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Abstract

Nearly all studies aiming to determine the effect of modern teaching methods on academic success using an experimental design contain control groups in which traditional methods are used. Effect of traditional methods in geometry and numbers learning domains on academic achievement has not been conclusively studied by researchers yet. On the other hand, it is claimed that almost all experimental designed studies aiming to determine the effect of "modern" teaching methods, have utilized traditional methods in their control group. While there are some review studies within the literature, for experimental groups' effects on academic achievement, no review studies on control groups' effect have been detected so far. Consequently, our aim is to systematically review the studies' control group findings on traditional methods in experimental researches. The purpose of this meta-analysis study is to calculate the overall effect of traditional methods in Geometry and Numbers Learning Domains (G & N LD) on academic achievement. With this in mind, data was collected from the master and doctoral theses submitted in Turkey, to indirectly answer the following research question: "Does traditional methods in (G & N LD) effect students' academic achievement?" A meta-analysis aims to compare and combine the findings from various independent studies on a subject and determine their overall effect. Data sources of the study are studies giving pretest and posttest values for their control groups from the studies with pretest and posttest experimental and control group designs on (G & N LD).Included studies were retrieved from Advanced Thesis Search Database of Council of Higher Education (YÖK), using keywords search "geometry", "number", "mathematics" and "control" (both in Turkish and in English). The theses on (G & N LD) and using middle school (5th to 8th grades) as the sample were included into the meta-analysis considering the inclusion criteria. The results show that traditional methods differ by an average of 0.83 standard deviations, and it can be interpreted that traditional methods increase success in mathematics teaching. As a result of analysis, it was seen that this success was not by chance ($p<0.001$). As a recommendation, it is important to note that there is no loss of data since testing will not reveal whether the experienced method is different from the conventional method by testing one-sample t-test for the value obtained in their experimental study with a point increase corresponding to the 0.83 standard deviation.

Introduction

Geometry and Numbers are the longest learning domains in all classes in middle schools. Geometry learning domain begins with the presenting, explaining and drawing of basic geometric concepts in the first year of middle school. When it comes to the final class, the triangles are complemented by the deepening of sub-learning, as well as the geometry of transformation, the identification and construction of equipollence and similar polygons, and the handling of geometric objects. On the other hand, the achievements in the Numbers learning domain are likewise shown from the first year of the middle school to the last year. Firstly, Natural Numbers are included in this learning field. There are fractions, decimals, integers, rational numbers, percentages, exponentials and square roots (MEB-TTKB, 2013). Projected Outcome counts and Lesson Duration for Geometry and Numbers Domains are given in Table 1 according to the classes.

Table 1. Geometry and numbers learning outcomes according to classes (MEB-TTKB, adapted from 2013)

