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THE EFFECT OF USING TECHNOLOGY IN PRIMARY SCHOOL MATHEMATICS TEACHING ON STUDENTS' ACADEMIC ACHIEVEMENT: A META-ANALYSIS STUDY

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Abstract

In this study, it was aimed to reveal the effect of using technology on the students' academic achievement in primary mathematics education. In accordance with this purpose, the current study is to determine the overall effect size by bringing together the experimental studies conducted on the effect on students' academic achievement of using technology in primary school mathematics teaching between 2013 and 2019. The meta-analysis method was used because it was aimed to calculate the effect sizes of studies examining the effect of technology-based applications used in mathematics education on academic achievement. The effect size of the analyzed studies was found to be 0.483. Also, a significant difference was found between the effect sizes in relation to grade level, technology-based applications, the duration of the studies, the type of the study, and whether the study was conducted nationally or internationally. It was concluded that the technologies used in primary school mathematics teaching have a small positive effect on students' mathematics achievement.

Keywords: mathematics education, academic achievement, primary education, instructional technology, meta-analysis

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Introduction

For many years, educators have used different strategies, methods, and approaches to increase the efficiency of education and to make students' learning processes more effective. The rapid and dizzying developments in the field of technology in the 21st century affect education as well as our daily life. With the advancement of technology and the development of the functions of technological tools such as portability, usability, and internet access, technology has gained wide acceptance among people and has become a learning tool beyond the walls of the school and classroom and the borders of education have been expanded with these technological tools (Borba, Askar, Engelbrecht, Gadanidis, Llinares & Aguilar, 2016). Due to the potential of today's technologies that support students' learning, students, parents, and educators show high interest in educational technologies. As the lives of students and teachers outside the school are increasingly integrated with technology (Means, 2010), it is impossible for schools not to be affected by this situation. Some educational theorists argue that the increase in the competence of students in using technology makes the integration of technology into education an inevitable phenomenon (Franklin & Peng, 2008). The use of technology in classroom environments at the primary school level increases the quality of teaching and thus provides the opportunity to enrich students' learning experiences (Hsu, 2013).

This is the case especially for teaching mathematics. Although mathematics is seen as a difficult school subject by many students, the methods teachers use in mathematics classes have an effect on the student's level of understanding (Murphy, 2016). The negative beliefs of people about the teaching and learning of mathematics appear as one of the biggest obstacles to effective teaching and learning in mathematics classes (Philipp, 2007). In other words, many people believe that mathematics should be taught to today's students in the same way as they were taught mathematics (e.g. by memorizing formulas and procedures and repeating them over and over again (Sam & Ernest, 2000). Eccles (1999) stated that children between the ages of 6 and 10 cannot think abstractly, and their abstract thinking skills develop mainly from the age of 11. In this sense, it is important to reification, which is mathematics built on an abstract structure, for a child to learn in primary school age. As for mathematics, technology's potential to embody abstract mathematical concepts supports this argument.

Technology can be integrated into education at all levels of schooling and technology is an important teaching tool, especially in mathematics education, and the use of technology allows the reshaping of mathematics teaching (Abidin, Mathrani & Hunter, 2017). Integrating technology into mathematics is important in two respects; it is difficult to learn for many students and technological tools will facilitate this situation, whereas using digital tools with a good pedagogy have the potential to facilitate the development of various skills such as critical thinking and problem solving (Viberg, Grönlund & Andersson, 2020). In addition, it is considered important in terms of developing positive attitudes towards mathematics lessons, increasing interest, reducing anxiety and fear towards mathematics lessons, and more importantly, developing effective thinking habits such as analytical and critical thinking (Glazer, 2001; Peker, 1985).

Instructional technologies have become an indispensable part of mathematics education. Technological tools also support students' conceptual understanding as they provide the opportunity to use multiple representations. Robinson, Molenda, and Rezabek (2008) defined instructional technology as "… the study and ethical practices of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources" (p.15). The increase in students' mathematics performance causes their anxiety towards mathematics to decrease (Yüksel-Şahin, 2008; Namkung, Peng & Lin, 2019).

Professional organizations such as the International Society of Technology in Education (ISTE, 2018) and the National Council of Teachers of Mathematics (NCTM, 2000, 2011) strongly recommend the use of technology in educational settings. The National Council of Teachers of Mathematics (2000) identified six principles for mathematics teaching. One of these principles is "Technology is essential in mathematics teaching and learning, influences the mathematics taught and improves students' learning" (NCTM, 2000, p.24). NCTM (2014) highlighted the importance of technology use in mathematics education and stated that "an excellent mathematics program integrates the use of mathematical tools and technology as essential resources to help students learn and make sense of mathematical ideas, reason mathematically, and communicate their mathematical thinking" (p.78). Especially in early mathematics education, the use of technology makes new learning and teaching methods possible.

The use of technology allows teachers to relate mathematical concepts to real-world problems, allowing students to explore mathematical concepts (Sawaya & Putnam, 2015). Moreover, technologies used in mathematics teaching increase students' participation in the mathematics learning process (Getenet, 2020). The number of technological resources available to students and teachers is increasing. Therefore, teachers need to design innovative applications for their students to benefit more from technology-assisted learning environments. To support this argument, a study conducted by Project Tomorrow stated that 35% of primary school teachers use digital games in their classrooms, and 88% of teachers using digital games have higher student participation (Project Tomorrow, 2014). The number and type of technological devices used in mathematics education are increasing with each day. Battista (2001) classified the tools used in math teaching into three categories:

- General technological tools refer to the tools not specially prepared to be used in mathematics teaching (e.g. Kahoot, Blendspace).
- Technological tools used in mathematics refer to the tools developed to be used in the field of mathematics (e.g. calculator, electronic tables, and statistical programs).
- Technological tools developed for mathematics learning are specially designed tools to facilitate students' learning of mathematics (e.g. Geogebra).

Various studies have been conducted on the usability of technologies such as computers, graphical calculators, mobile devices, software, and the Internet in mathematics teaching (Çoruk & Çakır, 2017; Hot, 2019; Shoemaker, 2013). Educational technologies have long been recognized as a valuable approach to improving primary school children's mathematics achievement (Chang, Yuan, Lee, Chen & Huang, 2013; Pilli & Aksu, 2013). In the literature, it is stated that the use of technology in mathematics classrooms has an effect on student achievement (Cheung & Slavin, 2013; Li & Ma, 2010; Pilli & Aksu, 2013; Slavin & Lake, 2008) and engagement (Hilton, 2018; Musti-Rao & Plati, 2015; Ok & Bryant, 2016; Pilli & Aksu, 2013; Yang & Tsai, 2010). The purpose of the current study is to determine the overall effect size by bringing together the experimental studies conducted on the effect of using technology in primary school mathematics teaching between 2013 and 2019 on students' academic achievement.

Due to the development and widespread use of technology, it is thought that studies conducted after 2013 will better reflect technological developments, so studies published between 2013 and 2019 were included in the study. When domestic and international meta-analysis studies are examined, computers (Camnalbur, 2008; Li & Ma, 2010; Dikmen & Tuncer, 2018), SmartBoard (Gündüz & Kutluca, 2019; Akar, 2020), digital games (Byun & Joung, 2018), mobile devices (Sung, Chang, & Liu, 2016; Tingir, Cavlazoglu, Caliskan, Koklu, & Intepe - Tingir, 2017) and dynamic geometric software (Chan & Leung, 2014; Kaya & Öçal, 2018) have been mainly investigated the effect of students at different grade levels on mathematics achievement. When the literature is examined, there is a limited meta-analysis study examining the effect of technology use on the mathematics achievement of primary school students. In this direction, this study is essential because of the importance of technology in teaching abstract mathematics to students who cannot think abstractly. Accordingly, the following research questions were answered:

- What is the effect of using technology in mathematics teaching on the academic achievement of primary school students?
- Is there a significant difference between the effect sizes of the studies according to grade levels?
- Is there a significant difference between the effect sizes of the studies according to the technology types?
- Is there a significant difference between the effect sizes of the studies according to the duration of the study?
- Is there a significant difference between the effect sizes of the studies according to the type of the study?
- Is there a significant difference between the effect sizes of the studies as to whether there is a national or international publication?

Method

In the current study, the meta-analysis method was used because it was aimed to determine the effect sizes of studies examining the effect of technology-based applications used in mathematics education on academic achievement. In the meta-analysis method, it is aimed to achieve a more inclusive result by combining the results of studies on the same subject (Cohen, Manion and Morrison, 2007; Dinçer, 2014). Höffler and Leutner (2007) stated that the following three steps should be followed in order to carry out meta-analysis studies;

1. Determination of the studies serving the purpose of the research, In this study, it was aimed to show a more general tendency through experimental studies carried out in order to determine how the use of technology in primary mathematics education has an effect on academic achievement.
2. Calculation of the effect sizes of the determined studies after coding them, in this section, after the name of the research was coded according to the author and publication information, data was entered into the CMA program for analysis. The effect size of each study was calculated with the cma program and the overall effect size was reached.
3. Conducting statistical analyses on the effect sizes calculated and then interpreting them, in the study, the variables of type of publication, where it was published, grade level, applications used in research, experimental implementation duration and sample size were determined as moderators. The results obtained are presented in the findings.

Data Collection

While collecting research data, keywords were determined in accordance with the purpose of the study. The determined keywords for the current study are as follows: "Technology-enhanced", "Animation", "Augmented reality", "Blog", "Computer-aided", "Computer-based", "Computer-assisted", "Distance learning", "e-learning", "Mobile learning", "Smartboard", "Web-based", "Wiki", "Multimedia", "Web 2.0", "Web 3.0", "Video", "Simulation", "Social networking", "Digital game", "Game-based", "Social media", "Web supported", "Virtual reality", "Blended learning", "achievement" or "success", "experimental", "control group", "elementary education", "primary education", "mathematics education". After the keywords had been determined, they were searched in the following academic databases "SOBIAD", "YOK Thesis Centre", "ERIC", "Web of Science", "Google Scholar" and "Proquest Dissertations and Thesis". The criteria for inclusion in the current study were determined by the researchers as follows:

- The title and abstract of the study should be related to above-given key words
- The study should be conducted at primary level (As the length of primary level can differ in different countries abroad, studies conducted on students up to the 5th grade in the international literature were included)
- The study should have a control and an experimental group and both of the groups should be administered a pretest and posttest.
- The study should have the statistical data necessary for meta-analysis (standard deviation, arithmetic mean, etc.)
- The study should be published between 01.01.2013 and 12.31.2019.

As a result of the search based on the determined keywords, 95 studies were reached and collected in a pool. 95 experimental studies examining the effect of technology use on academic achievement in mathematics teaching were obtained. 43 of these were excluded because they are above primary school in terms of grade level. In this study, while conducting meta-analysis, pretest and posttest of the studies were used, as well as means, standard deviations and sample numbers. 30 studies that did not meet these qualifications were excluded from the study. These studies were coded according to the author's surname and year of publication. As one of these studies (Hot, 2019) compared a traditional instructional method with two different technology-based applications, it was coded as 2019a and 2019b. Information on the publications used in the study are shown in Table 1.

When Table 1 is examined, it is seen that most of the studies used the traditional teaching method in the control group. When analyzed on the basis of the topics in which the researches are carried out, it is seen that fractions come to the fore. However, it is striking that geometric topics such as triangle, rectangle and angle are also preferred. When examined in terms of duration, it is seen that studies were carried out for 12 weeks and longer or 0-5 weeks. Finally, it is seen that the random sampling method is mostly used as the sampling method and then the convenience sampling method is preferred.

Table 1
Information on Research

Name of the Study	Sampling Method	Duraition Of Study	Topic where the application is used	Study applied in the control group
Al-Masbeqh, 2016	NA	3 months	NA	Traditional teaching
Bulut et al., 2016	Random	10 hours	NA	Normal teaching sequence
Çakıcı, 2018	Random	5 weeks	Fractions	Traditional teaching
Chu et al., 2014	Random	3 weeks	Fractions	conventional web-based test system
Çoruk & Çakır, 2017	NA	12 weeks	Fractions	Traditional teaching
Fabian & Topping, 2019	Random	6 weeks	Symmetry, Angles, Area and Perimeter)	Traditional teaching
Genç & Öksüz, 2016	Random	5 weeks	Polygons and quadrilaterals	NA
Hot, 2019a	Convenience	3 weeks	Triangles and quadrilaterals	Traditional teaching
Hot, 2019b	Convenience	3 weeks	Triangles and quadrilaterals	Traditional teaching
İnam & Ünsal	Random	4 weeks	NA	Traditional teaching
Nelson, 2014	Convenience	2010-2011 school year	NA	NA
Ocal, 2017	Convenience	3 weeks	Algebra systems and dynamic geometry environments	Traditional teaching
Özmen, 2019	Random	A semester	Prisms and space	Traditional teaching
Pehlivan, 2018	Convenience	16 weeks	Geometry, Measuring Lengths and Natural Numbers	Traditional teaching
Perry, 2013	Convenience	2011-2012 school year	NA	NA
Pilli & Aksu, 2013	Random	4 months	NA	Traditional teaching
Shoemaker, 2013	Convenience	14 weeks	NA	Traditional teaching
Soybas & Türkmen, 2019	Appropriate	14 weeks	Fractions	Traditional teaching
Sülün Taş, 2015	Criteria sampling	9 weeks	NA	Traditional teaching
Sümen, 2013	Random	3 hours	Symmetry	Traditional teaching
Ünlütürk Akçakın, 2016	Random	17 hours	Fractions	Traditional teaching
Yalçınkaya, 2017	Random	20 hours	Angle and angle measure	Traditional teaching

Data Analysis

While conducting the analysis of the data, the CMA (Comprehensive Meta-Analysis) program was used. For the measurement of the normal distribution of the studies used in the current study, the SPSS program was used. In the calculation of the effect sizes, the formats in which the means, standard deviation values, and sample sizes of the experimental and control groups can be entered through the interface provided by the CMA program were selected. After the effect sizes have been calculated, they are shown with Cohen d (Cohen, 1988), Glass g (Glass, 1976), and Hedges g (Hedges, 1981). In the current study, Hedges g was preferred. The classification of effect sizes are shown by Cohen, Manion, and Morrison (2007) as follows:

- 0 ≤ Effect size value ≤ 0.20 weak
- 0.21 ≤ Effect size value ≤ 0.50 small
- 0.51 ≤ Effect size value ≤ 1.00 medium
- ≤ Effect size value strong

In the current study, in the classification of the effect sizes, the classification method proposed by Cohen et al. (2007) was used. These criteria are used in evaluating the effect size calculated in the meta-analysis. In other words, in this study, the total effect size of the studies examining how the use of technology in primary school mathematics teaching affects academic achievement was calculated and the effect of the obtained result was determined according to the above-mentioned classification.

Findings

Findings Related to Descriptive Analysis

The studies included in the current study were analyzed according to the type of the study, the year of publication, sample groups across grade levels, where the study is published, and sample size of the study, and the length of time in which the study has been completed and the results are presented in Table 2.

As can be seen in Table 2, 45.345% of the studies analyzed in the current study are articles while 54.55% of them are theses. Of these studies, 22.72% were published in 2019, 18.18% in 2017. Fifty percent of the studies were conducted on 5th graders while 36.38% were conducted on 4th graders. In the studies, GeoGebra (27.31%) and web-based applications (31.81%) seem to have largely been used. When the duration of the study is examined, it is seen that 45.45% of them lasted for 0-5 weeks, 9.1% for 6-11 weeks, and 45.45 for 12+ weeks. The great majority of the studies were published in national sources (72.69).

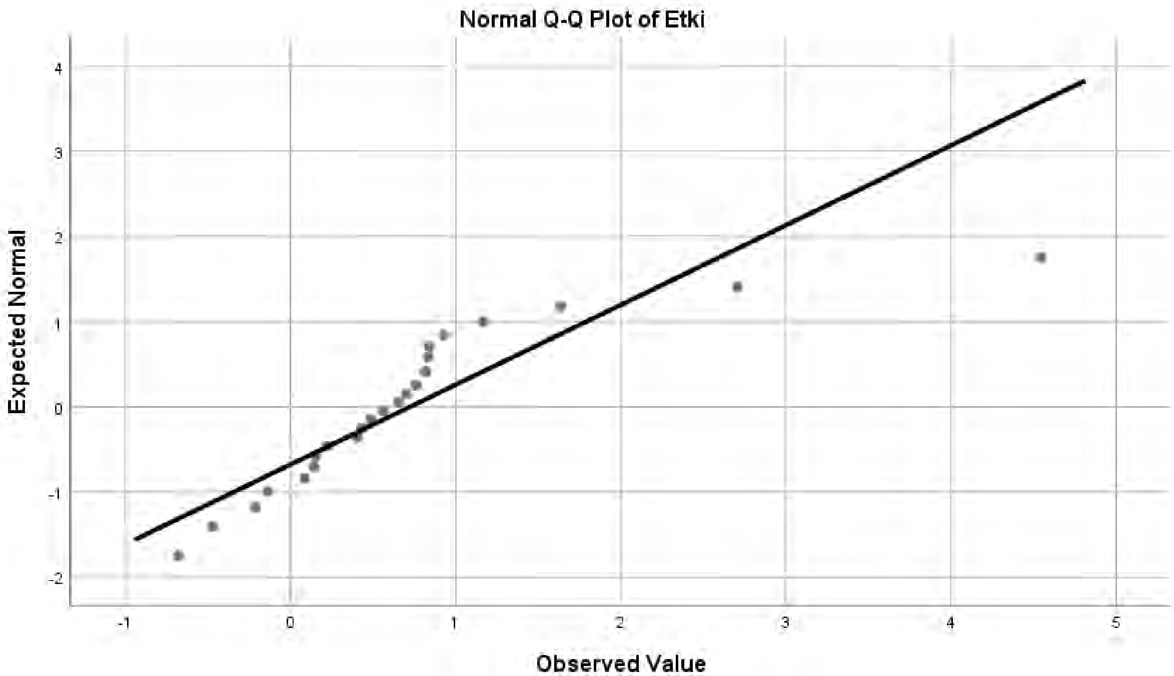
Findings related to the Normality Distribution and Bias of the Studies

In order to determine whether the studies included in the current research showed a normal distribution, an analysis was conducted. The results of the analysis are shown in Figure 1.

Table 2
Descriptive Statistics for the Studies Investigating the Effect of Technology-based Applications on Academic Achievement

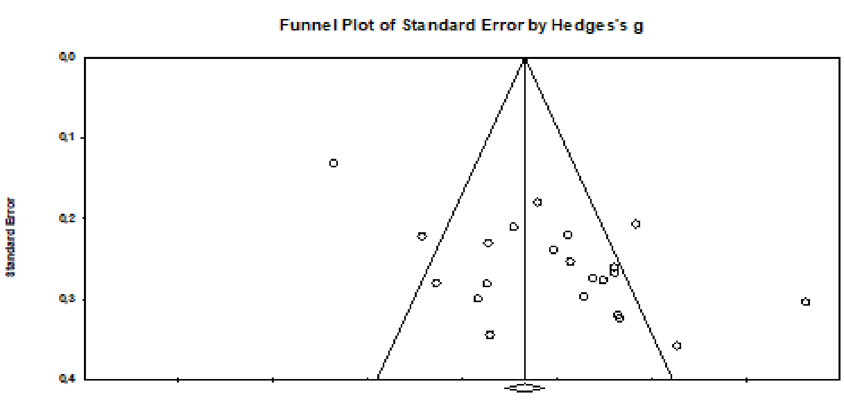
		Frequency	Percentage
Type of the study	Article	10	45.45%
	Thesis/Dissertation	12	54.55%
Year of publication	2013	4	18.18%
	2014	2	9.09%
	2015	1	4.54%
	2016	4	18.18%
	2017	4	18.18%
	2018	2	9.09%
	2019	5	22.74%
Samples across the grade levels	1st grade	1	4.54%
	2nd grade	1	4.54%
	3rd grade	1	4.54%
	4th grade	8	36.38%
	5th grade	11	50%
Applications used in the study	GeoGebra	6	27.31%
	Web based	7	31.81%
	Multimedia Software	2	9.09%
	Tablet	2	9.09%
	Frizbi Math.	1	4.54%
	Sea Perch	1	4.54%
	Digital story	1	4.54%
	Cabri 3D	1	4.54%
	Sketch Pad	1	4.54%
Duration of the study	0-5	10	45.45%
	6-11	2	9.1%
	12+	10	45.45%
Where the study is published	International	6	27.31%
	National	16	72.69%
Total	22	100%	

Figure 1
Normal Distribution Graph of the Effect Sizes



As can be seen in Figure 1, the effect sizes of the studies included in the current research were found to accumulate in the X=Y direction. The effect sizes of the studies included in the current research within the context of this graph were found to have a normal distribution. Moreover, the Kurtosis value (1.277) and skewness value (.106) were calculated for the effect sizes. Tabachnick and Fidell (2013) state that when Kurtosis and skewness values are between -1.5 and +1.5, then the distribution is accepted to be normal. Based on these values, it was concluded that the effect sizes of 22 studies included in the current study have a normal distribution and it would be suitable to combine these studies for a meta-analysis.

Figure 2
Funnel Chart of the Effect Sizes of the Studies Included in the Current Research



In meta-analysis studies, in order to investigate whether the studies included in the meta-analysis have publication bias, a funnel chart is used. The funnel chart created in the current study is presented in Figure 2.

In the funnel chart, the distribution of the studies within the graph, within the funnel, and symmetrically indicates that there is no publication bias (Dinçer, 2014). As can be seen in Figure 2, many of the studies are within the funnel and systematically distributed. Therefore, the studies included in the current research are said to have no publication bias. Another way of calculating publication bias is Rosental Fail-Safe N statistics. The data obtained from the calculation of N statistics are shown in Table 3.

Table 3.
Rosental FSN Calculation

Classic Fail-Safe N	
Z value for the analysed studies	8.06509
P value for the analyzed studies	0.00000
Alpha	0.05000
Direction	2.00000
Z value for Alpha	1.95996
The number of studies analyzed	22
FSN	351

As can be seen in Table 3, the obtained FSN value is 351. For the studies analyzed, the p-value was found to be 0.0000. In order to be able to annul the finding obtained in the current meta-analysis study, it is necessary to find at least 351 studies having the effect size value (p=0.00) and having findings contradictory to the finding of the current study. This seems to support the funnel chart.

Findings related to the Results of the Effect Sizes and Calculation of Q and I2 Values

In meta-analysis studies, it is necessary to determine the method to be used in the calculation of the effect size. The values obtained as a result of the analyses conducted in the current study are presented in Table 4.

As can be seen in Table 4, the homogeneity value (Q) of the 22 studies included in the study was calculated as 125,839.. The x2 table was found to be 21, the degree of freedom was found to be 95% and the critical value at the significance level was found to be 32.671. Within the context of the obtained findings, the Q statistics value (125.839) is seen to be bigger than the value of 21 degree of freedom in the x2 table (x2=32.671) at the 95% significance level. Thus, the studies analyzed in the current research can be said to be heterogeneous. Another indicator supporting that the studies are heterogeneous is the I2 value. As a result of the analysis, the I2 value was found to be 83.312%, which supports that the studies are heterogeneous.

Table 4
Mean Effect Sizes, Confidence Interval Values, Q and I^2 Values of the Studies Included in the Current Study

Model	Mean Effect Size (ES)	Standard Error (SE)	95% Confidence Interval		Degree of Freedom	Homogeneity Value (Q)	I^2	p
			Lower	Upper				
Constant	0.330	0.052	0.229	0.431	21	125.839	83.312	0.000
Random	0.483	0.129	0.230	0.737				

On the basis of the obtained values, the analyses conducted in the current study were carried out according to the random-effects model. According to the random-effects model, the effect size (ES) was calculated to be 0.129 and the standard error (SE) was calculated to be 0.483. According to these values obtained as a result of the analyses conducted, it can be argued that the use of technology in mathematics teaching has a small effect on academic achievement and moreover, as the obtained value is positive, this small effect is in favor of the experimental group (Cohen, Mansion and Morrison, 2007). The forest plot showing the effect sizes of the studies analyzed in the current research according to the random effects model is presented in Figure 3.

The squares in the graphic presented in Figure 3 show the effect sizes of the studies, and the lines next to the squares show the lower and upper limits in the 95% confidence interval. Accordingly, when the graph was examined, the largest effect size value was found to be 1.820 (Hot, 2019a), and the smallest effect size value was found to be -0.678 (Perry, 2013). In three of the studies, the effect size was found to have a negative direction while in 19 of them, the effect size was found to have a positive direction. Thus it can be said that in 19 of the studies, the effect is in favor of the experimental group while in 3 of them, it is in favor of the control group.

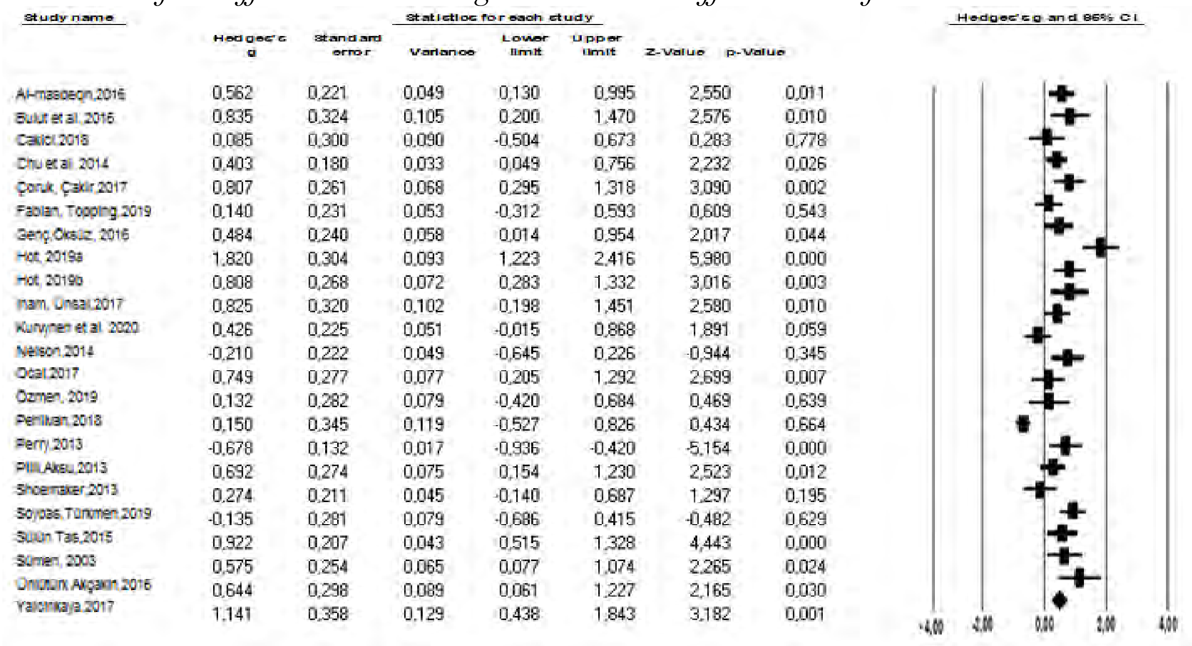
Findings Related to Effect Sizes According to Grade Level Differences

The results of the analysis conducted to determine whether the effects of technology-based applications in mathematics teaching on academic achievement vary significantly depending on grade level are shown in Table 5.

In the results of the analysis conducted, the homogeneity value ($Q=18.144$ $df=4$) was found to be higher than the value in the x2 table (9.488) at the 95% confidence interval. Therefore, the hypothesis analyses were constructed according to the mixed-effects model. As a result of the homogeneity test conducted, no significant difference was found between the grade levels ($Q=18.144$, $p<0.5$). As can be seen in Table 5, the effect size was found to be 0.408 for fourth graders while it was found to be 0.481 for the fifth graders. Although there were 1st, 2nd, and 3rd graders in the studies, they were excluded as there have to be at least two studies for the effect size.

Figure 3

Forest Plot of the Effect Sizes According to the Random Effects Model of the Studies



Study name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Al-masdeqn,2016	0,562	0,221	0,049	0,130	0,995	2,550	0,011
Bulut et al. 2016	0,835	0,324	0,105	0,200	1,470	2,576	0,010
Cakici,2018	0,085	0,300	0,090	-0,504	0,673	0,283	0,778
Chu et al. 2014	0,403	0,180	0,033	0,049	0,756	2,232	0,026
Çoruk, Çakir,2017	0,807	0,261	0,068	0,295	1,318	3,090	0,002
Fabian, Topping,2019	0,140	0,231	0,053	-0,312	0,593	0,609	0,543
Genç,Öksüz, 2016	0,484	0,240	0,058	0,014	0,954	2,017	0,044
Hot, 2019a	1,820	0,304	0,093	1,223	2,416	5,980	0,000
Hot, 2019b	0,808	0,268	0,072	0,283	1,332	3,016	0,003
Inam, Ünsal,2017	0,825	0,320	0,102	0,198	1,451	2,580	0,010
Kurvynen et al. 2020	0,426	0,225	0,051	-0,015	0,868	1,891	0,059
Nelson,2014	-0,210	0,222	0,049	-0,645	0,226	-0,944	0,345
Ocal,2017	0,749	0,277	0,077	0,205	1,292	2,699	0,007
Özmen, 2019	0,132	0,282	0,079	-0,420	0,684	0,469	0,639
Perilkan,2018	0,150	0,345	0,119	-0,527	0,826	0,434	0,664
Perry,2013	-0,678	0,132	0,017	-0,936	-0,420	-5,154	0,000
Pilli,Aksu,2013	0,692	0,274	0,075	0,154	1,230	2,523	0,012
Shoemaker,2013	0,274	0,211	0,045	-0,140	0,687	1,297	0,195
Soybas,Türkmen,2019	-0,135	0,281	0,079	-0,686	0,415	-0,482	0,629
Sülün Tas,2015	0,922	0,207	0,043	0,515	1,328	4,443	0,000
Sümen, 2003	0,575	0,254	0,065	0,077	1,074	2,265	0,024
Ünlütürk Akçakin,2016	0,644	0,298	0,089	0,061	1,227	2,165	0,030
Yalcinkaya,2017	1,141	0,358	0,129	0,438	1,843	3,182	0,001

Findings Related to Effect Sizes According to the Technology Types

The results of the analysis conducted to determine whether the effects of technology-based applications in mathematics teaching on academic achievement vary significantly depending on the application tools used are shown in Table 6.

Table 5

Effect Sizes According to Grade Level

Grade Level	N	Mean Effect Size (ES)	Standard Error (SE)	95% Confidence Interval		Homogeneity Value (Q)	P
				Lower	Upper		
4th grade	8	0.408	0.271	-0.123	0.939	18.144	0.001
5th grade	11	0.481	0.156	0.175	0.787		

As a result of the homogeneity value analysis, the following value was obtained: Q=17.319, df=5. As the calculated homogeneity value is higher than the value in the x2 table (11.070) at the 95% confidence interval, the hypothesis among the effect sizes was constructed according to the mixed-effects model. Based on these results, it can be argued that technology-based applications whose effects on academic achievement were investigated in the studies analyzed in the current research led to statistically significant differences (Q=17.070, $p<0.05$). As can be seen in Table 6, the highest value of the effect sizes was found for multimedia software (0.922).

Table 6
Effect Sizes According to the Technology Types

Applications Used	N	Mean Effect Size (ES)	Standard Error (SE)	95% Confidence Interval		Homogeneity Value (Q)	P
				Lower	Upper		
Geogebra	6	0.833	0.192	0.457	1.210	17.319	0.002
Web-based	7	0.322	0.165	-0.002	0.646		
Multimedia Software	2	0.922	0.211	0.509	1.336		
Tablet	2	0.357	0.211	-0.057	0.770		

Findings Related to Effect Sizes According to the Duration of the Application

The results of the analysis conducted to determine whether the effects of technology-based applications in mathematics teaching on academic achievement vary significantly depending on the duration of the application are shown in Table 7.

Table 7
Effect Sizes According to the Duration of the Application

Duration of the Application	N	Mean Effect Size (ES)	Standard Error (SE)	95% Confidence Interval		Homogeneity Value (Q)	P
				Lower	Upper		
0-5	10	0.740	0.139	0.467	1.013	32.156	0.000
6-11	2	0.462	0.333	-0.190	1.115		
12+	10	0.231	0.199	-0.159	0.620		

As a result of the homogeneity value analysis, the following value was obtained: Q=32.156, df=2. As the calculated homogeneity value is higher than the value (5.991) in the x2 table at the 95% confidence interval, the hypothesis among the effect sizes was constructed according to the mixed-effects model. On the basis of these results, it can be argued that the results of the studies investigating the effects of the technology-based applications on academic achievement in mathematics education vary significantly depending on the duration of the application ($Q=32.156$, $p<0.05$). As can be seen in Table 7, the highest value was found for 0-5 weeks (0.740).

Findings Related to Effect Sizes According to the Type of the Study

The results of the analysis conducted to determine whether the effects of technology-based applications in mathematics teaching on academic achievement vary significantly depending on the type of the study are shown in Table 8.

Table 8
Effect Sizes According to the Type of the Study

Type of the Study	N	Mean Effect Size (ES)	Standard Error (SE)	95% Confidence Interval		Homogeneity Value (Q)	P
				Lower	Upper		
Article	10	0.509	0.095	0.323	0.696	7.969	0.000
Thesis/ Dissertation	12	0.455	0.219	0.026	0.883		

As a result of the homogeneity value analysis, the following value was obtained: Q=7.969, df=1. As the calculated homogeneity value is higher than the value (3.841) in the x2 table at the 95% confidence interval, the hypothesis among the effect sizes was constructed according to the mixed-effects model. On the basis of these results, it can be argued that the results of the studies investigating the effects of the technology-based applications on academic achievement in mathematics education vary significantly depending on the type of the study ($Q=7.969$, $p<0.05$). As can be seen in Table 8, the highest value was found for the articles (0.509).

Effect Sizes Depending on Whether the Study Is Published Nationally (Turkey) or Internationally

The results of the analysis conducted to determine whether the effects of technology-based applications in mathematics teaching on academic achievement vary significantly depending on whether the study is published nationally or internationally are shown in Table 9.

Table 9
Effect Sizes Depending on Whether the Study Is Published Nationally or Internationally

National or International	N	Mean Effect Size (ES)	Standard Error (SE)	95% Confidence Interval		Homogeneity Value (Q)	P
				Lower	Upper		
National	16	0.655	0.224	-0.368	0.510	48.257	0.000
International	6	0.071	0.111	0.437	0.873		

As a result of the homogeneity value analysis, the following value was obtained: Q=48.257, df=1. As the calculated homogeneity value is higher than the value (3.841) in the x2 table at the 95% confidence interval, the hypothesis among the effect sizes was constructed according to the mixed-effects model. On the basis of these results, it can be argued that the results of the studies investigating the effects of the technology-based applications on academic achievement in mathematics education vary significantly depending on whether the study is published nationally or internationally ($Q=48.257$, $p<0.05$). As can be seen in Table 9, the highest value (0.655) was found for the studies published nationally.

Discussion, Conclusion, and Suggestions

With this study, the overall effect size was determined by bringing together the experimental studies conducted on the effects of using technology in primary school mathematics education on students' academic achievement between 2013 and 2019 in national and international literature. As a result of the analysis, the effect size of the analyzed studies was found to be 0.483. In line with the findings of the current research, it was concluded that the technologies used in primary school mathematics teaching have a small positive effect on students' mathematics achievement. Xie, Cheung, Lau and Slavin (2020) conducted research examining the effects of computer-based applications on mathematics course achievement and concluded that they had a modest positive effect. In meta-analysis studies with the sample of the studies consisting of students with various education levels from kindergarten to college, Topbaş and Öztop (2019), Young (2017), Demir ve Başol (2014) stated that technology positively affects student achievement. Thus, the findings reported in the literature support the finding of the current research. In addition, Higgins, Huscroft-D'Angelo, and Crawford (2019) highlighted that technology has the potential to positively influence not only student mathematics achievement but also students' motivation to learn mathematics and attitudes towards mathematics.

A significant difference was found between the effect sizes in relation to grade level. The effect size at the 4th grade was calculated to be 0.408 while it was found to be 0.481 at the 5th-grade level. In other words, it was determined that as the grade level increases, the use of instructional technologies increases the mathematics achievement of primary school students. Dowker, Cheriton, Horton, and Mark (2019) found that the higher grade level led to a positive attitude towards mathematics, as well as better performance in mathematics. Xie, Cheung, Lau, and Slavin (2020) added that the higher the grade level, the more effective the technology in academic success in grades K-12. Therefore, it can be concluded that there are limited studies in the literature that investigate the effects of instructional technologies in mathematics education at lower grades. Only one study has been found on the mathematics achievement of primary school students for 1st, 2nd and 3rd grades, each. Thus, it was concluded that teachers might not be using technology in mathematics classes in the lower grades of primary school as the main focus is on teaching reading and writing to students and they think that the readiness level of students is not enough to introduce them to technology in these grade levels and accordingly they may not prefer experimental activities to teach the target subject in these grade levels.

Traditionally, there is a perception that early childhood learners' cognitive capacity is not enough to understand mathematics (Lee & Ginsburg, 2009). 21st-century learning theorists also emphasized that children in this age group are disadvantaged to learn mathematics (Baroody, 2000). Studies show that teaching mathematics is limited in the period from pre-school to second grade (Hachey, 2013). The finding obtained in this study that studies on the use of technology in teaching mathematics in the first years of primary school is limited may be the result of this perception towards mathematics teaching.

In the studies examined within the scope of the current research, it has been determined that Geogebra and Web-based are the most used technological tools. Multimedia Software and Tablet technologies were used in two studies and Frisbee Math, Sea Perch, Digital story, Cabri 3D, and Sketch Pad were used in one study. It was found that technology-based applications used in mathematics classes have a statistically significant effect on students' academic achievement. The effect sizes of Geogebra and Multimedia Software technologies were found to be bigger than those of the other technologies (e.g. Web-based and Tablet). Chan and Leung (2014) stated that the use of Dynamic Geometry Software has a positive influence on students' mathematical achievement, especially greater in primary education. It has been concluded that different technological tools used in mathematics teaching affect the academic success of primary school students at different levels. Cheung and Slavin (2013) stated that different technologies can affect student success at different levels. Kaya and Öçal (2018) conducted a meta-analysis study to investigate the effect of the Geogebra application used in mathematics classes on academic achievement and in this study, the effect size was found to be 0.886 in a positive direction.

The duration of the study was found to cause a significant difference in the effects of the technology-based applications on primary school students' academic achievement in mathematics education. The biggest effect size was found for 0-5 weeks (0.740) while the smallest effect was found for 12+ weeks (0.231). These findings showed that with increasing duration of application, the effect of using instructional technologies on student academic achievement decreased. Xie, Cheung, Lau and Slavin (2020), stated that the shorter the time, the more positive effects computer-based mathematics applications have on mathematics achievement. Higgins, Huscroft-D'Angelo, and Crawford (2019) stated in their meta-analysis study that the implementation period did not significantly affect the academic achievement of primary school students, but that short-term applications are more effective than long-term applications. Gersten and Edyburn (2007) suggested that the implementation period should be 8-10 sessions, but the result of this study differs from the result of the current research.

The effects of technology-based applications on academic achievement of primary school students in mathematics were found to be varying significantly depending on the type of study. The effect size of the articles (0.509) was found to be higher than that of the theses (0.455). In their meta-analysis study, Li and Ma (2010) examined the effect of computer-assisted mathematics teaching on academic achievement and stated that the effect size of the articles was higher than the theses. Examining the effects of video games on mathematics achievement, