Id: 930349

Participatory Educational Research (PER)
Vol.9(2), pp. 358-397, March 2022
Available online at http://www.perjournal.com
ISSN: 2148-6123
http://dx.doi.org/10.17275/per.22.45.9.2

The Effect of Technology Assisted Teaching on Success in Mathematics and Geometry: A Meta-Analysis Study*

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Article history
Received:
03.05.2021

Received in revised form:
12.07.2021

Accepted:
24.07.2021

Key words:
Academic achievement; teaching of mathematics/geometry; meta-analysis

In this research, experimental studies comparing the effectiveness of technology-assisted teaching to traditional method up on mathematical and geometry success are combined through meta-analytical review method. For that purpose, articles, master's, and doctoral theses carried out between the years 2000-2016 in Turkey are examined. 98 studies on academic achievement meet the specified criteria and thus were included in the meta-analysis and the effect size between variables has been demonstrated by assembling numerically the findings of these studies. CMA 2.0, MS Office Excel 2010 programs were used in the analysis of the data. As a result of the calculations of meta-analysis, the effect size of the technology-assisted teaching is calculated as 0,758 on students' mathematics achievement and as 1,136 on students' geometry achievement. This study is based on the classification system according to Cohen (1988). The effect sizes attained represent a medium effect size for mathematics academic achievement and a very large size for geometry achievement. Those both values are regarded as medium effect size according to Cohen (1988). In addition, the comparative effect sizes of the studies included in the study were calculated according to techniques of implementation, level of education and learning fields. At the end of the research, it is found that according to the traditional learning method of technology-assisted mathematic and geometry teaching is more effective in terms of achievement. It is concluded that the effect size on the academic achievement of mathematic and geometry does not differ according to time of implementation, level of education, and learning fields.

Introduction

The studies on the ever-changing concepts of education and teaching frequently stem from searching for an answer to the question: "How can we provide a better education?" It will not be right to adopt status quo in the field of education and do nothing new in a world where

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needs change and increase day by day. It is not difficult to predict that the future teaching method will be oriented toward technological developments (Çavuş, 2006).

Today, dazzling advances in science, culture, and technology have affected many fields as well as the field of education. Many concepts from education programs to classroom structure such as teaching environments, educational tools, teacher, and student roles are rapidly changing and renewed with these technologies. Exciting developments in technology have provided new opportunities in mathematics teaching (Ertem Akbaş, 2019). This universal dimension offered by technology has significantly impacted on the question of "what should we teach and how?" Therefore, it is recommended to use technological facilities efficiently in designing learning environments where students can learn by doing (Güven, 2002). The needs to adapt education and teaching to the technological age on a constantly evolving and changing ground has been one of the top priorities in this context. In parallel with this, it was seen that the desired quality and contemporary goals could not be achieved with classical methods in teaching, and new searches were started.

In recent years, important mentality changes have occurred in mathematics education. As it is known, in traditional mathematics education, mathematical knowledge is presented to the student as small skills expected them to gain these skills with repeating and exercises. A student who must learn by memorizing many relations, rules, and symbols without comprehending, becomes unable to solve a problem (Olkun & Toluk, 2001). However, as in every modern country, today's business world seeks people who have an analytical mindset, perceive problems correctly, and deliver creative solutions. For this reason, in mathematics education, raising individuals who know not only mathematics but also learn mathematics by doing mathematics has come to the fore. Therefore, the demonstration of the effectiveness of the Technology Assisted Instruction (TAI) method, which has become accepted among the teaching methods, has attracted the attention of the researchers, and led them to do many studies on this subject.

In the literature, although the number of studies on the effectiveness of TAI continues to increase over time, many independent studies came up with different findings from each other. In this case, it is considered important to combine the data obtained from these studies to give clear information to the target audience by gathering these independent studies under a single roof. Accordingly, the meta-analysis method, which allows us to make more general comments by combining these studies, emerges as a method that eliminates such problems.

Although there are many studies and applications on TAI in Turkey, any literature review allowing for large-scale generalizations in the area could not be found. It is thought that a meta-analysis study, which will be formed by the synthesis of the data obtained from the experimental studies that reveal the effect of technology-based learning in the fields of mathematics and geometry, conducted in Turkey, since 2000, will contribute to the literature by serving an important academic need in the field of technology-based learning and will shed light on the directions of future research. Combining the previous research results on the subject with the meta-analysis method and showing common results about its effects and practices in Turkey will contribute to reaching general conclusions. In this sense, this study will be useful in combining the research results to reveal whether the technological methods and tools used in mathematics and geometry lessons are effective in our country than the traditional teacher-centered teaching method. Within the scope of the study, it is thought that the examination of meta-analytical effect size values and the effect of TAI on academic achievement in mathematics and geometry lessons can guide the plans and applications of technology supported education projects. In addition, the absence of a similar study showing the effect of technology-supported teaching methods on student achievement in mathematics and geometry increases the importance of this study. In this study, it was aimed to examine the effect of TAI on the students' achievement in mathematics and geometry lessons, considering the role of TAI in learning and teaching in mathematics and geometry within the scope of the literature. For this purpose, in this study, which examines how TAI affects the academic achievement of students compared to the traditional method, independent study results are combined with a meta-analysis method. Thus, it will be possible to see the big picture of the subject.

Technology Supported Mathematics-Geometry Teaching and Academic Achievement

Teaching such important branches of science is equally important. However, most students see mathematics and geometry as difficult science to learn and state that these are the subjects, they fear the most and do not like. Therefore, these courses are among the courses in which students are least successful. Carter and Good reported that the knowledge and skills usually developed in classes and determined by the grades, test scores, or both, appreciated by teachers, are called academic achievement (as cited in Arslan, 2008). To achieve success in teaching mathematics, students must have abilities such as reasoning, critical thinking, and problem-solving skills. Some international exams reveal that our country is insufficient in acquiring such skills with current mathematics education (Arslan, 2008). As a matter of fact, the academic achievements obtained in mathematics and geometry exams such as the International Mathematics and Science Trends Survey (TIMSS), the International Student Assessment Program (PISA), the International Reading Skills Development Project (PIRLS) are not very pleasant. This situation may be associated with the lack of attention of students in traditional settings, as the subject to be learned is not individualized (Ministry of Education, 2016). However, it is possible to attract attention to the lesson with individualized learning in a student-centered teaching environment prepared through software with information technology. In addition, it is possible to animate and model abstract content with computer technology. Thus, abstract concepts can be concretized and understood more easily by students. While National Council of Teachers of Mathematics (NCTM, 2004) shows one of the six items determined for quality mathematics education as the "technology principle", it supports and guides the use of technology. In the relevant literature, it is stated that technology should be used during the mathematics course, and this will help students learn mathematics (Ersoy, 2003; Ertem Akbaş, 2019; Ertem Akbaş, 2016; Nikolaou, 2000). In addition, although the use of technology in education is a requirement in general, mathematics specifically is a very suitable field for using technological facilities (Öksüz & Ak, 2010). This situation is explained by the fact that computers used in mathematics education embody abstract concepts (MEB, 2016). For this reason, there is a general orientation and need for almost everyone to be mathematics and technology literate. Therefore, the efficient use of information technologies will make it possible for all students to reach mathematical thinking regardless of the level difference in the context of fulfilling certain mathematical skills of technology (Ersoy, 2003). In this respect, the tools used will lead students to use multimedia by saving them from time-consuming and repetitive calculations. Therefore, it should be important to teach students how to technologies effectively and appropriately use information and communication (MEB, 2016).

Even though information technologies and TAIs remind of computers, they are not limited to computers only. These technologies can be evaluated within the scope of hardware and software (Computer Algebra System (CAS)), Dynamic Geometry Software (DGY) in the fields of mathematics-geometry (Ersoy, 2003; Baki, 2002). Within the scope of this hardware and software, the importance of TAI in mathematics and geometry cannot be denied. In terms of facilitating the concretization and solution of the problems with tables, graphics, and symbols, TAIs help students. They help teachers and students to overcome some of the obstacles encountered during the problem-solving process. In addition, TAIs allow students to express numerical values with graphics, embody them with animations, use mathematical symbols, and examine the subject from different angles. For example, instead of discussing topics that are completely disconnected from their lives, such as finding or graphing the roots of a third-order polynomial function whose roots can be easily found, but rather it will allow students to discuss a more complex polynomial function that models a situation they may encounter in their daily lives which is meaningful to them. In this way, students will be able to think about the solution to the problem rather than finding ordinary roots and drawing graphics. Therefore, this thinking process will enable students to create meaningful information and deal with real problems, helping them understand that mathematics and geometry are an effort to find solutions to the human life problems (Durmuş, 2001). Similarly, it can be stated that the most important problem in teaching geometry is that the geometry course content is perceived as abstract and detached from daily life (Özkeleş-Çağlayan, 2010). However, it is complicated to explain subjects that require three-dimensional and spatial thinking skills with traditional methods. Parallel to this, since the geometric concepts are explained with two-dimensional tools such as books and pictures, the student faces some problems when moving from two dimensions to three dimensions. In this framework, the benefit of technology-supported applications is undeniable (Karal & Berigel, 2008).

Only blackboard, chalk, or paper and pencil were used as tools for many years during mathematics-geometry education and training. Nowadays, information tools that will facilitate and assist the process have started to be used. Thanks to these informatics tools, TAIs bring along some developments such as creative thinking, problem solving skills, mathematical thinking instead of tiring minds empty and meaningless with memorization (Ersoy, 2003). As a matter of fact, students learn mathematics more profoundly and effectively and achieve academic success using information and communication technology (Ersoy, 2003). For this purpose, technological facilities should be utilized as much as possible to enrich students' mathematical understanding skills in mathematics classes (Hacısalihoğlu Karadeniz & Akar, 2014; NCTM, 2004).

The content mentioned so far has dealt with the place and importance of TAI in mathematics-geometry teaching and its effect on academic achievement. In this sense, the importance of presenting studies investigating the effect of technology support on academic achievement in mathematics and geometry teaching with meta-analysis (Yıldız, 2009) method allows us to combine and provide more information by using one or more statistical methods, becomes evident.

Purpose and Problem of the Research

This study's main purpose is to synthesize the results obtained from experimental studies examining the effect of the TAI method on the academic achievement of students in mathematics and geometry lessons compared to the traditional method through meta-analysis. For this purpose, 98 studies were examined to evaluate how effective technology-supported teaching methods are in Turkey, and investigated the answers to the following questions within the scope of the research:

(1) What effect does TAI have on students' academic achievement in mathematics and geometry course areas?
(2) How do the effect sizes of the TAI techniques (animation, computer work, CD, computer software, smart board, calculator, simulation) differ?