Learning Domain	Grade	Topics	Outcomes	Duration Course Hour	Duration Percentage
Geometry	5	Basic Geometry Notions and Drawings	5	16	9
		Triangle and Quadrangle 1	5	16	9
		Area Measurement	2	12	7
		Length and Time Measurement	5	16	9
		Geometric Objects	3	9	5
		Total (Grade 5)	20	69	39
	6	Degrees	3	8	4
		Area Measurement	7	8	11
		Geometric Objects and Volume Measurement	5	14	8
		Liquid Measurement	3	7	4
		Circle	4	11	6
		Total (Grade 6)	22	48	33
	7	Direction Angles	3	10	6
		Circle and Round	3	10	6
		Polygons	5	17	9
		Transformation Geometry	6	20	11
		Different Aspects of Things	2	5	3
		Total (Grade 7)	19	62	35
	8	Triangles	4	13	7
		Right Triangle and Pythagorean relation	1	5	3
		Transformation Geometry	4	13	7
		Equipollence and Similarity	2	8	4
		Geometric Objects	6	20	11
		Total (Grade 8)	17	59	32
		TOTAL (GEOMETRY)	78	238	34,75
Numbers	5	Natural Numbers	3	9	5
		Processes in Natural Numbers	12	30	16
		Fractions	7	20	11
		Fraction Processes: Addition and Subtraction	2	9	5
		Decimal Notation	5	16	9
		Percentages	4	12	7
		Total (Grade 5)	33	96	53
	6	Processes in Natural Numbers	4	11	6
		Factors And Multiples	5	16	8
		Fraction Processes	9	24	13
		Decimal Notation	8	19	11
		Integers	6	16	9
		Ratio	3	8	4
		Total (Grade 6)	35	94	51
	7	Integers-Multiplication and Division Processes	3	12	7
		Rational Numbers	4	10	6
		Rational Number Processes	5	20	11
		Ratio and proportion	7	24	13
		Percentages	4	14	7
		Total (Grade 7)	23	80	44
	8	Factors And Multiples	3	10	6
		Exponential notations	5	17	9
		Square Roots	9	27	15
		Total (Grade 8)	17	54	30
		TOTAL (Numbers)	108	324	44,5
		TOTAL (NUMBERS + GEOMETRY)	186	562	78
		TOTAL (ALGEBRA+DATA PROCESSING+PROBABILITY)	47	158	22
		TOTAL (MIDDLE SCHOOL)	233	720	100

When Table 1 is examined, it can be seen that 108 of the total 233 achievements shown in the middle school are numbered learning domain, and 78 is located in the Geometry learning domain. For the 186 achievements in the two learning domains, 562 teaching hours have been allocated. This period, which took 78% of the total mathematics time, was divided into 3.00 hours per acquisition, 3.05 hours in Geometry learning, 3.36 hours in other learning domains. This data shows that despite the longer time allocated for numbers and geometry learning domains, the duration of lesson per achievements is less.

Better teaching of numbers and geometry learning domains is important in order to increase the efficiency of the 562 hours spent and many academic studies are being conducted in this area. Particularly, experimental studies provide important findings and suggestions for practitioners and researchers. These suggestions generally can be summarized as using the teaching methods used in the experimental group in accordance with the results of the research and the applications to the control group should not be preferred. One of the important points that draws attention here is that the operations carried out in the control group are generally called using the same title: "traditional methods". Demirel (2012) defines traditional teaching as "teacher-centered teaching in which certain textbooks are used and the method of expression is emphasized". According to this definition, in order for a teaching to be traditional, it is necessary to use a method of expression and teacher-centered based on a textbook. When the studies are examined, it is seen that there is no point mentioned in the definition of traditional teaching. This situation obscures the practices of the control group. The Turkish Education System has been trying to implement a constructivist approach in schools since 2005 and has announced that it has left the teacher-centered understanding long ago, as the traditionalization of an application can only be possible after many years. In this case, the study of traditional methods in the control group seems to be based on the use of classroom teaching methods that have already been changed.The lack of clarity of how the traditional method used in the control groups prevents the repeatability of experimental researches. This problem is found in almost all academic studies that prefer control group pre-test post-test experimental design, independently of the method used in experimental groups, with a recurrent problem in many studies.

In this study, it is aimed to investigate the overall effect of the traditional method by taking advantage of the data of the experimental studies used in the control group of the traditional method. It is considered that there is no need to reapply the traditional method that is said to have been practiced in almost every experimental design. It can be possible to calculate whether the relevant method differs from the traditional method by comparing the score of the overall effect obtained in this study with the score obtained in the experimental group. In this case, the traditional method may not be used in the classroom where the constructivist approach is included in the curriculum and it is aimed to prevent the students from being exposed to old applications which are not in the program.

That's why these studies must be examined through meta-analysis to reach a conclusion. The purpose of the study is to calculate overall effect size of the studies analyzing the effect of traditional methods in geometry and numbers learning domain on academic achievement in Turkey, and also to reveal whether traditional methods' effect sizes differentiate significantly according to sample size, year, learning domain, department, grade, geographical region.

Method

One of the research review methods, meta-analysis was employed to examine the effect of traditional methods in geometry and numbers learning domain on academic achievement. Meta-analysis is a collective procedure used to compare and combine the findings obtained from individual studies and consists of following stages (Borenstein, Hedges, Higgins and Rothstein, 2009; Card, 2012; Cooper, 2010):

- Formulating the problem
- Searching the literature
- Gathering information and findings from individual studies
- Evaluating the quality of studies
- Analyzing and interpreting the outcomes of studies
- Interpreting the results (evidence)

Literature Search

The studies included in this research were obtained from CoHE (Council of Higher Education) National Thesis Center (2017) database. Search in the database was conducted between March 2017 and May 2017. While searching, the following keywords were entered in both Turkish and English: "traditional method", "mathematics", "academic achievement". 255 studies were attained from the first literature search, related to the effect of traditional methods in mathematics on academic achievement. According to the inclusion criteria, 31 studies were retained for further analysis.

Study Inclusion and Exclusion Criteria

The quantitative studies published between 2004-2017 (2004 is the start of new curricula) and on the effect of traditional methods in geometry and numbers learning domain on academic achievement were examined in the context of this study. Inclusion criteria are as follows:

- It must be a master or doctoral thesis thesis.
- It must be experimental design with control groups – in which «traditional method» was used.
- The participants of the study must be from Turkish population.
- It must contain quantitative values (mean, standard deviation, sample size for pre and post groups) to calculate an ES-effect size.
- It must examine the relationship of traditional methods in geometry and numbers learning domain on academic achievement.
- Studies must employ parametric tests (t-test, F test, etc.).

255 studies examining the effect of traditional methods in geometry and numbers learning domain on academic achievement were identified according to the criteria above. Some of these studies were eliminated as 37 of them were conducted in qualitative design, 42 of them had limited access, 96 of them was not about middle school level, 49 of them had not any pre-post test analyse information for control group. As a result, 31 studies about geometry/numbers learning domain and academic achievement were identified to review.

Coding of Study Characteristics

The theses chosen according to inclusion criteria were coded in terms of their supervisor of the author, date, type, topic, study group size, department, grade. Randomly chosen 4 studies (12,90 %) were given a second coder to check the reliability of coding and intercoder reliability was calculated by comparing the codes. Equalization rate over 80% is accepted high enough (Miles and Huberman, 1994). After the coding process, intercoder reliability was found 100%.

Data Analytic Strategy

In this study, Cohen's d effect size index (Standardized Mean Difference) was employed. Cohen's d is calculated by dividing the difference between pretest and posttest means by standard deviation. According to Cohen (1988), the effect size is accepted as "no effect" if d-value is up to 0.20, "low" between 0.20-0.50, "moderate" between 0.50-0.80, and "large" over 0.80.Having calculated the effect sizes of individual studies, the effect sizes are compared and combined through a statistical method and overall effect size is calculated. Two models are used in calculating an overall effect size: Fixed and random effects models. Yet, in social sciences, random effect model is suggested due to lack of fixed effect model assumptions such as same population, same procedure etc. (Hedges and Pigott, 2001; Borenstein et al., 2009).

Moreover, categorical moderator analysis and meta-regression analysis were applied to reveal whether overall effect size of traditional methods in geometry and numbers learning domain on academic achievement shows a significant difference regarding sample size, year, learning domain, department, grade, geographical region.Whether the moderator is significant is determined by significance level of Qbetween value under Fixed Effects Model. Funnel plot, Orwin's Fail-safe N and Egger's Regression Intercept tets were done to reveal the possible existence of publication bias and its effect on the overall effect size. Comprehensive Meta-Analysis Software (CMA) Ver.2.0 was utilized in data analysis.

Results

The following are characteristics of the included studies, overall effect size and heterogeneity test forest plot, moderator analysis, meta-regression publication bias, characteristics of the included studies.

Characteristics of the Included Studies

Total sample size of empirical studies included in this study is 854 participants while it is 437 for geometry learning domain and it is 417 for numbers learning domain. Descriptive statistics of the studies included in meta-analysis are given in Table 2.

Table 2. Frequency distribution of studies by publication type, learning domain, departments, grades, geographical region

Variable	*Frequency (n)*	*Percentage (%)*
Publication Type		
Master Thesis	*30*	*96,77*
Doctoral Thesis	*1*	*3,23*
Learning Domain		
Geometry	*16*	*51,61*
Numbers	*15*	*48,39*
Department		
Informatics	*2*	*6,45*
Educational Sciences	*5*	*16,13*
Primary Education	*21*	*67,74*
Mathematics	*3*	*9,68*
Grades*		
5th grade	*7*	*23,33*
6th grade	*11*	*36,67*
7th grade	*8*	*26,67*
8th grade	*4*	*13,33*
Geographical Region		
Eastern Anatolia	*2*	*6,45*
Eagean	*2*	*6,45*
South Eastern Anatolia	*2*	*6,45*
Central Anatolia	*11*	*35,48*
Blacksea	*4*	*12,90*
Marmara	*10*	*32,27*

**10th grade (only one study) is not included into the analysis*

It is seen in Table 1 that 96,77 % (f=30) of studies were conducted as Master theses, 51,61 % (f=16) in Geometry Learning Domain, 48,39 % (f=15) in Numbers Learning Domain. It was also reported that 67,74 % (f=21) of these studies were from Primary Education Department while 16,13 % (f=5) were Educational Sciences Department. 36,67 % (f=11) were conducted in 6th grade, 26,67 % (f=8) in 7th grade. 35,48 % (f=11) of studies were from Central Anatolia, while 32,27 % (f=10) were from Marmara region.

Overall Effect Size and Heterogeneity Test

To get an overall effect size, all included studies’ effect sizes were calculated, compared and combined. The results is Random Effect Model output, which is -0829 [-1,019; -0,640]. Heterogeneity test was done to reveal whether variance observed in effect sizes distribution of individual studies indicates a significant difference from the expected sampling error variance. Overall and heterogeneity results are shown in Table 3:

Table 3. Heterogeneity statistics

	Model	Fixed	Random
	Number of Studies	31	31
	Cohen d	-0,684	-0,829
	Std. Error	0,04	0,097
	Lower limit	-0,762	-1,019
	Upper limit	-0,605	-0,64
	Z-Value	-17,092	-8,571
	p-value	0,0000	0,0000
Heterogeneity	Q-value	166,273	
	df (Q)	30	
	p-value	0,0000	
	I-squared	81,957	

Heterogeneity test result was found significant ($p<0.05$) according to Table 2. Q-value was calculated as 166,273, with 30 degrees of freedom (df). I2 index is 81.957%, indicating a factual and high amount of heterogeneity among included studies. All in all, these result reveals that included studies do not share a common effect size, and the variance observed in effect sizes of inluded studies suggests a significant difference from the variance of sampling error. Since true effect sizes vary from study to study, it should be analyzed using random effects model, and the overall effect is the mean of these effects (Borenstein et al., 2009). When effect sizes of 31 studies included in this review were combined using random effects model, the overall effect size was calculated as (Cohen d) -0.829 with 0.097 standard error and 95% confidence intervals of -1.019 and -0.640. It is "large" effect according to Cohens (1988) classification.

Forest Plot

Forest plot is one of the most frequently used tools in summarizing meta-analysis results by visualizing (Borenstein et al., 2009; Card, 2012). In forest plot, an individual study is like a tree, while all trees come together to form the forest to give an idea for the synthesis. Forest plot of meta-analysis results of 31 included studies in this meta-anlaysis is given in Figure 1:

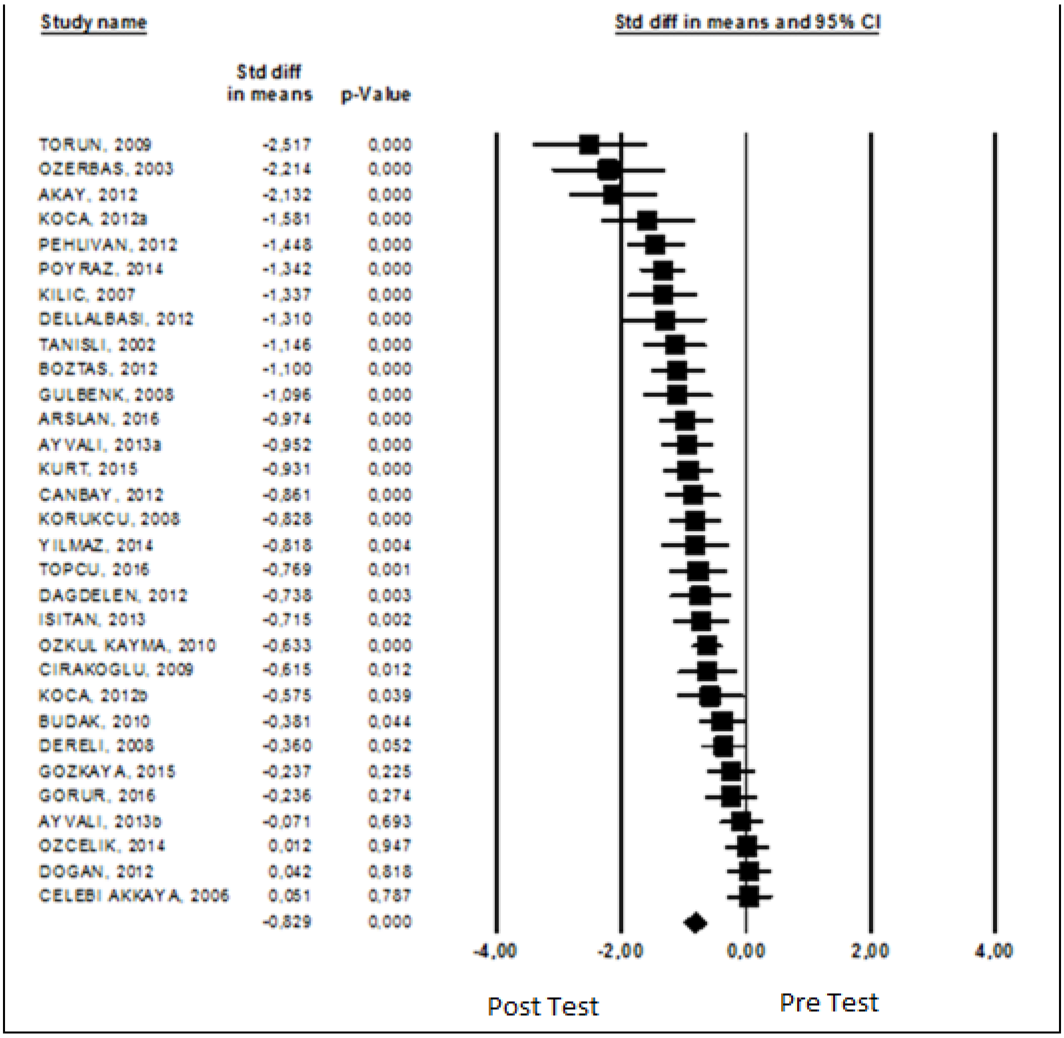

Figure 1. Forest plot of meta-analysis results

When standardized means differences of pretest and posttest groups are calculated in addition to effect sizes in 95% confidence interval, the result is seen to be in favor of the posttest group. 24 of 31 studies have a statistically significant results while the rest 7 studies do not.

Classifying these studies in regard to Cohen's (1988) effect size classification, the effect size was found to be "large" in 17 studies, "moderate" in 6 studies, "low" in 4 studies, and "no effect" in 4 studies. 28 studies' effect sizes are in favor of posttest, whereas there are only 3 studies favoring pretest.

Moderator Analysis

Moderator analysis was done to reveal whether the effect of traditional methods in geometry and numbers learning domain on academic achievement shows a significant difference in terms of learning domain department, grade, geographical region. The results can be seen in Table 4:

Table 4. Moderator analysis

Moderator	*k*	*Effect size Cohen d (Random Effect Size)*	*95 % Confidence Interval*		*Heterogeneity*		
			Lower Limit	*Upper Limit*	*$Q_{between}$*	*df*	*p*
Learning Domain					*1,359*	*1*	*0,224*
Geometry	*16*	*-0,948*	*-1,280*	*-0,616*			
Numbers	*15*	*-0,718*	*-0,917*	*-0,519*			
Department					*7,317*	*3*	*0,062*
Informatics	*2*	*-1,267*	*-1,573*	*-0,960*			
Educational Sciences	*5*	*-0,826*	*-1,455*	*-0,198*			
Primary Education	*21*	*-0,762*	*-0,982*	*-0,542*			
Mathematics	*3*	*-1,163*	*-1,956*	*-0,371*			
Grades*					*6,851*	*3*	*0,077*
5th grade	*7*	*-1,016*	*-1,407*	*-0,625*			
6th grade	*11*	*-0,558*	*-0,814*	*-0,302*			
7th grade	*8*	*-0,889*	*-1,355*	*-0,422*			
7th grade	*4*	*-1,090*	*-1,482*	*-0,699*			
Geographical Region					*5,192*	*5*	*0,393*
Eastern Anatolia	*2*	*-0,897*	*-1,545*	*-0,250*			
Eagean	*2*	*-1,162*	*-3,019*	*0,695*			
South Eastern Anatolia	*2*	*-1,042*	*-2,025*	*-0,058*			
Central Anatolia	*11*	*-0,983*	*-1,368*	*-0,599*			
Blacksea	*4*	*-0,969*	*-1,274*	*-0,664*			
Marmara	*10*	*-0,559*	*-0,845*	*-0,274*			

**10th grade (only one study) was not included into the analysis.*

It is seen in Table 3 that there is no significant difference in effect size of categorical moderator subgroups (p>.05). In other words, the effect of traditional methods in geometry and numbers learning domain on academic achievement does not vary significantly according to learning domain, department, grades and geographical region.

Meta-regression

For continuous moderators, meta-regression was done to reveal whether the effect of traditional methods in geometry and numbers learning domain on academic achievement shows a significant difference in terms of sample size and year. The results can be seen in Table 5:

Table 5. Results of meta-regression (mixed effect regression – method of moments)

Moderator	*Slope*	*Lower limit*	*Upper limit*	*p-value*
Sample size	*0,00647*	*-0,00989*	*0,02282*	*0,43835*
Year	*0,03715*	*0,01920*	*0,09351*	*0,19629*

It is seen in Table 4 that there is no significant difference in meta-regression of sample size and year variables (p>.05). In other words, the effect of traditional methods in geometry and numbers learning domain on academic achievement does not vary significantly according to sample size and year.

Publication Bias

Possible publication bias of a synthesis result may be a misleading higher overall effect size than normally it should be. That's why, for any meta-analysis, publication bias test are done to determine whether there is publication bias for the results of meta-anlaysis. For this study the following methods were used to check publication bias: Funnel plot, Classic fail-safe n (Rosenthal), Orwin's fail-safe N, Egger Regression Intercept Method. Funnel plot for this study is given in Figure 2:

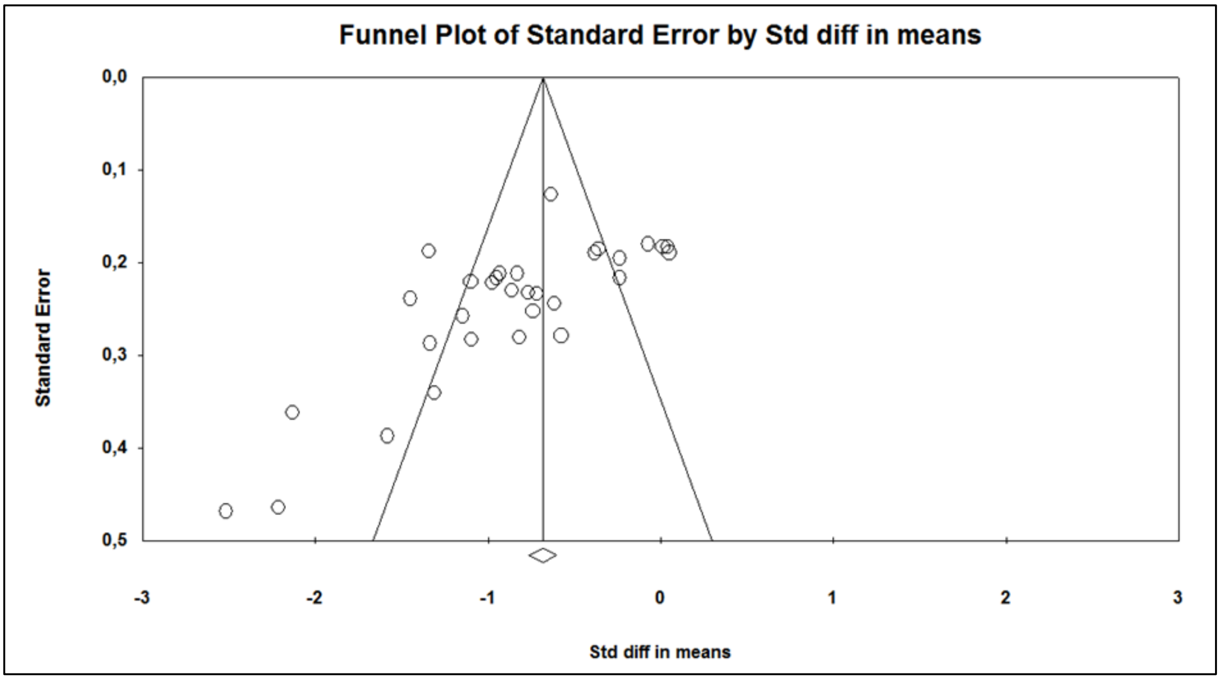

Figure 2. Funnel plot of publication bias

When there is no publication bias, effect sizes of studies included in analysis range around overall effect size symmetrically and towards the upper part of the funnel shape. (Borenstein et al., 2013). Partial bias can be observed from the figure 2, yet this way of determining publication bias is only visual detection and not taken as sufficient since the interpretation of funnel plot is of utmost subjectivity (Borenstein et al., 2009), Egger's Regression Intercept test and Rosenthal's Fail-safe N test, Orwin's fail-safe N were applied to evaluate the amount and impact of publication bias on the overall result.

As a result of Egger's regression intercept test, the intercept value was computed as -5,75921 and two-tailed p-value as 0.00009. According to these results, it can be interpreted that visual interpretation of asymmetry is true, and funnel plot indicates publication bias. However, this study is composed of only master and doctoral thesis. Taking into account Fail-safe Numbers may be more important to evaluate bias. According to Rosenthal (1979), if up to 5k or 10k (k is the number of the studies) of the studies included in the analysis are needed, the overall effect size may be biased. Accordingly, for Rosenthal's Fail-safe N, 2780 studies (nearly 90 times more), and for Orwin's fail-safe N, 2089 studies (nearly 68 times more) are needed to decrease the overall effect size to "no effect" level. In Turkey, all graduate theses are only kept in CoHE (Council of Higher Education) National Thesis Center database, it is impossible this much inaccessible theses. Thus, it proves no publication bias for this meta-analysis.

Discussion and Conclusion

This study, which has reached the finding that traditional methods differ by an average of 0.83 standard deviations, can be interpreted that traditional methods increase success in mathematics teaching. As a result of analysis, it was seen that this success was not by chance (p=0,0000). According to the findings obtained as a result of the analysis to determine which variable causes heterogeneity, variables such as learning domain, years of study, class level and geographical region, and size of the study group do not cause heterogeneity. In this case present heterogeneity (I2=% 82) can be attributed to sampling error.

When the studies were examined, it was seen that there was no lesson plans for the control group. Although the name of the method is the same, the reasons for the increase in success in different forms, different implementations, and studies performed on different groups may be due to the uncontrolled implementation of traditional methods or the internalization of these methods. While studies usually informed about the experiment group, the option of uncontrollability comes to the forefront because almost no information is given about the applications made in the control group. As noted by Evrekli, İnel, Denis and Balım (2011), not so much attention is paid to scientific research methods, especially in studies conducted. The fact that the applications are not included in the lesson plan, such as the absence of camera recording, undermines the practices that are meant by the traditional method. This problem of confrontation as a reliability problem in studies can be overcome by recording the control groups in new studies to be done and ensuring that this record is included in the thesis.

On the other hand, since 2005, the educational philosophy of curricula has been the constructivist approach that reflects the training of the progressive mentality. Teachers and other practitioners are expected to make appropriate teaching of this approach. The fact that such homogeneous character is shown in the course of traditional approaches can be deduced by the optimistic estimation that the traditional method has left a very permanent mark on the subconscious of the practitioners. According to Stigler, Gonzales, Kawanaka, Knoll, Serrano (1999), teachers are having difficulty in changing the ways of teaching mathematics. This expression, which is parallel when compared to the result reached in the study, slightly upsets the difficulty of change. In addition to these difficulties, in the studies conducted with Turkish teachers (Artut and Bal, 2006), it has been stated that the awareness of the teachers about the new program is not enough. Bal and Artut (2013) stated that most of the teachers in their study of the updated program did not fit the learning-teaching process envisaged in the programs.

The traditionalization of an application is the natural result of being highly preferred. The underlying reasons for preference can often be explained by the fact that the application is less tiring in the short run. However, it can be argued that teachers' traditional ways of choosing are not internalized by teachers as the methods mentioned in the new programs. Korkmaz (2006) points out the inadequacy of in-service training for teachers' introduction of the program. Rea-Dickins & Germanie (2001) argues that the practice will be carried out positively, with the teachers being as informed as possible before the program is implemented. The heterogeneity in this work can not be explained to the moderators because of the lack of information about the program. As a natural consequence of this situation, the traditional methods still constitute the basis of the teaching approach of the teachers and it can be interpreted that it makes it possible to increase the success without any additional effort.
The results obtained from this study are related to studies on geometry and numbers learning domains in mathematics teaching. For the experimental procedures to be performed, it is thought that the design without the control group is preferred and the studies will be supported with more than one experiment group. This can be made more efficient by the use of other methods or other experimental groups. On the other hand, in spite of the progressive understanding in the curriculum, it is possible to reduce the mistakes that would result from teaching students in traditional ways with schooling. It is important to note that there is no loss of data since testing will not reveal whether the experienced method is different from the conventional method by testing one-sample t-test for the value obtained in their work with a point increase corresponding to the 0.83 standard deviation obtained, and it is also seen as a source of motivation.

Recommendations

The results obtained from this study are related to studies on geometry and numbers learning domains in mathematics teaching. For the experimental procedures to be performed, it is thought that the design without the control group is preferred and the studies will be supported with more than one experiment group. This can be made more efficient by the use of other methods or other experimental groups. On the other hand, in spite of the progressive understanding in the curriculum, it is possible to reduce the mistakes that would result from teaching students in traditional ways with schooling. It is important to note that there is no loss of data since testing will not reveal whether the experienced method is different from the conventional method by testing one-sample t-test for the value obtained in their work with a point increase corresponding to the 0.83 standard deviation obtained, and it is also seen as a source of motivation.

Notes

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