mathematical knowledge; but, guiding the students and expose their theoretical knowledge (Gravemeijer & Doorman, 1999; Van den Heuvel-Panhuizen, 2001, 2003).

The Present Study

When the literature is reviewed, a great deal of research can be found on the effect of activities conducted based on RME on mathematics teaching and learning on an international level (Fauzan, 2002; Gravemeijer & Doorman, 1999; Le, 2006; Sembiring, Hadi, & Dolk, 2008) as well as in Turkey (Demir, 2017; Korkmaz, 2017; Taş, 2018; Yorulmaz, 2018). In these studies which were conducted independently from each other, the teaching activities implemented based on RME, the effect of different variables such as sample size, level of education, treatment duration, and field of study were examined. These studies also have various limitations and due to this reason, conclusions of these studies may differ or show similarities to each other. Bringing together the research findings and creating a synthesis will lead the way to draw a conclusion and making generalizations of the results. Within this context, meta-analysis studies show great significance. Meta-analysis allows a coherent process of gathering and interpreting the results of individual studies conducted independently from each other (Cohen, Manion, & Morrison, 2007). When the literature is examined, it can be seen that a study by Kaplan, Duran, Doruk, and Öztürk (2015) brings together 12 dissertations that examine the effectiveness of teaching based on RME in Turkey. In their study, the overall effect size regarding the individual studies conducted between 2007-2014 was calculated. Another study by Özdemir (2020), brings together 23 studies that examine the effectiveness of teaching based on RME in Turkey. In the mentioned study the overall effect size regarding the individual studies conducted between 2007-2019 was calculated. In a meta-analysis study conducted by Çelik (2013) examining the effect of alternative learning methods, the overall effect size of 4 dissertations which examined teaching based on RME 2007-2011 was calculated.

Considering years that these studies were published and the number of studies they took in the analysis, it can be stated that there is a need for a meta-analysis study which takes into consideration more recent studies and summarized the current situation on the matter. In this respect, this study aims to determine the effects of RME-based teaching on mathematical achievement of the students through meta-analysis. The studies in which the effects of RME-based teaching are measured by standardized achievement tests (knowledge and abilities towards the learning outcomes of mathematics are tested in writing and measured on a standard score) were focused in the study. Moreover, different from the studies of Çelik (2013), Kaplan et al. (2015) and Özdemir (2020), the present study is to investigate if there is a significant difference in the effect sizes of studies included in the meta-analysis in terms of field of study, level of education, size of sampling, and treatment duration regarding RME-based teaching.

In line with this aim, the following research questions were sought to be answered:

1. What is the overall effect of mathematics lessons based on RME on students' mathematics achievement?
2. Does the effect size of mathematics lessons taught based on RME on students' mathematics achievement differ according to the field of study?
3. Does the effect size of mathematics lessons taught based on RME on students' mathematics achievement differ according to the level of education?
4. Does the effect size of mathematics lessons taught based on RME on students' mathematics achievement differ according to the sample size?

5. Does the effect size of mathematics lessons taught based on RME on students' mathematics achievement differ according to the treatment duration?

Method

Research Design

Meta-analysis method was implemented in this study. A meta-analysis provides a general assessment through the analysis of quantitative results obtained from individual studies on a specific topic (Glass, 1976; Lipsey & Wilson, 2001). Through a meta-analysis, the current state of the related subject can be discovered. Effect size is used in the assessment of the findings of the meta-analysis study (Mertens, 2010). The value of the effect size reflects the relationship between two variables (Borenstein, Hedges, Higgins, & Rothstein, 2009; Ellis, 2010). In other words, it represents the size of the relationship between variables. The effect size is a common metric for studies that are included in effect size meta-analysis and it provides the opportunity of interpreting the statistically analyzed studies through the same measurement. There are certain steps to be followed in a meta-analysis study. Firstly, the problem is identified; and then the literature related to the literature is reviewed. The studies obtained as a result of the study are coded in specified criteria. Finally, the statistical analyses of the studies are conducted, and a conclusion is drawn (Pigott, 2012; Sánchez-Meca & Marín-Martínez, 2010). This study made use of the aforementioned steps.