(3) When examined in terms of course areas (mathematics and geometry) in which the studies are conducted, what kind of difference is there between the effect sizes of the TAI method on academic achievement?
(4) How do the effect sizes of the TAI method differ in terms of students' education level (preschool, primary school, middle school, high school, university)?

Method

Research Method

This study is designed as a meta-analysis method, which is one of the quantitative research methods. Meta-analysis is a method that provides more reliable and clear results by presenting inferences based on standard numerical data instead of heuristic inferences used in other literature searches (Cohen et al., 2007). In addition, meta-analysis is the method used to combine and analyze the information called effect size quantitatively using data from individual studies (Camnalbur, 2008). In other words, meta-analysis is a method in which limited data can be examined in detail with a systematic review, and a single trend data can be obtained from scattered studies containing different characteristics (Binbay et al., 2011). The meta-Analysis, in short, is the analysis of analyses that combine the results of other studies consistently and harmoniously manner (Cohen et al., 2007). In this context, meta-analysis is the most suitable method for this study, which aims to combine and analyze in detail the studies conducted in our country between 2000-2016 to determine the effect of technology on student achievement in mathematics and geometry lessons. Besides, although the meta-analysis method has been a very popular in recent years, it is seen that the number of studies conducted with the meta-analysis method is quite low in Turkey, and the method has entered the domestic literature after the 2000s (Özcan, 2008). In this direction, it is thought that this study will contribute to the relevant literature.

Data Collection (Application Process)

Databases of ERIC (2015), Google Scholar (2015), and Turkish Academic Network and Information Center (ULAKBİM) (2015) scanned to access the articles published in journals, conference presentations, and papers obtained from the related subjects to answer the research questions, while Council of Higher Education in Turkey (CoHE) National Thesis Center was referred to for masters and doctoral dissertations. Apart from this, it has been tried to reach related studies by following the bibliography of similar studies that can be accessed from various search engines, libraries, and web pages of universities. The specified databases were first scanned in March 2015, and new studies were included in the research by re-scanning in January 2016.

Studies have been scanned using keywords such as "technology-supported teaching/learning / education", "technology-based/based teaching/learning/ education", "mathematics / geometry", "mathematics/geometry achievement", "mathematics achievement", "academic achievement", "technology-based learning / teaching / training", "technology-assisted learning / teaching / training", "effectiveness of technology-assisted education over mathematics achievement". 176 master's and doctoral theses and 107 articles in Turkey about the TAI between the years 2000 and 2016 have been reached. The studies found were included in the study pool according to the experimental studies' criteria in the scanned 16 years (2000-2016). Studies that do not have the necessary data for meta-analysis studies are eliminated. According to the selection features, a total of 98 studies including 11 doctoral theses, 70 master's theses and 17 articles were determined. It was seen that of these studies, 52 studies on mathematics and 46 studies on geometry research according to the academic achievement variable. While determining the course area to which the studies belong, the sub-learning area's acquisitions in which the application is carried out were taken as a basis. These studies included in the study are given in ANNEX-2.

Inclusion Criteria

Determining the criteria is the most critical point of meta-analysis. The criteria determine which studies will be included in the analysis and which will not. The criteria can be more than one. The most common criteria are experimental studies, data type, time frame, keywords, database, and publication type (Dinçer, 2014). The criteria for the inclusion of the research to be used for meta-analysis in this study are as follows:

- Aiming to determine the effectiveness level of technology-supported methods in teaching mathematics and geometry between 2000 and 2016.
- The subject sample is within the borders of Turkey.
- Studies that can be accessed from published theses, periodical academic journals, online academic journals, databases, academic studies presented in congresses and papers.
- Experimental studies with pretest-posttest control groups and the topics were taught to the experimental group by technology-supported methods and by traditional methods in the control group.
- Having the numerical data (arithmetic mean, standard deviation, sample numbers of the experimental group and the control group) is necessary for calculating the effect size.

Data Coding

Studies to be included in the meta-analysis were first saved in an electronic file format with a pdf extension, and a common data repository was created. These studies are grouped under three main headings in the Microsoft Excel worksheet: work identity, study content, and study data. Related data are presented under three headings as in Table 1.

Table 1. Coding Formats of Studies

Study ID	Study Content	Statistics
Title Authors Year City City the Study Applied Publication Type	Learning Area (Mathematics /Geometry) Subject Applied Learning Level Method/Technique Used Application Period Dependent Variable (Achievement)	Sample Size (N) Arithmetic Mean (X) Standard Deviation (SD)

Data were obtained by opening a column for each subtitle and adding the investigated studies under the sections they belonged to in the coding form. To ensure coding reliability, the data were coded for a second time independently from the previous ones after a while. The coding form is given in ANNEX-1.

Dependent Variables

The research's dependent variable is the effect sizes of the TAI calculated based on the students' academic achievement scores in mathematics and geometry lessons.

Study Characteristics

Study characteristics are independent variables of meta-analysis. Study characteristics are coded to evaluate the relationships between the effect sizes, and they are used as explanatory variables in data analysis (Tarım, 2003). The operating characteristics added to the coding form (Annex-1) are listed as follows:

- Publication Year
- Publication Type (master's thesis, doctoral dissertation, article)
- Learning Area (Mathematics /Geometry)
- Grade Level of the Sample
- Techniques used (software, computer, interactive board, projector, calculator, distance education... and others)
- Sample Size

Categorical Descriptive Statistics of the Studies Included in the Study

To calculate the effect size of the students' academic achievements in the mathematics and geometry lessons of TAI, 52 studies within the scope of mathematics lessons and 46 studies within the scope of geometry lessons which met the criteria determined were examined. The information about these studies, whose statistical significance level is accepted as p = 0.05, are specified in the Table of Studies Included in the Meta-Analysis in Annex-2. Descriptive statistics of these studies for categorical independent variables are presented in Table 2.

Table 2. Frequency and Percentage Values for the Categorical Independent Variables of Studies that Contain Data on Academic Achievement

Variable	Frequency		Percentage	
	Mathematics	*Geometry*	*Mathematics*	*Geometry*
Year of Publication				
2002	1	0	1,92	0
2003	0	1	0	2,17
2004	1	0	1,92	0
2005	2	0	3,85	0
2006	2	2	3,85	4,34
2007	6	5	11,53	10,87
2008	8	4	15,38	8,69
2009	7	4	13,46	8,69
2010	5	7	9,61	15,21
2011	5	7	9,61	15,21
2012	5	7	9,61	15,21
2013	3	5	5,76	10,87
2014	6	3	11,53	6,52
2015	0	1	0	2,17
Type of Publication				
PhD Thesis	9	2	17,30	4,34
Master's Thesis	34	36	65,38	78,26
Paper	9	8	17,30	17,39
Level of Application				
Pre-school	1	1	1,92	2,17
Elementary	4	2	7,69	4,34
Middle School	24	32	46,15	69,57
High School	12	2	23,07	4,34
University (Undergraduate)	11	3	21,15	6,52
Technology Used				
Interactive board	5	3	9,61	6,52
Computer	15	7	25	13,04
Calculator	2	0	3,85	0
Software applications	20	36	42,30	80,43
Web Supported	10	0	19,23	0
Total	52	46		

When Table 2 is analysed according to the years in which the studies were conducted, it is observed that the number of studies containing data on the academic achievement variable among the studies included in the analysis increased after 2007. While studies investigating the effectiveness of TAI on the achievement of mathematics lessons focused especially between the years of 2007-2009, it is observed that the studies examining the achievement of the geometry lesson increased in 2009-2012. It is safe to say that the number of master's theses ranks first with a high rate of 71.43% in terms of the type of publication of the studies included in the analysis. Based on the grade level, the studies conducted at the secondary school (5^{th}, 6^{th}, 7^{th}, and 8^{th} grades) level have 57.17% of the studies included in the meta-analysis and constitute more than half of the studies included in the research. To examine the effectiveness of TAI methods on the academic achievement variable, it is seen that the most used technique in the implementation process of the studies, software programs with a rate of 42.30% for mathematics lessons and 80.43% for geometry lessons.

Data Analysis

The term that forms the nature of meta-analysis is the effect size. The effect size, which is also mentioned in the literature as the effect coefficient, is used in a study to give information about how the independent variable affects the dependent variable positively or negatively (Dinçer, 2014). For this purpose, the impact coefficients of the studies included in the research were calculated using the method developed by Hedges by using the Transaction Effectiveness Meta-Analysis in Group Comparison in the analysis of the data. The homogeneity test was performed for the effect size values found, and the "fixed effects" model was used in cases where homogeneity was achieved; otherwise, the "random effects" model was preferred. Since the significance level was taken as 0.05 in the studies included, 0.05 was determined as the significance level of the statistical analyses in this study. Below, various transformation formulas used in effect size calculations are given:

Table 3. Statistical Data Conversion Table

Statistics to be Converted	Formulas	Commentary
Means and Standard Deviations	$d = \frac{X_e - X_c}{S_p}$	d = Effect Size X_e= Mean of Experimental Group X_c= Mean of Control Group S_p= Sum of Squares
Sum of Squares	$S_p^2 = \frac{(N_e-1)S^2e + (N_c-1)S^2{}_c}{(N_e+N_c-2)}$	N_e = Size of Experimental Group N_c = Size of Control Group S_e^2= Variance of Experimental Group S_c^2= Variance of Control Group S_p = Sum of Squares
t	$d = \frac{2t}{\sqrt{df}}$ $df = N_e + N_c - 2$	Used in independent or paired groups t test. d = Effect Size df =Degrees of freedom N_e = Size of Experimental Group N_c = Size of Control Group
F	$d = \frac{2\sqrt{F}}{\sqrt{df(error)}}$	Used only in the study when given the F statistic value. df =Degrees of freedom d = Effect Size
		Used only in the study when given the r statistic value.

r	$d = \frac{2r}{\sqrt{1-r^2}}$	d = Effect Size $Var(d)$ = d Variance of Effect Size
Variance	$Var(d) = \frac{N_c + N_e}{N_c \cdot N_e} + \frac{d^2}{2(N_c + N_e)}$	$Serr = d$ Standard Error of Effect Size
Standard Error	$Serr = \sqrt{Var(d)}$	

The conversion formula used for effect size:

$$d = \frac{X_e - X_c}{S_p}$$

d = Effect Size
X_e= Mean of Experimental Group
X_c= Mean of Control Group
S_p= Sum of Squares
The conversion formula used for summed standard variance:

$$S_p^2 = \frac{(N_e - 1)S_e^2 + (N_c - 1)S_c^2}{(N_e + N_c - 2)}$$

The conversion formula used for the summed standard deviation:

$$S_p = \sqrt{\frac{(N_e - 1)S_e^2 + (N_c - 1)S_c^2}{(N_e + N_c - 2)}}$$

N_e = Size of Experimental Group
N_c = Size of Control Group
S_e^2= Variance of Experimental Group
S_c^2= Variance of Control Group
S_p = Sum of Squares
The conversion formula used in effect size calculations from t test:

$$d = \frac{2t}{\sqrt{df}}$$

$$df = N_e + N_c - 2$$

The conversion formula used in effect size calculations from F test:

$$d = \frac{2\sqrt{F}}{\sqrt{df(error)}}$$

$$df = df(error)$$

While interpreting the calculated effect sizes, two effect size classification methods were used. One of them is one of the most frequently used classifications in the literature based on arithmetic averages developed by Cohen (1988). According to Cohen's, the other is the one developed by Thalheimer and Cook (2002), which is a relatively more detailed classification.

Classification of Cohen (1988) d = 0.20 - 0.50 low level (small); d = 0.50 - 0.80 medium level (medium); d = 0.80 <d is high level (large). In addition, the following comments are made for the effect sizes whose values vary between -∞ and ∞ as a result of the calculations (Cohen, 1998):

- If the effect size is zero, there is no difference between the experiment and control group.
- If the effect size is negative (-), the situation favors the control group, and the application has created an adverse effect.
- If the effect size is positive (+), it has a positive effect in favor of the experimental and application groups.
- The classification predicted by Thalheimer and Cook (2002) is - 0.15 <d <0.15 negligible; 0.15 <d <0.40 low level (small); 0.40 <d <0.75 medium; 0.75 <d <1.10 high (large); 1.10 <d <1.45 very large; 1.45 <d is perfectly (huge).

To perform the calculations and graphics in this meta-analysis study, mainly the CMA (Comprehensive Meta-Analysis) statistical package program was used, but the MS Office Excel 2010 program was also used.

Findings

Within the scope of the study, quantitative studies comparing the effect of traditional methods with the technology-supported teaching (TAI) in mathematics and geometry education between 2000 and 2016 on academic achievement were examined. This examination led to the selection of 98 studies, including 11 doctoral theses, 70 master's thesis and 17 articles conducted in Turkey with relevant TAI methods. Afterwards, the effect sizes of these 98 (52 mathematics and 46 geometries) studies containing data on academic achievement variables suitable for inclusion criteria to do meta-analysis were analysed. In addition, data belonging to a sample group of 6202 people in total, 3546 of which are mathematics and 2656 of which are geometry, were examined within these studies. In this part of the study, the effect size values obtained by meta-analytical method and their interpretations are given.

Findings of TAI's Effect on Academic Achievement Analysis in Mathematics and Geometry Lessons

To find an answer to the first sub-problem of the study, "What kind of effect does TAI have on the academic achievement of students in mathematics and geometry?" The relevant data in the studies were analyzed via meta-analysis method. Effect size findings obtained from this analysis are presented under subheadings, viz. fixed and random effects model findings, forest plot, homogeneity test results, and publication bias findings.

Uncombined Findings of the Effect Size Analysis of Studies According to Academic Achievement Variable

Hedges D effect sizes of the studies containing data on the sub-problem of *"What kind of effect does TAI have on the academic achievement of students in mathematics and geometry? "* error values and the minimum and maximum values within 95% confidence interval are given in order, in Table 4 (mathematics lesson) and Table 5 (geometry lesson).

Table 4. Hedges D Effect Size Analysis Concerning Academic Achievement in Mathematics Course Uncombined Findings

Study	Effect Size (d)	Standart Error	Variance	Lower Limit	Upper Limit
Şen, 2010	- 0,441	0,331	0,109	- 1,089	0,207
Öner et all, 2014	- 0,251	0,336	0,113	- 0,910	0,408
Erginbaş, 2009	- 0,179	0,311	0,096	- 0,788	0,429
Çelik & Çevik, 2011	- 0,001	0,259	0,067	- 0,509	0,507
Ünlü, 2007	0,013	0,232	0,054	- 0,442	0,467

Yigit, 2007	0,056	0,287	0,083	- 0,507	0,620
Esen, 2009	0,224	0,113	0,013	0,004	0,445
Tataroğlu, 2009	0,323	0,183	0,033	- 0,036	0,681
Aksoy, 2014	0,341	0,313	0,098	- 0,272	0,954
Aktümen, 2002	0,351	0,281	0,079	- 0,199	0,901
Şimşek, 2012	0,352	0,338	0,114	- 0,309	1,014
Kabaca, 2006	0,366	0,358	0,128	- 0,337	1,068
Ağaç, 2009	0,430	0,322	0,104	- 0,201	1,061
Karasel et all, 2009	0,441	0,265	0,070	- 0,078	0,960
Memişoğlu, 2005	0,497	0,195	0,038	0,115	0,879
Balkan, 2013	0,534	0,329	0,108	- 0,110	1,178
Aksoy et all, 2012	0,539	0,174	0,030	0,198	0,879
Turgut, 2010	0,558	0,219	0,048	0,128	0,988
Uygun, 2008	0,579	0,241	0,058	0,105	1,052
Özyurt ,2013	0,586	0,197	0,039	0,200	0,972
Aşıcı, 2014	0,587	0,256	0,066	0,085	1,090
Yorgancı, 2014	0,595	0,263	0,069	0,080	1,110
Arslan, 2008	0,600	0,261	0,068	0,089	1,111
Yorgancı & Terzıoğlu, 2013	0,603	0,261	0,068	0,092	1,114
Önür, 2008	0,610	0,275	0,075	0,071	1,148
Gelibolu, 2008	0,628	0,263	0,069	0,112	1,145
Tuluk, 2007	0,668	0,366	0,134	- 0,049	1,385
Tural & Sönmez, 2012	0,685	0,235	0,055	0,224	1,147
Aksoy, 2007	0,715	0,309	0,096	0,109	1,321
Kılıç, 2007	0,725	0,303	0,092	0,131	1,318
Çubuk, 2004	0,773	0,265	0,070	0,254	1,292
İnam, 2014	0,824	0,320	0,102	0,198	1,450
Özkök, 2010	0,884	0,284	0,081	0,327	1,440
Yazlık, 2011	0,884	0,179	0,032	0,532	1,236
Buran, 2005	0,961	0,211	0,045	0,547	1,375
Ekici, 2008	1,024	0,271	0,074	0,492	1,556
Şimşek, 2010	1,051	0,287	0,082	0,489	1,613
Gökcül, 2007	1,072	0,329	0,108	0,427	1,717
Doğan, 2009	1,105	0,254	0,065	0,606	1,603
Kutluca, 2009	1,111	0,383	0,147	0,360	1,862
Andıç, 2012	1,115	0,361	0,130	0,407	1,823
Özdoğan, 2008	1,120	0,238	0,057	0,652	1,587
Kepçeoğlu, 2010	1,226	0,339	0,115	0,562	1,890
Baytur, 2011	1,307	0,281	0,079	0,756	1,859
Bayturan & Keşan, 2012	1,307	0,281	0,079	0,756	1,859
Alabay, 2006	1,497	0,336	0,113	0,837	2,156
İnce, 2008	1,503	0,278	0,077	0,957	2,048
Oğuz, 2008	1,568	0,267	0,071	1,044	2,092
Zengin, 2011	1,606	0,318	0,101	0,982	2,230
Kan, 2014	1,990	0,294	0,087	1,413	2,567

Fırat, 2011	3,728	0,348	0,121	3,046	4,409

When Table 4 is examined, it is observed that the effect sizes of 52 studies standardized according to the mathematics lesson's academic achievement variable vary between -0.441 and 3.728.

Table 5. Hedges Effect Size Analysis Related to Academic Achievement in Geometry Course Uncombined Findings

Study	Effect Size (d)	Standart Error	Variance	Lower Limit	Upper Limit
Uzun, 2013	0,033	0,340	0,115	- 0,633	0,699
Akyar, 2010	0,050	0,253	0,064	- 0,446	0,545
Genç, 2010	0,478	0,240	0,058	0,008	0,948
Takunyacı, 2007	0,479	0,237	0,056	0,015	0,943
Uygan, 2011	0,525	0,289	0,083	- 0,042	1,091
Kurak, 2009	0,535	0,337	0,113	- 0,124	1,195
Özçakır, 2013	0,587	0,232	0,054	0,132	1,043
Şataf, 2010	0,587	0,296	0,088	0,007	1,168
Gülbağcı, 2009	0,607	0,303	0,092	0,012	1,202
Karakuş, 2008	0,648	0,287	0,082	0,085	1,211
Önal & Demir, 2012	0,663	0,301	0,091	0,072	1,253
Demir, 2010	0,670	0,262	0,069	0,156	1,183
Akçayır, 2011	0,671	0,153	0,023	0,372	0,970
Öztürk, 2012	0,678	0,281	0,079	0,127	1,229
Egelioğlu, 2008	0,699	0,367	0,134	- 0,020	1,417
Özdemir &Tabuk, 2003	0,754	0,242	0,058	0,280	1,227
Erdoğan, 2014	0,782	0,270	0,073	0,252	1,312
Özen, 2009	0,798	0,323	0,104	0,166	1,430
Sarı, 2012	0,800	0,295	0,087	0,221	1,379
Yıldız, 2009	0,800	0,302	0,091	0,209	1,392
Efendioğlu, 2006	0,810	0,233	0,055	0,352	1,267
Baki & Özpınar, 2007	0,830	0,250	0,063	0,340	1,320
Sarı, 2012	0,885	0,298	0,089	0,301	1,469
Birgi et all, 2007	0,961	0,317	0,100	0,340	1,582
Altın, 2012	0,991	0,329	0,108	0,346	1,636
Kaya et all, 2013	1,002	0,342	0,117	0,332	1,673
İçel, 2011	1,043	0,331	0,110	0,394	1,692
Uzun,2 014	1,088	0,327	0,107	0,448	1,728
Mercan, 2012	1,135	0,349	0,122	0,451	1,818
Öz, 2012	1,289	0,175	0,031	0,946	1,633
Karadeniz &Akar, 2014	1,290	0,428	0,183	0,451	2,129
Toker, 2008	1,291	0,376	0,142	0,554	2,029
Tutak, 2008	1,298	0,352	0,124	0,607	1,989
Selçik & Bilgici, 2011	1,352	0,384	0,148	0,599	2,106
Eryiğit, 2010	1,495	0,266	0,071	0,973	2,016
Küslü, 2015	1,510	0,305	0,093	0,912	2,108

Topaloğlu, 2011	1,573	0,356	0,127	0,875	2,272
Kaya, 2013	2,100	0,440	0,194	1,237	2,962
Kaya, 2013	2,100	0,440	0,194	1,237	2,962
Helvacı, 2010	2,192	0,309	0,096	1,586	2,798
Aydoğa, 2007	2,228	0,219	0,048	1,799	2,658
Tayan, 2011	2,355	0,342	0,117	1,685	3,026
Abdüsselam,2006	2,589	0,593	0,351	1,428	3,751
Budak, 2010	2,644	0,351	0,123	1,956	3,331
Kesici, 2011	2,916	0,518	0,268	1,901	3,930
Gündüz et all, 2007	3,124	0,263	0,069	2,609	3,639

When Table 5 is examined, it is seen that the standardized effect sizes of 46 studies according to the academic achievement variable in the geometry lesson vary between 0.033 and 3.124 values. The frequency and percentage values of these studies' effect size aspects, in which TAI was examined in terms of academic achievement, are given in Table 6.

Table 6. Frequency and Percentage Table for Effect Size According to Academic Achievement Variable

Effect Size Direction	Frequency		Percentage	
	Mathematics	Geometry	Mathematics	Geometry
0 (Zero)	0	0	0	0
+(Positive)	48	46	92.30	100
- (Negative)	4	0	7.69	0

Looking at the effect sizes in Table 6, it is seen that 48 studies (92.3%) have positive, and 4 studies (7.69%) have negative effect sizes for mathematics. When it comes to the geometry lesson, it is seen that all 46 studies have positive effect sizes. The positive effect size values indicate that the academic achievement value in these studies favors the experimental group, depending on the degree of effect size. If the value of the effect size is negative, it reveals that the achievement scores in the studied study are in favor of the control group, depending on the effect size (Wolf, 1986). Based on this result, a negative effect size percentage being 7.69% shows that the result favors the control group in these studies. In other words, these data show that student achievement, which is the studied variable, is in favor of TAI from the aspect of the effect size.

The effect sizes of the studies examined according to the academic achievement variable in the study were categorized based on Cohen's (1988) classification. Since the lower limit value in the effect size classification of Cohen (1988) is 0.20, it can be said that "no statistically significant effect has been found" for studies whose effect size is below this value. Effect sizes of 6 studies in mathematics (Şen, 2010; Öner et al., 2014; Erginbaş, 2009; Çelik & Çevik, 2011; Ünlü, 2007; Yiğit 2007) and 2 studies in geometry (Uzun, 2013; Akyar, 2010) remained below this value. The frequency and percentage values of studies above 0.20 are listed in Table 7 below:

Table 7. Frequency and Percentage Table of Cohen's Classification of Effect Size According to Academic Achievement Variable

Effect Size Level	Frequency		Percentage	
	Mathematics	Geometry	Mathematics	Geometry
Small	9	2	17.30	4.35
Medium	17	14	32.69	30.43
Large	20	28	38.46	60.86

According to Thalheimer and Cook's (2002) more detailed scale, effect sizes of these studies were classified. In this classification, the effect sizes of 3 studies (Şen, 2010; Öner et al., 2014; Erginbaş, 2009) in the field of mathematics, and the effect sizes of 0 (zero) study in the geometry field was seen below the lower limit of Thalheimer's and Cook's scale, -0.15. Since they are not within the confidence interval to which the effect size belongs, we can say that TAI does not significantly affect academic achievement in these studies. Effect size, frequency, and percentage values of the other studies are listed in Table 8 below:

Table 8. Frequency and Percentage Table of the More Detailed Classification of Effect Size According to Academic Achievement Variable (Thalheimer & Cook, 2002)

Effect Size	Frequency		Percentage	
	Mathematics	Geometry	Mathematics	Geometry
Negligible	3	2	5.77	4.34
Low	6	0	11.54	0.00
Medium	19	13	36.54	28.26
High	9	13	11.54	28.26
Very High	6	6	11.54	13.04
Excellent	6	12	11.54	26.08

In Table 8, based on Thalheimer and Cook's (2002) more detailed effect size classification, it was seen that the highest frequency for the effect size in the mathematics lesson is at a medium level with 19 studies (36.54%), and was perfect in the geometry lesson, with 12 studies (26.08%). In this context, it can be said that in most of the studies within this analysis, technology-assisted teaching has a greater effect on student achievement than traditional teaching.

Forest Graph of Studies According to Academic Achievement Variable

Figure 1 and Figure 2 show the forest graph of the studies included in the study according to the academic achievement variable in mathematics and geometry lessons, respectively.

Study name	Statistics for each study				
	Hedges's g	Standard error	Variance	Lower limit	Upper limit
ARSLAN. 2008	0.600	0.261	0.068	0.089	1.111
ERGINBAS.2009	-0.179	0.311	0.096	-0.788	0.429
TULUK 2007	0.668	0.366	0.134	-0.049	1.385
BAYTUR. 2011	1.307	0.281	0.079	0.756	1.889
KUTLUCA 2009	1.111	0.383	0.147	0.360	1.862
KABACA 2006	0.366	0.358	0.128	-0.337	1.068
AKSOY 2007	0.715	0.309	0.096	0.109	1.321
ÖZYURT 2013	0.586	0.197	0.039	0.200	0.972
YAZLIK 2011	0.884	0.179	0.032	0.532	1.236
SİMSEK 2012	0.352	0.338	0.114	-0.309	1.014
AGAC 2009	0.430	0.322	0.104	-0.201	1.061
KERCEDGLU 2010	1.226	0.339	0.115	0.562	1.890
ZENGIN 2011	1.606	0.318	0.101	0.982	2.230
CELIK CEMK 2011	-0.001	0.259	0.067	-0.509	0.507
SÖNMEZ. ARTUT	0.686	0.235	0.055	0.224	1.147
KARAGEL. AYDA TEZER 2009	0.441	0.265	0.070	-0.078	0.960
AKSOY CALIK ÇINAR 2012	0.539	0.174	0.030	0.198	0.879
DOGAN 2009	1.105	0.254	0.065	0.606	1.603
BAYTURAN. KESAN. 2012	1.307	0.281	0.079	0.756	1.889
YORGANCI.TERZIOGLU 2013	0.603	0.261	0.068	0.092	1.114
OGUZ 2008	1.568	0.267	0.071	1.044	2.092
YIGIT 2007	0.066	0.287	0.083	-0.507	0.620
MEMISOGLU 2006	0.497	0.195	0.038	0.115	0.879
TATAROGLU 2009	0.323	0.183	0.033	-0.036	0.681
ESEN 2009	0.224	0.113	0.013	0.004	0.445
ÖZDOGAN 2008	1.120	0.238	0.057	0.652	1.587
ALABAY 2006	1.497	0.336	0.113	0.837	2.156
BURAN 2006	0.961	0.211	0.045	0.547	1.375
ÖZKÖK 2010	0.884	0.284	0.081	0.327	1.440
EKICI 2008	1.024	0.271	0.074	0.492	1.556
BALKAN 2013	0.534	0.329	0.108	-0.110	1.178
KILIC 2007	0.725	0.303	0.092	0.131	1.318
GELIBOLU 2008	0.628	0.263	0.069	0.112	1.145
UYGUN 2008	0.579	0.241	0.058	0.105	1.052
TURGUT 2010	0.558	0.219	0.048	0.128	0.988
TURAL SÖNMEZ 2012	0.686	0.235	0.055	0.224	1.147
AKTÜMEN 2002	0.351	0.281	0.079	-0.199	0.901
GÖKCÜL 2007	1.072	0.329	0.108	0.427	1.717
INCE 2008	1.503	0.278	0.077	0.957	2.048
SEN 2010	-0.441	0.331	0.109	-1.089	0.207
SIMSEK 2010	1.051	0.287	0.082	0.489	1.613
FIRAT 2011	3.728	0.348	0.121	3.046	4.409
CUBUK 2004	0.773	0.265	0.070	0.254	1.292
ANDIC 2012	1.115	0.361	0.130	0.407	1.823
ÜNLÜ 2007	0.013	0.232	0.054	-0.442	0.467
ÖNÜR 2008	0.610	0.275	0.075	0.071	1.148
INAM 2014	0.824	0.320	0.102	0.198	1.450
AKSOY 2014	0.341	0.313	0.098	-0.272	0.954
ASICI 2014	0.587	0.256	0.065	0.085	1.090
KAN 2014	1.990	0.294	0.087	1.413	2.567
ÖNER YILDIRIM BARS 2014	-0.251	0.336	0.113	-0.910	0.408
YORGANCI 2014	0.595	0.263	0.069	0.080	1.110
	0.687	0.035	0.001	0.618	0.756

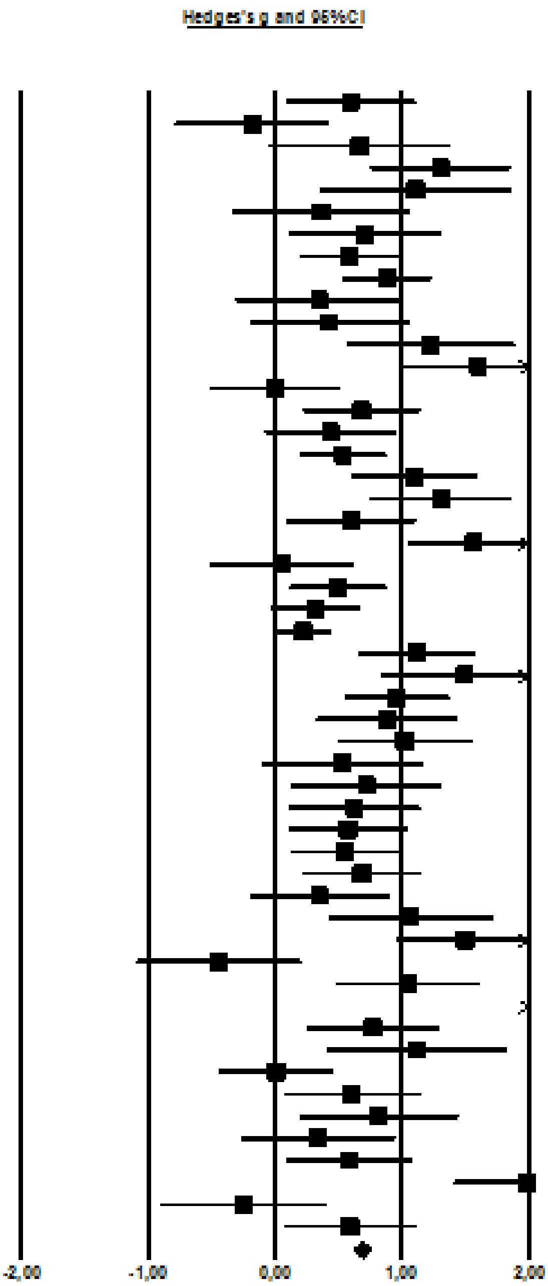

Figure 1. Effect Sizes Related to Academic Achievement in Mathematics Lesson Forest Graph

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit
ÖZ, 2012	1,295	0,176	0,031	0,950	1,641
EFENDIOGLU,2006	0,818	0,236	0,056	0,356	1,280
AYDOGA, 2007	2,241	0,220	0,049	1,809	2,673
ÖZTÜRK, 2012	0,689	0,285	0,081	0,129	1,248
HELVACI, 2010	2,218	0,313	0,098	1,604	2,831
ÖZCAKIR, 2013	0,593	0,235	0,055	0,133	1,053
UYGAN, 2011	0,534	0,294	0,086	-0,042	1,109
ÖZEN, 2009	0,814	0,329	0,108	0,169	1,459
TAYAN, 2011	2,388	0,347	0,120	1,709	3,068
GENC, 2010	0,484	0,243	0,059	0,008	0,959
KAYA G, 2013	2,156	0,452	0,204	1,271	3,042
GÜLBAGCI, 2009	0,618	0,309	0,095	0,013	1,224
SARII, 2012	0,900	0,303	0,092	0,306	1,493
SARI, 2012	0,813	0,300	0,090	0,225	1,402
SATAF, 2010	0,598	0,301	0,091	0,007	1,188
EGELYOGLU, 2008	0,718	0,377	0,142	-0,020	1,457
TOPALOGLU, 2011	1,605	0,364	0,132	0,892	2,318
AKYAR, 2010	0,050	0,256	0,066	-0,452	0,552
MERCAN, 2012	1,160	0,356	0,127	0,461	1,858
TAKUNYACI, 2007	0,484	0,239	0,057	0,015	0,953
UZUN, 2013	0,034	0,348	0,121	-0,648	0,717
KARAKUS, 2008	0,656	0,291	0,085	0,087	1,225
ERYIGIT, 2010	1,511	0,269	0,072	0,984	2,039
ICEL, 2011	1,065	0,338	0,114	0,402	1,727
ALTIN, 2012	1,011	0,336	0,113	0,353	1,669
BUDAK, 2010	2,678	0,356	0,126	1,981	3,375
TUTAK, 2008	1,326	0,360	0,130	0,620	2,032
DEMIR, 2010	0,679	0,266	0,071	0,158	1,199
KURAK,2009	0,548	0,344	0,119	-0,127	1,223
TOKER, 2008	1,324	0,386	0,149	0,568	2,080
YILDIZ, 2009	0,814	0,307	0,094	0,213	1,416
ÖZDEMIR, TABUK, 2003	0,762	0,244	0,060	0,283	1,240
KAYA, KESAN, IZGIOL, 203	1,024	0,350	0,122	0,339	1,710
BAKI, ÖZPINAR, 2007	0,840	0,253	0,064	0,344	1,336
SELCIK, BILGICI, 2011	1,387	0,394	0,156	0,614	2,160
ÖNAL, DEMIR, 2012	0,675	0,307	0,094	0,074	1,276
BIRGIN, KUTLUCA,GRBÜZ,2007	0,979	0,323	0,104	0,346	1,612
GÜNDÜZ,EMLEK,BOZKURT,2007	3,143	0,264	0,070	2,625	3,661
KAYA, 2013	2,156	0,452	0,204	1,271	3,042
AKCAYIR, 2011	0,674	0,153	0,023	0,373	0,974
ABDÜSSELAM, 2006	2,704	0,619	0,383	1,491	3,916
ERDOGAN, 2014	0,793	0,274	0,075	0,256	1,330
KÜBLÜ, 2015	1,532	0,310	0,096	0,925	2,139
KESIC, 2011	2,997	0,532	0,283	1,954	4,039
UZUN, 2014	1,109	0,333	0,111	0,457	1,761
KARADENIZ,AKAR, 2014	1,334	0,443	0,196	0,467	2,201
	1,071	0,043	0,002	0,987	1,155

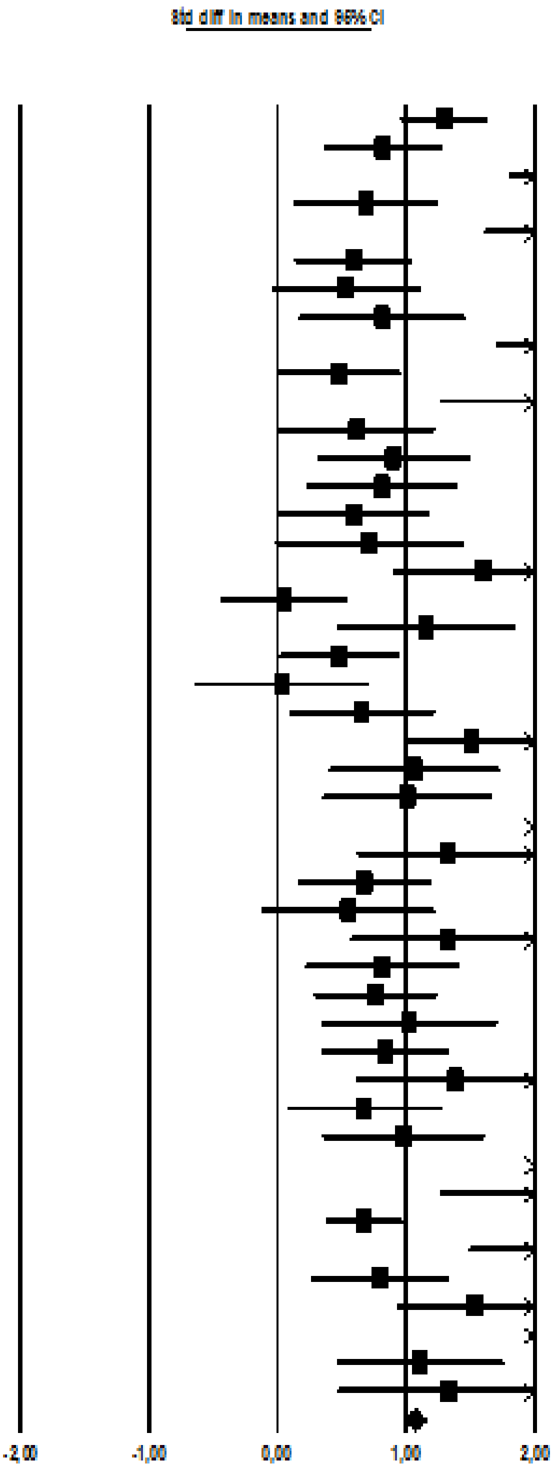

Figure 2. Effect Sizes Related to Academic Achievement in Geometry Lesson Forest Graph

When Figure 1 and Figure 2 are examined, it is seen that there is a meaningful difference in favor of TAI in terms of its effect on student achievement in both mathematics and geometry lessons. In these figures, each square shows the effect size value of the study it belongs to, and the lines extending to the right and left of each square show the 95% confidence interval for the value. The area of each square corresponds to the weight of individual studies in meta-analysis. As the sample size and precision increase, the weight of the study in meta-analysis will increase, so large squares also show studies with large samples. Finally, the diamond representation at the bottom indicates the overall effect size estimation obtained from meta-analysis and its confidence interval (Üstün & Eryılmaz, 2014).

Findings of the Effect Size Meta-Analysis in Terms of Academic Achievement Variable According to the Fixed Effects Model

To find an answer to the sub-problem ``Does technology supported teaching influence students' academic achievement in mathematics and geometry? '' according to the fixed effect model; mean of the combined effect sizes of the general effect sizes, standard error, and the lower and upper limits according to 95% confidence interval without eliminating extreme values are shown on Table 9 below:

Table 9. Findings According to Fixed Effects Model of Effect Size Meta-Analysis in case of Academic Achievement Variable

Study	Effect Size (d)	S.E.	Variance	Lower Limit	Upper Limit	Z	p
Mathematics	0.687	0.035	0.001	0.618	0.756	19.453	0.000
Geometry	1.056	0.042	0.02	0.973	1.139	24.192	0.000

As seen in Table 9, the effect size values of the studies containing data on the academic achievement are variable and combined according to the fixed effect model. The effect size value is ES = 0.687 for the mathematics lesson and the standard error of this effect size is SE = 0.035 while the lower and upper limit of the mean effect size is calculated as 0.618 and 0.756, respectively. For the geometry lesson, the combined effect size value according to the fixed effects model is ES = 1.056. The standard error SE = 0.042, and the lower limit of the effect size confidence interval are 0.973, while the upper limit is 1.139.

According to the fixed effects model, analysis values were found to favor TAI in mathematics lesson achievement compared to traditional methods. Since the effect size value is in the range of 0.5-0.8 for mathematics achievement, it has been determined that it has a moderate effect, according to Cohen's classification (Cohen, 1988). According to Thalheimer and Cook (2002) classification, it has been found to have a moderate effect, too, since the effect size is between 0.40-0.75. When the analysis values of the studies that contain data on the academic achievement variable are analysed according to the fixed effects model in the field of geometry, a result in favor of TAI is encountered again. Since the effect size value corresponds to a value greater than 0.8 for student achievement in geometry lessons, it has a high effect, according to Cohen's classification (Cohen, 1988). According to the more detailed classification of Thalheimer and Cook (2002), it is a very high (1.10 - 1.45) level difference.

Heterogeneity Test and Q-Statistics

When the statistical significance was calculated according to the Z test, it was found as Z = 19.449 in the mathematics lesson area, and Z = 29.914 in the geometry lecture area while the result obtained in both branches was found to be statistically significant with p = 0.000. It may be possible to understand the homogeneity and heterogeneity of the studies with funnel charts given in Figure 3 and Figure 4.

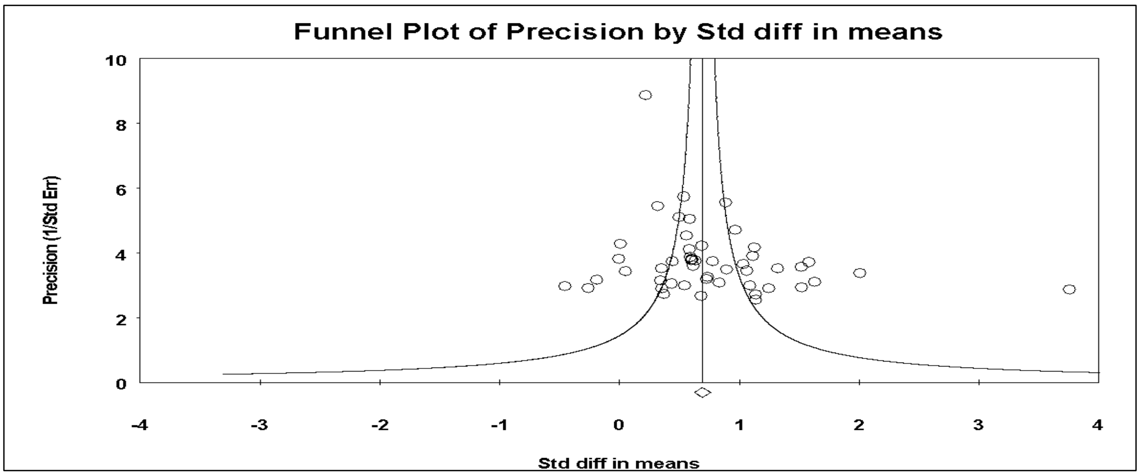

Figure 3. Funnel Plot of Studies Including Effect Size Data on Academic Achievement in Mathematics Lesson

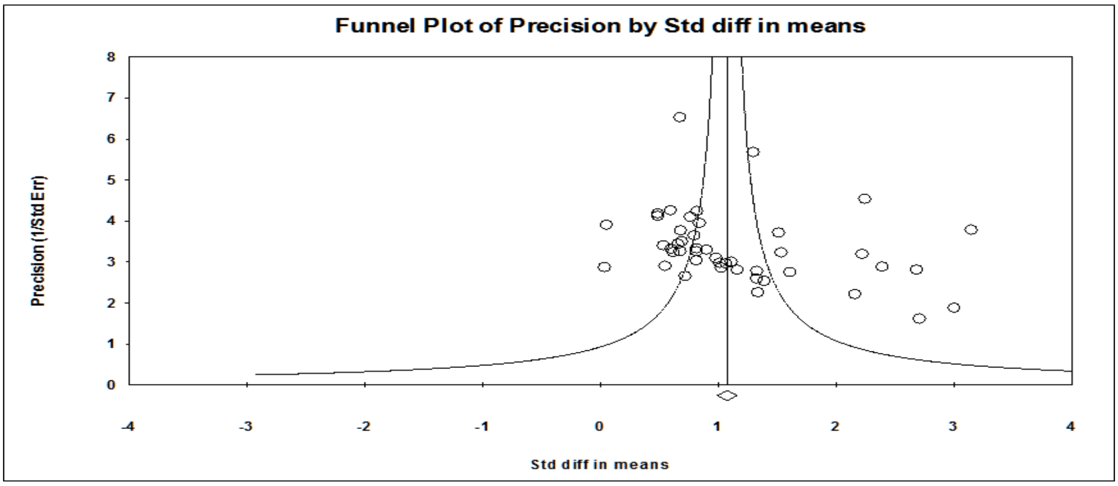

Figure 4. Funnel Plot of Studies Including Effect Size Data on Academic Achievement in Geometry Lesson

As shown in Figure 3 and Figure 4, the funnel graph is limited to ± 1 slope. It can be interpreted that the studies are heterogeneous since almost all individual studies are not within the slope lines. However, to interpret the heterogeneity situation more precisely, the Q-statistics (homogeneity test) should definitely be examined (Dinçer, 2014). The data of the effect size values resulting from the homogeneity test are just as in Table 10.

Table 10. Homogeneity Test Results of Effect Size Distribution in Terms of Academic Achievement Variable

	Q Value	df (Q)	p
Mathematics	236.524	51	0.000
Geometry	253.644	45	0.000

When Table 10 is examined, it is seen that Q-statistics is calculated as Q = 236,524 for the mathematics. At the 95% level of significance, 51 degrees of freedom from the $\times^2$-table corresponds to a value of 67,505. Since the Q-statistic value (Q = 236,524) with 15 degrees of freedom is greater than the critical value of the $\times^2$ distribution (67,505), the absence hypothesis of homogeneity for the distribution of effect sizes was rejected in the fixed effects model. In other words, it is understood that the studies have a heterogeneous structure (Dinçer, 2014). Since the homogeneity test due to the sampling error was higher than expected, the variance of the random effect component was calculated, and the model was converted into a random effects model (Kış, 2014). Likewise, the Q = 253,644 value found for the geometry lesson corresponds to the value of 45 degrees of freedom 61,656 from the $\times^2$-table at the 95% significance level. Since the Q-statistic value (Q = 253,644) is greater than the critical value of the $\times^2 2$ distribution with 45 degrees of freedom (61,656), the absence hypothesis of homogeneity of the distribution of effect sizes is rejected in the fixed effects model, and the research model has been converted to the random effects model.

Findings of Effect Size Analysis in terms of Academic Achievement Variable According to the Random Effects Model

The average effect size is combined according to the random effects model (without removing outliers), the standard error, and the lower and upper limits according to the 95% confidence interval are obtained from the studies included in the study according to the academic achievement variable as given.

Table 11. Findings of the Effect Size Meta-Analysis in Terms of Academic Achievement Variable According to Random Effects Model

Study	Effect Size (d)	Standard Error	Variance	Lower Limit	Upper Limit	Z	p
Mathematics	0.758	0.078	0.006	0.606	0.911	9.739	0.000
Geometry	1.136	0.103	0.011	0.935	1.338	11.055	0.000

According to Table 11, when statistical significance was calculated according to the Z test, it was found as Z = 9,739 for the mathematics lesson and Z = 11,055 for the geometry lesson. It was determined that the analysis result has statistical significance with p = 0.000 in both subject areas.

The combined effect size value of the studies containing data on academic achievement is variable according to the random effects model was calculated as ES = 0.758 for the mathematics lesson, and the standard error of this effect size was SE = 0.078, the lower and upper limit of the mean effect size were calculated as 0.606 and 0.911, respectively. Accordingly, TAI increased students' academic achievement in mathematics by 0.758 standard deviations compared to traditional teaching methods. This increase in the academic achievement of students is an indication that TAI is highly effective in the academic achievement of the mathematics course. In other words, according to the random effects model, analysis values were found to be in favor of TAI in mathematics lesson achievement compared to traditional methods. Since the effect size value is in the range of 0.5-0.8 for mathematics achievement, it has been determined that it has a moderate effect, according to Cohen's classification (Cohen, 1988). According to the classification of Thalheimer and Cook (2002), it has been found to have a high level of effect since the effect size is between 0.75-1.10.

According to the random effects model, the data collected by 46 studies included in meta-analysis within the scope of the geometry lesson; it is seen that the upper limit of 0.103 standard error and 95% confidence interval is 1.338, and the lower limit is 0.935, with the effect size value ES = 1.136. The geometry lesson student achievement is more positive than classical methods in favor of TAI. Because TAI increased students' achievement in geometry by 1.136 by standard deviations more than the traditional teaching methods, this is proof that TAI is very effective in the academic achievement of the geometry course. As the effect size value is greater than 0.8, it has been determined that it has a high effect, according to Cohen's classification (Cohen, 1988). According to the classification of Thalheimer and Cook (2002), it shows a very high level (1.10 - 1.45).

Bias inside the Publications

As Borenstein et al. (2009) defined, publication bias means that there is a tendency to publish positive and statistically significant studies when compared to studies that are negative and statistically insignificant (Kış, 2014). To see the reliability of the research, it was checked whether there is any bias in the publications. For this purpose, the publication bias of the first learning area (mathematics) is presented in Figure 5 below.

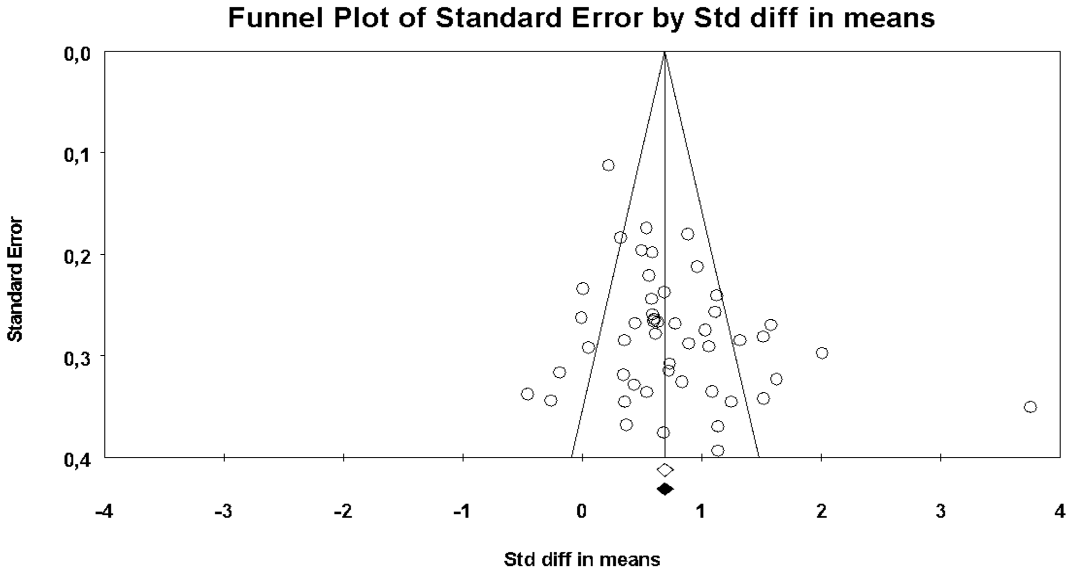

Figure 5. Funnel Plot of Studies Including Effect Size Data Related to Academic Achievement in Mathematics Lesson

In the funnel chart seen in Figure 5, the effect size is located on the horizontal (X) axis, and the standard error value is on the vertical (Y) axis. Studies with a large sample size are collected towards the top of the chart, while studies with small samples are piled up towards the bottom of the chart. Since almost all of the individual studies are located within the funnel lines symmetrically, it is understood that the studies examined do not have any publication bias (Borenstein et al., 2009). However, Egger et al. (1997) summarized the possible causes of asymmetry in the funnel plot: selection bias (publication bias, location bias), true heterogeneity, data irregularities, artifacts, and heterogeneity stemming from the wrong choice of effect size measurement, and chance alone. It is emphasized that the asymmetry in the funnel plot with the chance factor does not necessarily stem from bias (Üstün & Eryılmaz, 2014). Because of this, error protection number (Orwin's Fail Safe-N) was measured according to Orwin method to determine the publication bias more accurately in this study. As known, Orwin's error protection number determines the number of studies that may be missing in the meta-analysis process. (Borenstein et al., 2009).

As a result of this analysis, Orwin's Fail-Safe is calculated as N 5425. This means that the required number of studies is 5425 for the 0.758 average effect size determined as a result of the meta-analysis to reach approximately zero effect level. When the value obtained is found in the literature, the number of studies that are likely to have opposite values can invalidate the effect size obtained in the meta-analysis (Okursoy Günhan, 2009). In other words, for the findings of this meta-analysis, which consists of 52 studies to be considered invalid, there should be at least 5425 more studies in the literature with values opposite to the present findings. As a matter of fact, the number of studies included in meta-analysis in accordance with the inclusion criteria is 52, which can be accessed from published theses and articles about the effect of TAI on mathematics achievement. Since it is impossible to reach 5425 more studies within the specified criteria, this result is accepted as another indicator of the absence of publication bias in this meta-analysis study. Studies on the publication bias of the studies containing data on the geometry lesson area are presented below:

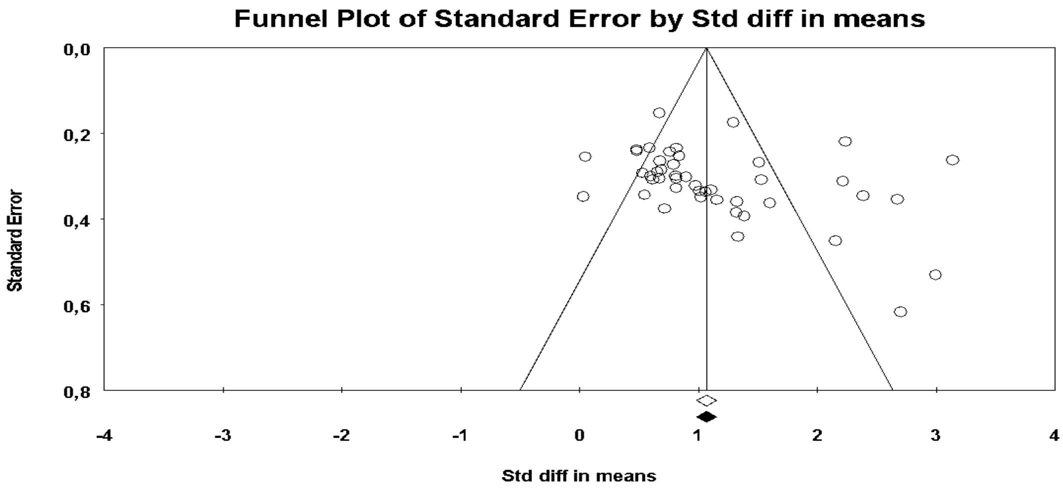

Figure 6. Funnel Scatter Plot of Studies Including Effect Size Data Related to Academic Achievement in Geometry Lesson

In Figure 6, it is seen that the majority of the 46 studies included in the study within the scope of the geometry course area are located towards the top of the figure, close to a symmetrical sequence and around the overall effect size value. In studies withno publication bias, the studies are expected to show a right and left symmetrical distribution around the vertical line representing the combined effect size. Some of the works protrude beyond the pyramid, but they still tend to accumulate in the middle and upper regions of the figure. (Borenstein et al., 2009). This graph is one of the signs that the studies do not show any publication bias. In addition, Orwin's Fail-Safe N calculation (calculation of the number of studies that may be missing in a meta-analysis) was also made to measure publication bias. Orwin's Fail-Safe was found as N 7599 in this calculation. This result means that the required number of studies is 7599 for the effect size found as 1,136 to reach almost zero effect level. In other words, for the findings of this meta-analysis consisting of 46 studies to be considered invalid, there should be at least 7599 studies in the literature with opposite values to the present findings. However, the number of studies that are known and included in meta-analysis by the criteria determined from published theses and articles conducted in our country regarding the effect of TAI on geometry achievement is 46. Since there is no possibility to reach 7599 more studies, this value means "there is no publication bias in this meta-analysis”, and there has been enough evidence to say this.

Findings Regarding the Effectiveness of Technology-Assisted Mathematics / Geometry Teaching According to the Techniques Used in the Application Process of the Studies

The third subproblem of this meta-analysis study constitutes the question of "How does the effect sizes of the TAI techniques (animation, computer work, CD, computer software, smart board, calculator, simulation) differ?" To answer this question, the studies included in the meta-analysis were examined according to the techniques used in the application process and classified according to the titles of, interactive boards, computers, calculators, web support, and software programs. The studies' distribution according to the techniques used in the implementation process is given in Table 12.

Table 12. Frequency and Percentage Table of the Techniques Used in the Studies

Variable	Technique Used	Frequency		Percentage	
		Mathematics	Geometry	Mathematics	Geometry
Academic Achievement	Interactive board	5	3	9.61	6.52
	Computer	15	7	25	13.04
	Calculator	2	0	3.85	0
	Software applications	20	36	42.30	80.43
	Web Supported	10	0	19.23	0

According to the frequency and percentage values are given in Table 12, the most frequently used technique is computer software programs in the application process of the studies examining the academic achievement variable. According to these data, it is possible to say that researchers tend to examine the effectiveness of computer applications or computer software rather than the effectiveness of interactive whiteboards, calculators, or web-assisted teaching. Especially in geometry, a very high percentage of 80.43% (academic achievement) is another data showing that the number of studies included in the meta-analysis is high, which examines software programs.

The table of effect size findings according to the techniques show that the techniques included technology support used during the implementation of the studies examined within the scope of meta-analysis is more effective, is given below:

Table 13. Effect Size Analysis Findings According to Techniques Used in Studies

Variable	Technique Used	Effect Size (d)	
		Mathematics	Geometry
Academic Achievement	Interactive board	0.654	1.603
	Computer	0.865	1.213
	Calculator	0.534	-
	Software applications	0.812	1.094
	Web Supported	0.592	-

When Table 13 is examined, according to the techniques used in the studies included in the current analysis, for the mathematics course academic achievement variable, the largest effect size was in the computer applications category with 0.865, and the smallest effect size was in the calculator category with 0.534. When the data were examined according to the academic achievement variable in mathematics, while interactive whiteboard, calculator, and web support had a moderate effect in Cohen's (1988) classification, computer and software applications showed a high effect. Due to the small number of studies in which calculator and interactive board applications were performed, it made the interpretation of these values difficult. Since it was useful to give an idea.

According to the academic achievement variable of the geometry lesson, it can be said that there is a high effective on the data in all applications (Cohen, 1988). According to the classification of Thalheimer and Cook (2002), while the interactive board has an excellent effect with an effect coefficient of 1.603 (1.45 <d), computer and software applications show a very high effect (1.10 - 1.45). Generally speaking, it is possible to say that the technique that increases student achievement is computer applications and software programs.

Findings Regarding the Effectiveness of Technology-Assisted Instruction According to the Learning Area (Mathematics / Geometry) Taught in Studies

"When examined in terms of course areas (mathematics and geometry) where the studies are carried out, what kind of difference is there between the effect sizes of the TAI method on academic achievement?" To find an answer to this sub-problem, the general effect size values obtained according to the learning areas in the studies included in the analysis were compared. The data obtained regarding these findings are given in Table 14.

Table 14. General Effect Size Analysis Findings According to the Learning Areas in which the Studies were Conducted.

Learning Area	Effect Size Value (d) Academic Achievement
Mathematics	0,758
Geometry	1,136

As can be seen in Table 14, the effect size of TAI on students' achievement in mathematics and geometry was found to be 0.758 and 1.136, respectively. While the result of 0.758 calculated as the effect size has a moderate effect according to Cohen's (1988) classification, the value of 1.136 indicates a high level of effect size. According to Thalheimer and Cook (2002), while TAI has a high effect on the academic achievement of the mathematics course, it has a very high effect on the geometry lesson. In other words, TAI increases students' achievement in geometry more than it does in mathematics, compared to traditional teaching methods.

Findings Regarding the Effectiveness of Technology-Assisted Mathematics/ Geometry Teaching According to the Education Level of the Study Samples

The fourth sub-problem of the study was: "Is there a difference between the effect sizes of technology-supported teaching methods in terms of students' education level (preschool, primary school, middle school, high school, university)?". To find an answer to this sub-problem, the studies examined in the study were categorized according to the academic achievement variable in mathematics and geometry lessons and analyses were made on the relevant data. The distribution of the studies according to the education levels dealt with is given in Table 15 below:

Table 15. Frequency and Percentage Table Regarding the Education Levels where the Studies were Conducted.

	Teaching Level	Frequency		Percentage	
		Mathematics	Geometry	Mathematics	Geometry
Academic Achievement	Preschool	1	1	1.92	2.17
	Elementary	4	2	7.69	4.35
	Middle School	24	32	46.15	69.57
	High School	12	8	23.08	17.39
	University (Undergraduate)	11	3	21.15	6.52

According to Table 15, while studies on the effectiveness of TAI in terms of academic achievement at secondary school (5th, 6th, 7th, and 8th grade) in both subject areas constitute most of the studies (57.14%) included in meta-analysis. In the study, it is seen that the number of studies (2.04%) implemented at the preschool level is quite low. Table 16, which shows the comparison of the general effect sizes of the samples in terms of education levels according to the academic achievement variable, is shown below. As a result of the homogeneity tests conducted based on the teaching level, it was determined that the studies at all levels have a heterogeneous structure. For this reason, the values in Table 16 are given according to the random-effects model.

Table 16. Effect Size Analysis Findings of Study Samples Regarding Education Level According to Academic Achievement Variable

Teaching Level	Effect Size (d)	
	Mathematics	Geometry
Preschool	1.554	2.916
Elementary	0.567	0.959
Middle School	0.719	0.994
High School	0.776	1.769
University (Undergraduate)	0.845	0.852

When Table 16 is examined, it is seen that the highest effect value in the field of mathematics belongs to the preschool level with a value of d = 1.554. However, since this result belongs to 1 (N = 1) study, it cannot be said to be a significant finding. Similarly, since the number of studies in the geometry lesson preschool academic achievement group is 1, it can be said that the values found only reveal the current situation. Although there is a moderate effect (0.5 - 0.8), according to Cohen's (1988) classification in primary, secondary, and high school levels, the university level has a high effect (0.8 <d) with an effect value of 0.858. According to the detailed classification of Thalheimer and Cook (2002), since the effect value of studies with primary and secondary school samples is between 0.40 - 0.75, the effect size of studies with a medium level effect, high school and university level samples is 0.75 - 1, since it is in the range of 10, it has a high level of impact. Based on these results, it can be argued that the higher the teaching level, the higher the mathematics achievement scores.

According to Table 16, when the effect sizes of the education levels in geometry are examined, it is seen that all levels (preschool, primary school, secondary school, high school, university) have a high level of effect since the values of Cohen's (1988) classification are higher than 0.8. According to the detailed classification of Thalheimer and Cook (2002), the effect sizes of the studies that have samples at the primary and university levels are in the range of 0.75 - 1.10, while the studies at the secondary school level have an effective value in the range of 1.10 - 1.45, it shows a very high level of effect. Although preschool level has the highest effect value, this finding cannot be significant since the number of studies having data at preschool level is 1 (N = 1). According to the academic achievement variable, the level that has an excellent is studied containing data belonging to the high school level with an effective value greater than 1.45 (Thalheimer & Cook, 2002). It was also found that the effect of TAI on students' achievement in geometry was greater than its effect on mathematics. This can be interpreted as TAI improves students' geometry achievement more than mathematics achievement.

In summary, within the direction of the analysis results of Table 16, it can be said that because the effect size obtained according to the academic achievement variable is higher in the geometry lessons, it can be said that TAI has a more positive effect on the academic achievement of geometry compared to the mathematics lessons. In addition, the undergraduate (university) level has the highest effect (d = 0.845) in mathematics, while the secondary school level has the highest effect (d = 0.994) in geometry.

Conclusion and Recommendations

In this title, based on the results obtained regarding the main findings of the analysis study and the results given in parallel with the sub-problems of this research, some suggestions were made below.

Conclusions

In this study, it was aimed to determine the effect of TAI on the academic achievement of students in mathematics and geometry courses, and the experimental studies conducted on the subject were examined according to the inclusion criteria, and their findings were combined with a meta-analytical method.

Results Regarding the Academic Achievement Variable

To calculate the TAI's effect size of students' academic achievements in the mathematics and geometry lessons, 52 studies in accordance with the criteria determined were examined within the scope of mathematics lessons, and 46 studies within the scope of geometry lessons. The number of research increased after 2007, the master's thesis (n = 70, 71.43%) in terms of the type of publications, the secondary school level (n = 56, 51.14%) on the basis of the education level where the studies were carried out, software programs according to the technique used in the application process (n = 56, 51.14%) ranked first.

When the effect size results of the studies included in meta-analysis are examined according to academic achievement variable; it was observed that 48 (92.3%) studies in the mathematics lesson and 46 (100%) studies in geometry lesson had positive effect size, and 4 (7.69%) studies in mathematics lesson had negative effect size. The fact that almost all the studies had a positive effect size shows that the academic achievement value in these studies favors the experimental group, depending on the degree of effect size. When the effect sizes are classified according to Cohen's (1988) classification, it was found that 9 studies (17.30%) were small, 17 studies (32.69%) were medium, and 20 studies (38.46%) had a large effect on the academic achievement of mathematics. Looking at the geometry lesson findings 2 studies (4.35%) were small, 14 studies (30.43%) were medium, and 28 studies (60.86%) had a high effect.

As a result of the combination according to the fixed effects model, it was seen that there was a positive and statistically significant ($p < .05$) effect size of 0.687 for the mathematics lesson and 1.056 for the geometry lesson in favor of TAI. This finding is a moderate value according to the classification of Cohen (1988), and Thalheimer and Cook (2002).

The heterogeneity test was performed for the model selection to be used to calculate the overall effect, and the Q value was calculated as 236.524 in the mathematics course area. At the 95% significance level, 51 degrees of freedom value from the × ^ 2 = table corresponds to the value of 67,505. Since the Q-statistic value (Q = 236,524) with 51 degrees of freedom is greater than the critical value of the × ^ 2 distribution (67,505), it has been concluded that the studies are heterogeneous. The same is true for geometry. For this reason, the random effects model was used as the analysis model, and the overall effect size was calculated as 0.758 within the boundaries of 0.606 and 0.911 for mathematics and 1.336 within the limits of 0.935 and 1.338 for geometry. It was determined that the analysis result has statistical significance with p = 0.000 in both subject areas. it is stated that TAI increases the mathematics academic achievement score by approximately 0.76 and geometry by approximately 1.34 standard deviation. The fact that students' academic achievement has increased so much is an indication that TAI is very effective in students' achievement in mathematics and geometry lessons. According to Cohen's (1988) classification, this result is a medium level but close to a high level in the mathematics lesson and a high-level result in the geometry lesson. According to the classification of Thalheimer and Cook (2002), TAI shows a high level of effect on student achievement for mathematics and a very high effect on geometry lessons.

In addition, it can be said that TAI in the geometry lesson area has a more positive effect on academic achievement than the mathematics lesson due to the greater effect size obtained in the studies containing data on the geometry.

The publication bias of the studies included in the study according to the academic achievement variable was tested with both Orwin's Fail-Safe N account and funnel scatter plot. It was found that there was no publication bias in terms of the academic achievement variable of the study by examining and interpreting it with funnel scatter plot and Orwin's Fail-Safe N method for both areas.

Results According to the Techniques Used in the Application Process of the Studies

Technology-supported techniques used by the studies included in the meta-analysis during the application process were examined. it was found that there were 5 categories: *interactive whiteboard, computer, calculator, software programs*, *and web support*. Among these categories, software programs have the highest value, with a 55.86% share. Especially in geometry, 80.43% (academic achievement) showed that the number of studies examining software programs among the data included in the current research with a very high percentage. However, another remarkable point is that the number of studies examining the effectiveness of the calculator (N = 2, 3.85%) is quite low.

It is the technical computer applications that TAI has the greatest effect on the academic achievement for the mathematics course. The result of this effect size, which is found to be high, positive, and statistically significant, is 0.865 (Cohen, 1988). The second highest impact factor belongs to software programs (d = 0.812). While the calculator has a low impact on the mathematics achievement variable, the interactive whiteboard and web support applications have a moderate impact. On the other hand, all techniques (interactive whiteboard, computer, and software programs) have a high level of influence on the academic achievement for the geometry course. Generally speaking, it is possible to say that the techniques that increase student achievement relatively more are computer applications and software programs.

Results According to the Teaching Areas of the Studies

Positive and significant results were obtained regarding the achievement variable in both course areas (mathematics / geometry). The effect size of TAI on students' achievement in mathematics and geometry courses was found as 0.758 (medium level) and 1.136 (high level), respectively. As a result, TAI increases students' achievement in geometry lessons more than their achievement in mathematics lessons than traditional teaching methods.

Results According to the Education Level of the Study Samples

The findings reached by the study is conducted of the studies included in the analysis stage review of studies on the effects on academic achievement in secondary level TAI mathematics and geometry courses in Turkey has created a 55,17% volume of the studies included in the meta-analysis. While it was found that the studies conducted at the secondary school level were more common, the number of studies conducted at the preschool level (2.04%) was found to be quite low.

The TAI method was most effective at the university level (d = 0.858) in the academic achievement for mathematics, and it has a moderate effect in primary, secondary, and high school levels, according to Cohen's (1988) classification. As the education level increased, the mathematics achievement scores also increased. When the effect sizes of education levels in geometry lesson areas are examined, it is seen that the values of all levels (preschool, primary school, middle school, high school, university) have a high level of effect. It has also been concluded that the effect of TAI on students' achievement in geometry has more effect size than its effect on mathematics achievement; thus, it has been concluded that TAI improves students' geometry achievement more than their mathematics achievement. In addition, while the undergraduate level has the highest effect (d = 0.845) in mathematics, geometry has the highest effect (d = 0.994) at the secondary school level.

Suggestions

Based on the results of the study, the following recommendations can be made for the researchers and practitioners.

Suggestions for Researchers

According to the findings of the study, TAI has a greater effect value on the academic achievement variable in the geometry course area compared to the mathematics course area. The reason for this difference, which varies according to the course area, can be investigated.

In the current meta-analysis study, the achievement of TAI in mathematics and geometry and its effectiveness in these lessons were examined and the effects other than these were excluded from the scope of the study. Again, the general effect of the studies that examine the effect of TAI on variables such as self-efficacy perception, problem solving skill, permanence, spatial thinking, and anxiety can be investigated by doing meta-analysis.

It was determined that more than half of the studies included in the analysis were conducted at the secondary school level. The increase in the number of studies with pre-school and undergraduate level samples, where the number of studies is quite low, will be more decisive in terms of seeing the general picture.

This study sample was composed of only the studies conducted in Turkey. The opportunity to compare can be provided by making an international sample of the same study. Only studies with quantitative data were used in the study. As a complement to this research, more comprehensive results can be obtained by examining qualitative studies in the subject area.

Suggestions for Practitioners

Although there are many investigations and a wide range of resources in the field of meta-analysis, which is the method of the research, there is very limited research and resources in our country. In addition, the need for meta-analysis, which brings common results by combining similar study data, which is increasing day by day in the literature, reveals the need for more studies on this subject. For this purpose, researchers can be supported, and postgraduate meta-analysis courses can be included.

The meta-analysis method is a study that requires systematic and planned study. Missing even one of the variables to be used as data requires a re-examination of all studies. In this respect, researchers considering meta-analysis should make an excellent plan initially and work very carefully during the coding of the data.

One of the difficulties of the meta-analysis method is that the studies comply with the criteria determined to answer the question to be investigated in the meta-analysis. At this point, while coding studies for calculating the effect size, studies that do not have the necessary numerical data pose difficulties. In this case, existing data are calculated with statistical methods, or researchers are tried to be reached. Studies whose data are not available cannot be included in the meta-analysis. To solve such difficulties, a standard can be provided for presenting data from studies. In this way, the coding of the studies included in the meta-analysis will be more systematic and easier, and more comprehensive and healthy results will be achieved.

Publication bias is one of the main problems in terms of the validity for the meta-analysis review. To eliminate publication bias, it is crucial to include published and unpublished studies in the analysis. However, reaching unpublished studies is one of the research difficulties. In this context, the relevant units may be recommended to create a common sharing platform by removing the obstacles to sharing scientific knowledge.

Note

This article is produced from the Serap DENİZ's master thesis.

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ANNEXS

ANNEX 1: Meta Analysis Coding Form

I. Research ID
   1. Research Name
   2. Author Name/s
   3. Research Year
   4. Application City
   5. Publication of the Research

II. Content of the Research
   1. Learning Area (mathematic /geometry)
   2. Subject of Application
   3. Education Level
   4. The type of technology used.
   5. Application Period.
   6. Dependent Variables (success, attitude)

III. Research Data.
   1. Number of Samples (N)
   2. Mean (X)
   3. Standard Deviation (SD)

ANNEX 2: Studies Included in Meta-Analysis.

Abdüsselam, M. (2006). *Matematiksel denklem ve ifadelerin bilgisayar ortamında grafikleştirilerek öğretilmesinin eğitime katkıları [The contribution of teaching mathematical equation and expressions by using computer graphics to education]*. Karadeniz Teknik Üniversitesi [Karadeniz Technical University]: Yüksek Lisans Tezi [Master's thesis].

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Kutluca, T. (2009). *İkinci dereceden fonksiyonlar konusu için tasarlanan bilgisayar destekli öğrenme ortamının değerlendirilmesi [Evaluation of a computer assisted learning environment designed for the subject of quadratic functions]*. Karadeniz Teknik University: Doktora Tezi [Doctoral thesis].

Küslü, F. (2015). *Bilgisayar destekli matematik öğretiminin 8. sınıf öğrencilerinin "prizmalar" konusundaki başarısına etkisi [The effect of computer assisted mathematics teaching on the success of the 8th grade students in the topic of 'prisms']*. Sakarya University: Yüksek Lisans Tezi [Master's thesis].

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