Data Collection

The data of this study were collected within October 2020. The data source is constituted by studies that examined the effect of RME-based teaching on students' mathematical achievement in Turkey. In order to reach the studies, "realistic mathematics education, RME" keywords were searched on indexes such as Web of Science, Education Resources Information Center (ERIC), EBSCOhost, Scopus, Council of Higher Education Thesis Center, TR Index, and Google Scholar. A total of 96 master's thesis, doctoral dissertations and articles were reached as a result of the scanning. It was seen that some of the articles were reproduced from dissertations; instead of thesis, these articles were included in the meta-analysis, and the rest of the studies were picked in accordance with the following criteria:

1. The studies must be conducted in Turkey.

2. The studies must be conducted in 2020 or earlier.
3. The studies must have an experimental research design (experimental and control group design with pre-test and post-test).
4. There must not be a statistically significant difference between the achievement scores of experimental and control groups as determined by the results of pre-test (groups must be homogeneous in terms of achievement).
5. Experimental groups must be taught based on RME and the control groups must be taught based on the mathematics program determined by the national curriculum for the specific year.
6. Publication language must beTurkish or English.
7. The studies must be open to access in indexes such as Web of Science, ERIC, EBSCOhost, Scopus, Cohe Thesis Center, TR Index, and Google Scholar.
8. The studies must include reliability and validity statements regarding the data collection tools (achievement tests).
9. The studies must include statistical values (pre-test and post-test achievement scores for experimental and control groups, sampling size, standard deviation values, *p*-values etc.) in order to calculate the effect size.

In line with the specified criteria, 40 studies were included in the meta-analysis. Two of these studies used two different achievement tests and one study included one experimental and two control groups. For these reasons, the effect sizes in these studies were calculated and presented in forest table with labels a and b next to the year of the studies. As a result, 43 effect sizes were calculated regarding 40 studies.

Data Coding

A feature to be encoded in meta-analysis studies may have a structure that will affect the effect sizes of the research (Ellis, 2010). For this reason, a coding has been made that can transform the data in these studies into categorical variables by using the studies that meet the inclusion criteria of the research (Lipsey & Wilson, 2001). Thus, the characteristics of the study were determined. The coding form of the study has a structure that is general enough to include all studies related to the effect of Realistic Mathematics Education-based teaching on mathematics achievement, but enough to determine research differences. A coding form was prepared by the researcher by taking into consideration the specified criteria of inclusion. The information included in the forms are: title of the study, year, author, type, sample size (experimental-control), level of education, field of study of the implemented teaching activities, treatment duration, reliability and validity statements regarding the data collection tools (present-absent), and arithmetic mean and standard deviation of the measurements at the end of the teaching activity. The information which was to be included in the study was coded on the form by the researcher. Three weeks after the initial coding, the forms were recoded by the researcher using the same forms. The forms were compared after the two processes and no difference was observed between the two forms. Through this procedure, an error-free statistical analysis of the data gathered from the studies was targeted. In Table 1, the descriptive statistics regarding the studies included in the meta-analysis which investigated the effects of RME-based on mathematical achievement in Turkey are presented.

Table 1. The studies included in the meta-analysis which investigated the effects of RME-based teaching on students' mathematical achievement in Turkey

		Frequency	Percentage (%)
Type of Study	Research Article	13	32.5 %
	Master's Thesis	24	60 %
	Doctoral Dissertation	3	7.5 %
Year of the Study	2006-2010	5	12.5 %
	2011-2015	13	32.5 %
	2016-2020	22	55 %
Sample Size*	1-15 participants	2	5 %
	16-30 participants	24	60 %
	31-45 participants	11	27.5 %
	46-60 participants	2	5 %
	61-75 participants	-	-
	76-90 participants	1	2.5 %
Level of Education	Primary School	12	30 %
	Middle School	24	60 %
	High School	4	10 %
Field of Study**	Mathematics	32	80 %
	Geometry	8	20 %
Duration of the Treatment	1-5 hours	4	10 %
	6-10 hours	10	25 %
	11-15 hours	7	17.5 %
	16-20 hours	9	22.5 %
	21-25 hours	-	-
	26-30 hours	1	2.5 %
	31-35 hours	-	-
	36-40 hours	2	5 %
	Not specified in hours	7	17.5 %
Total		40	%100

*Only the experimental groups. **Mathematics field includes topics such as numbers and operations, fractions, sets, probability and algebraic expressions. The geometry field includes topics such as transformation geometry, polygons, geometric shapes, length, area and volume.

Table 1 reveals that 13 (32.5%) of the studies are articles, 24 (60%) of the studies are master's thesis, and 3 (7.5%) of the studies are doctoral dissertations. Before 2006, there was no experimental study on this subject. Most studies were conducted between 2016-2020 (22 studies, 55%). In terms of the sample size, most of the studies included between 16-30 participants (24 studies, 60%). In terms of the level of education, most of the studies included middle school (24 studies, 60%), least number of the studies included high school level (4 studies, 10%). There was not meet any study at undergraduate level. 32 (80) of the studies were related to mathematics, and 8 (20%) of the studies were related to geometry. While 6-10 hours of implementation (10 studies, 25%) and 16-20 hours of implementation (9 studies, 22.5%) were most prevalent, 7 (17.5%) of the studies did not specify the hour of implementation.

Data Analysis

While calculating the effect size of studies through meta-analysis, the fixed-effects model and random-effects model were used (Borenstein et al., 2009). In the fixed-effects model, the effect sizes of the studies to be included in the meta-analysis are assumed to be fixed; therefore, the effect sizes and standard deviations are taken as zero. In the random-effects model, the effect sizes of the studies to be included in the meta-analysis are assumed to differ in every study, and the effect sizes and standard deviations are assumed to be different from zero (Ellis, 2010). The distribution of the effect size determines which one of these two models are to be used in a meta-analysis study. For this purpose, meta-analysis studies make use of Q value. Q value in statistics is used with the purpose of testing the null hypothesis that the meta-analysis studies which were analyzed through chi-square distribution share a common effect size. If the Q value is smaller than the equivalent value from the table of chi-square (χ^2) in terms of the degree of freedom (df) and level of significance (*p*-value), the homogeneity is established (Borenstein et al., 2009). If the distribution is homogeneous, the fixed-effects model is used; and, if it is heterogeneous, the random-effects model is used (Ellis, 2010). However, studies with extremely small or large effects, in other words, individual studies that differ significantly from the overall effect, affect the Q statistic result (Harrer, Cuijpers, Furukawa, & Ebert, 2019). Therefore, outliers should be detected. Outliers have a dramatic inflationary effect on the variance. Correlations that are so far out of the distribution that they are clearly outliers so they could be thrown out (Hunter and Schmidt, 2004). In order to detect such outliers in the data set, all studies were examined according to the following conditions:

> For which the upper bound of the 95% confidence interval is lower than the lower bound of the pooled effect confidence interval (i.e., extremely small effects), and for which the lower bound of the 95% confidence interval is higher than the upper bound of the pooled effect confidence interval (i.e., extremely large effects) (Harrer et al., 2019, Searching for extreme effect sizes (outliers) section, para. 2).

As a result, individual studies with extremely small or large effects were excluded from the analysis process (9 studies were excluded).

While calculating the effect sizes, Hedges'g, which determines the intergroup pooled and standard means were used, and the confidence level was accepted as 95% in the calculations. In interpreting the effect size, "0-0.20 level was accepted as weak, 0.21-0.50 was accepted as small, 0.51-1.00 level was accepted as medium, and a level greater than 1 was accepted as large" (Cohen et al., 2007, p. 521).

In the determination of the publication bias of the studies included in the meta-analysis, the funnel plot and Rosenthal's Fail-Safe N-FSN statistics were examined together. If the effect sizes of the studies in the funnel plot were symmetrically distributed on the overall effect size, this indicates that there is no publication bias (Borenstein et al., 2009). The value obtains as a result of Rosenthal's fail-safe N indicates the number of studies to be included in order to zero out the calculated effect in the meta-analysis (Borenstein et al., 2009). The FSN value being large in proportion to the studies examined indicates that the results are resistant to publication bias (Rosenthal, 1991). Therefore, it can be stated that as FSN value rises, the reliability of the results increases (Ellis, 2010). This study also made use of N/(5k+10) (k referring to the number of studies included in the meta-analysis) formula which was suggested by Mullen, Muellerleile, and Bryant (2001) based on Rosenthal's fail-safe N. According to this formula, if the value to be obtained is greater than 1, the results are resistant enough against publication bias.

This study made use of Comprehensive Meta-Analysis (CMA) software in obtaining the effect sizes, moderator analyses, publication bias analyses, funnel plot, and forest plot. And MetaWin statistics program was used to examine the normal distribution of effect sizes. By making use of the interface that CMA offers, the format which enables values such as the sample size (*N*), mean ($\bar{X}$), standard deviation (*SD*), and *p* and *t* values were used. In this study, the field of study, education level, sample size, and treatment duration were determined as the moderators.

Findings

In order to determine whether it is convenient to combine the effect sizes of the studies with meta-analysis, the normal distribution chart was examined. Normal distribution chart is given in Figure 1.

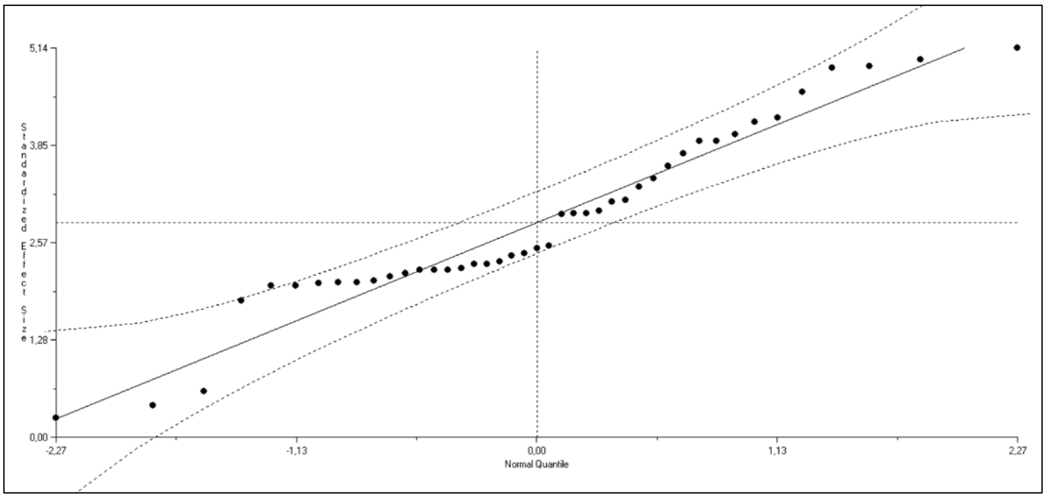

Figure 1. Normal distribution chart of effect sizes of studies included in meta-analysis.

When Figure 1 is examined, it is seen that the effect sizes of the studies are distributed around the normal distribution line and within the confidence interval shown with dashed lines. In this regard, it can be stated that the effect sizes show normal distribution and can be combined statistically with meta-analysis.

A funnel plot was examined in order to determine the publication bias of the studies. The funnel scatter plot is given in Figure 2.

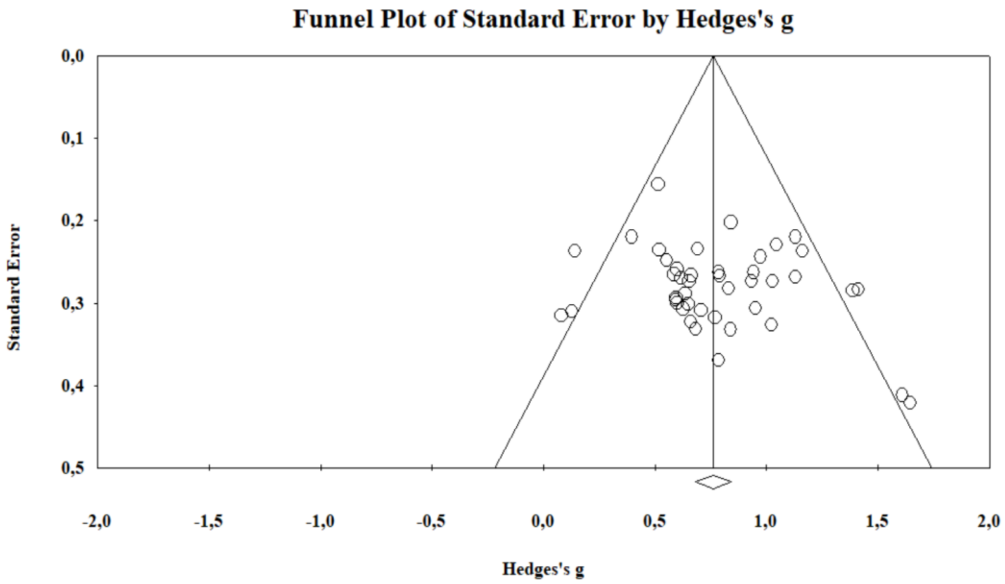

Figure 2. Funnel scatter plot regarding the publication bias of the studies included in the meta-analysis

Figure 2 reveals that the funnel plot is concentrated in the middle and scattered as symmetric around either side of the vertical line which demonstrates the effect size, except for a few studies. The fact that the effect sizes of the studies included in the study are very close to the combined effect size value in the center of gravity region, is an indication that there is no publication bias (Borenstein et al., 2009). In the funnel scatter plot, it is seen that the individual effect sizes of some studies are outside the funnel. This may be due to the excess of primary studies. Considering that more than one finding from the same study is used in a small number, it may not be said that this situation has a negative effect on publication bias. However, interpretation of a funnel scatter plot is subjective (Rothstein, Sutton, & Borenstein, 2005). Therefore, Rosenthal's N-FSN value was also examined in determining the publication bias. Statistics regarding this value are given in Table 2.

Table 2. Results of Rosental's FSN regarding the studies included in the meta-analysis

Bias Level	
Z value for the studies examined	18.58677
p-value for the studies examined	0.00000
Alpha	0.05
Direction	2
Z value for Alpha	1.95996
Number of the studies examined	43
FSN	3825

Table 2 indicates that the FSN value is 3825. From this result, it can be stated that a total of 3825 studies with zero effect size are needed so that the effect size calculated as a result of meta-analysis is not statistically significant. In other words, in order for the findings of this meta-analysis, which consists of 43 research data, to be deemed invalid, there should be at least 3825 studies that contradict the values of the findings in the literature. When considered in Turkey reached a total of 96 relevant studies on the same subject matter will be contrasting findings of the 3825 study is not easily visible. Moreover, In addition, since the value calculated according to the N / (5k + 10) formula (3825 [5 * 43 + 10] = 17) is greater than the critical value of 1, it shows that the studies included in the meta-analysis are sufficiently resistant to the publication bias of future studies (Mullen et al., 2001; Rosenthal, 1991).

On the other hand, in this study, both heterogeneity test was performed and graphics were used to determine whether the effect sizes were suitable for normal distribution. According to this, the results regarding the fixed effects model and random effects model of the studies included in the meta-analysis are presented in Table 3.

Table 3. Results of the studies in regard to effect models

Model	Overall Effect Size Value (ES)	95% Confidence Interval for Effect Size		Standard Error (SE)	Degree of Freedom (df)	Homogeneity Value (Q)	Chi-Square Table Value (χ^2)	*p*
		Lower Limit	Upper Limit					
Fixed	0.760	0.680	0.840	0.041	42	57.615	58.124	0.055
Random	0.768	0.672	0.863	0.049				

When Table 3 is examined it can be seen that the homogeneity value of the studies included in the meta-analysis is Q=57.615 according to fixed effects model. The critical value of the degree of freedom at the 95% significance level on the chi-square table is 58.124. It can be seen that the calculated Q value is smaller than the critical value in the chi-square. Moreover, the *p*-value is not significant (p=.055>.05). On this basis, it can be stated that the studies included in the meta-analysis are homogeneous; therefore, while calculating the effect size of the studies, the fixed effects model was used. With regard to the fixed effects model, the calculated overall effect size is 0.760 with a standard error of 0.041. The effect size being positive means that the process effect is in favor of the experimental group. The calculated effect value is medium, according to Cohen et al. (2007). Consequently, it can be stated that RME-based teaching has a positive moderate effect on students' mathematical achievement.

Forest plot demonstrating the distribution of the effect size of the studies included in the meta-analysis according to the fixed effects model is shown in Figure 3.

Meta Analysis

Study name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Relative weight
	Statistics for each study							
Aksari, 2019	0,599	0,259	0,067	0,092	1,107	2,316	0,021	2,50
Akyuz, 2010	0,596	0,293	0,086	0,020	1,171	2,030	0,042	1,94
Altayli, 2012	0,635	0,288	0,083	0,070	1,201	2,202	0,028	2,01
Altiparmak & Ciftci, 2018	1,160	0,237	0,056	0,696	1,625	4,901	0,000	2,98
Altunay, 2018	0,770	0,318	0,101	0,147	1,393	2,422	0,015	1,66
Arseven, 2010	0,691	0,234	0,055	0,232	1,150	2,952	0,003	3,05
Aydin Unal & Ipek, 2009	0,660	0,323	0,104	0,028	1,292	2,046	0,041	1,61
Aytekin Uskun, 2020	0,142	0,237	0,056	-0,322	0,606	0,599	0,549	2,99
Ayvali, 2013a	0,941	0,263	0,069	0,427	1,456	3,584	0,000	2,43
Ayvali, 2013b	1,132	0,269	0,072	0,605	1,658	4,214	0,000	2,32
Bildircin, 2012	0,683	0,331	0,110	0,033	1,333	2,061	0,039	1,52
Buyukikiz Kutkut, 2017	0,663	0,266	0,071	0,141	1,185	2,489	0,013	2,36
Cakir, 2011	0,627	0,307	0,094	0,025	1,229	2,042	0,041	1,78
Cakir, 2013	0,933	0,273	0,075	0,398	1,468	3,415	0,001	2,24
Camel, 2020	0,786	0,263	0,069	0,271	1,300	2,991	0,003	2,43
Can, 2012	0,080	0,315	0,099	-0,537	0,697	0,255	0,799	1,69
Cengiz, 2020	0,838	0,332	0,110	0,187	1,490	2,523	0,012	1,52
Cilingir & Dinc Artut, 2016a	0,842	0,202	0,041	0,445	1,238	4,159	0,000	4,09
Cilingir & Dinc Artut, 2016b	1,129	0,220	0,048	0,699	1,560	5,139	0,000	3,47
Cilingir Altiner & Dinc Artut, 2017	0,952	0,306	0,094	0,352	1,553	3,109	0,002	1,78
Demirdogen & Kacar, 2010	0,649	0,301	0,091	0,060	1,239	2,158	0,031	1,85
Donmez, 2018	1,412	0,283	0,080	0,857	1,967	4,983	0,000	2,09
Erdogan & Ayvaz Tuncel, 2018	1,646	0,421	0,177	0,821	2,471	3,911	0,000	0,94
Ersoy, 2013	0,395	0,220	0,048	-0,035	0,826	1,800	0,072	3,47
Gozkaya, 2015	0,586	0,265	0,070	0,066	1,106	2,208	0,027	2,38
Isýk, 2019	1,610	0,412	0,169	0,803	2,416	3,911	0,000	0,99
Isitan & Dogan, 2018	0,553	0,248	0,062	0,067	1,039	2,230	0,026	2,72
Karadol, 2019	0,515	0,156	0,024	0,209	0,821	3,300	0,001	6,86
Karatas, 2019	0,618	0,270	0,073	0,089	1,147	2,288	0,022	2,30
Kaylak, 2014	0,653	0,273	0,075	0,118	1,188	2,392	0,017	2,24
Korkmaz & Korkmaz, 2017	0,129	0,310	0,096	-0,479	0,737	0,415	0,678	1,74
Korkmaz & Tutak, 2017	1,023	0,327	0,107	0,383	1,664	3,134	0,002	1,57
Kurt, 2015	0,594	0,296	0,088	0,013	1,175	2,003	0,045	1,91
Nama Aydin, 2014	1,046	0,230	0,053	0,596	1,496	4,557	0,000	3,18
Okuyucu & Bilgin, 2019	1,388	0,285	0,081	0,830	1,946	4,878	0,000	2,07
Ozcelik & Tutak, 2017	0,707	0,309	0,095	0,102	1,313	2,289	0,022	1,75
Ozdemir & Uzel, 2011	0,975	0,244	0,059	0,498	1,453	4,001	0,000	2,82
Ozkaya & Yetim Karaca, 2017	0,600	0,300	0,090	0,013	1,188	2,003	0,045	1,86
Ozkurkculer, 2019	0,785	0,369	0,136	0,061	1,509	2,124	0,034	1,23
Uygur, 2012a	0,790	0,267	0,071	0,266	1,313	2,957	0,003	2,35
Uygur, 2012b	1,027	0,274	0,075	0,490	1,563	3,749	0,000	2,23
Uzel, 2007	0,519	0,236	0,055	0,057	0,980	2,202	0,028	3,02
Yonucuoglu, 2018	0,830	0,282	0,080	0,277	1,384	2,940	0,003	2,10
	0,760	0,041	0,002	0,680	0,840	18,578	0,000	

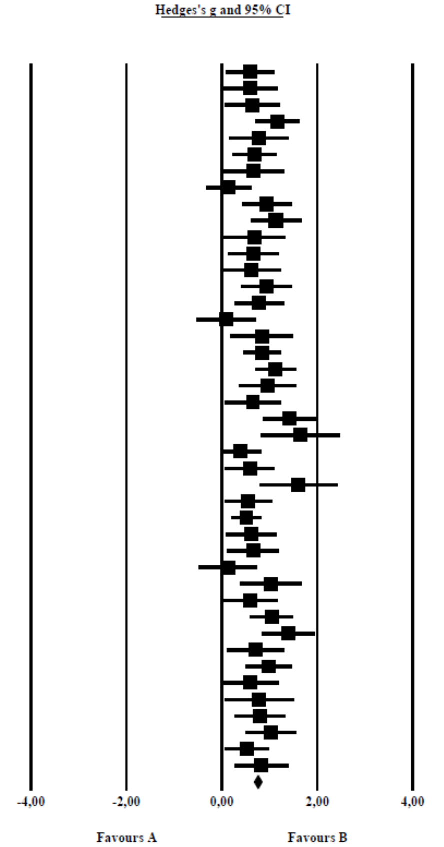

Figure 3. Forest plot regarding the effect size of the studies included in the meta-analysis according to fixed effects model

Each black dot in Figure 3 represents an effect size of a study. The lines on either side of the squares indicate the lower and upper limits in a 95% confidence interval of the calculated effect sizes. The area of the squares represents the magnitude of related study in the effect size. Moreover, some statistical values are given in the rightest column of the figure. The rhombus at the bottom represents the calculated overall effect size. When the forest plot showing the effect direction of the studies is examined, it can be said that the majority of the studies included in the study are far from the ineffectiveness line and are distributed in a balanced way between medium-wide effect level. When the effect size values of the studies are examined, it is determined that the highest effect size value was 1.646 and the smallest effect size value was 0.129. The reason why the square sizes representing the effect sizes of the studies included in the study are close to each other is that the sample numbers of the experimental-control group students in the studies included in the research are close to each other. When the calculated effect size values are examined, all of them are positive. In this case, it can be said that the studies examining the effect of teaching based on realistic mathematics education on mathematics achievement are in favor of the experimental group.

Results regarding the significant difference between the effect sizes of the studies in terms of field of study (mathematics and geometry) of RME-based teaching in are shown in Table 4.

Table 4. Results regarding the effect size in terms of field of study

Moderator	Intergroup Homogeneity Value (Q_B)	*p*	n	Overall Effect Size Value (ES)	%95 Confidence Interval for Effect Size		Standard Error (SE)
					Lower Limit	Upper Limit	
Field of Study*	0.081	0.777					
Mathematics			34	0.753	0.659	0.847	0.048
Geometry			9	0.779	0.625	0.933	0.079

*Mathematics field includes topics such as numbers and operations, fractions, sets, probability and algebraic expressions. The geometry field includes topics such as transformation geometry, polygons, geometric shapes, length, area and volume.

When Table 4 is examined, it can be seen that intergroup homogeneity value (Q_B) in terms of the field of study is 0.081. In the chi-square table, the critical value of 95% confidence interval with 1 degree of freedom is 3.841. It is also observed that the intergroup homogeneity value is smaller than the critical value in the chi-square table (Q_B=0.081, p=.777>.05). In this regard, it can be stated that the RME-based teaching does not show a significant difference in terms of the field of study.

The results regarding the significant difference between the effect sizes of the studies in terms of the level of education (primary school, middle school, and high school) of RME-based teaching are shown in Table 5.

Table 5. Results regarding the effect size in terms of level of education

Moderator	Intergroup Homogeneity Value (Q_B)	p	n	Overall Effect Size Value (ES)	%95 Confidence Interval for Effect Size		Standard Error (SE)
					Lower Limit	Upper Limit	
Level of Education	3.716	0.156					
Primary school			13	0.787	0.645	0.929	0.073
Middle school			26	0.715	0.612	0.818	0.052
High school			4	1.013	0.719	1.307	0.150

Table 5 indicates that intergroup homogeneity value (Q_B) in terms of the level of education is 3.716. In the chi-square table, the critical value of 95% confidence interval with 2 degree of freedom is 5.991. It is also observed that the intergroup homogeneity value is smaller than the critical value in the chi-square table (Q_B=5.991, p=.156>.05). In this regard, it can be stated that the teaching RME-based teaching does not show a significant difference in terms of the level of education.

The results regarding the significant difference between the effect sizes of the studies in terms of sample size (16-30, 31-45, and 46-60 participants) of RME-based teaching are shown in Table 6.

Table 6. Results regarding the effect size in terms of sample size

Moderator	Intergroup Homogeneity Value (Q_B)	p	n	Overall Effect Size Value (ES)	%95 Confidence Interval for Effect Size		Standard Error (SE)
					Lower Limit	Upper Limit	
Sample size*	0.722	0.697					
16-30 participants			25	0.735	0.618	0.851	0.059
31-45 participants			12	0.812	0.671	0.953	0.072
46-60 participants			3	0.792	0.550	1.033	0.123

*Only the experimental groups

Three study was not included in the analysis as two of them had 1-15 participants and one of them had 76-90 participants as the sample size. Table 6 shows that intergroup homogeneity value (Q_B) in terms of sample size is 0.722. In the chi-square table, the critical value of 95% confidence interval with 2 degree of freedom is 5.991. It is also observed that the intergroup homogeneity value is smaller than the critical value in the chi-square table (Q_B=0.722, p=.697>.05). In this regard, it can be stated that RME-based teaching does not show a significant difference in terms of sample size.

The results regarding the significant difference between the effect sizes of the studies in terms of treatment duration (1-5, 6-10, 11-15, and 16-20 hours) of RME-based teaching are shown in Table 7.

Table 7. Results regarding the effect size in terms of treatment duration

Moderator	Intergroup Homogeneity Value (Q_B)	*p*	n	Overall Effect Size Value (ES)	%95 Confidence Interval for Effect Size		Standard Error (SE)
					Lower Limit	Upper Limit	
Treatment duration	11.276	0.010					
1-5 hours			4	0.616	0.336	0.896	0.143
6-10 hours			12	0.910	0.752	1.068	0.081
11-15 hours			7	0.513	0.335	0.692	0.091
16-20 hours			9	0.705	0.521	0.890	0.094

Only one study was determined to have 26-30 hours of treatment, two studies were determined to have 36-40 hours of treatment and seven studies did not specify the hour of treatment and these studies were not included in the analysis. Table 7 reveals that intergroup homogeneity value (Q_B) in terms of sample size is 11.276. In the chi-square table, the critical value of 95% confidence interval with 3 degree of freedom is 7.815. It is also observed that the intergroup homogeneity value is greater than the critical value in the chi-square table (Q_B=11.276, p=.010<0.05). In this regard, it can be stated that RME-based teaching shows a significant difference in terms of treatment duration. The calculated effect sizes of the groups are medium. However, it can be stated that the effect size of the 6-10 lesson hours is at the large limit, while the effect size of the 11-15 lesson hours is at the weak limit.

Discussion and Conclusion

This study examining the effects of RME-based teaching on the mathematical achievement of students in Turkey, and a total of 43 effect sizes from 40 studies were examined. It was observed that all the studies had positive values, meaning that RME-based teaching was effective, in favor of the experimental groups. The overall effect size as calculated in accordance with fixed effects model is 0.760. This value is considered medium according to Cohen et al. (2007). In this regard, it can be stated that the RME-based teaching has a positive effect on the mathematical achievement of students. This finding is in agreement with the findings of Kaplan et al. (2015) (ES=0.607) and Çelik (2013) (ES=0.714) whereas the findings of Özdemir (2020) (ES=1.048), and the findings of Tamur, Juandi and Adem (2020) (ES=1.104), reveals that the effect of RME on students' mathematic achievement is large. Inclusion criterias and the number of studies included in the meta-analysis may have been effective in the difference of the research result from Özdemir (2020). Moreover, this finding is also in alignment with the findings of some studies claiming that RME-based teaching has positive effects on the mathematical achievement (Demir, 2017; Fauzan, 2002; Gravemeijer & Doorman, 1999; Korkmaz, 2017; Le, 2006; Sembiring et al., 2008; Taş, 2018; Yorulmaz, 2018).

In this study, the field of study, level of education, sample size, and treatment duration were specified as the moderators. The purpose of this study is to examine if there was a statistically significant difference in the effect size of RME-based teaching in terms of these moderators. As a result of the analysis of the moderators;

- The effect size values which were calculated in terms of mathematics (ES=0.753) and geometry (ES=0.779) fields had a medium level effect (Cohen et al., 2007), and there was no statistically significant difference.
- From the effect size values which were calculated in terms of primary school (ES=0.787), middle school (ES=0.715), and high school (ES=1.013) levels of education, the primary and middle school effect sizes had a medium level effect and high school had large effect, and there was no statistically significant difference.
- The effect size values which were calculated in terms of sample size, 16-30 participants (ES=0.735), 31-45 participants (ES=0.812), and 46-60 participants (ES=0.792) had a medium level effect, and there was no statistically significant difference.
- The effect size values which were calculated in terms of treatment duration, 1-5 hours (ES=0.616), 6-10 hours (ES=0.910), 11-15 hours (ES=0.513), 16-20 hours (ES=0.705) had a medium level effect, and there was statistically significant difference. Accordingly, it can be stated that the effect size of the 6-10 lesson hours is at the large limit, while the effect size of the 11-15 lesson hours is at the weak limit.

This study only examined the effects of RME-based teaching on students' mathematic achievement. Future studies can examine the effects of RME-based teaching on students' attitudes towards mathematics, motivation, reflective thinking skills, creative thinking skills etc. Moreover, the effect of different moderators on the mathematic achievement may also be examined. As a result of the problems arising from the nature of experimental research, meta-analysis studies can also be negatively affected. Uncontrollable factors other than the independent variable may affect the dependent variable. For example, students in the experimental group make an intense effort to show themselves better to their teachers or researcher. It even keeps their anxiety and motivation levels different than normal. This situation may negatively affect the effect values that will appear in meta-analysis studies due to the results obtained from experimental studies. As a matter of fact, the data in the meta-analysis are combined in the light of the results obtained from the experimental studies. The fact that such meta-analysis studies are quantitative here adds a misleading perception to readers and researchers in terms of certainty. For this reason, it should be stated in the conclusion part of the study that caution should be exercised in meta-analysis studies and that the final correct finding cannot be obtained only with these studies. If the data obtained from meta-analysis are supported with qualitative and other quantitative results, it makes better sense. Just as a good meal comes with the combination of ingredients that increase the flavor of that meal.

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The data used in this study does not require the approval of Institutional Ethical Review Board.

Authorship Contribution Statement

Sedat TURGUT: *Conceptualization, design of the work, , literature search, data collection, data analysis, data interpretation, writing - review and editing.*

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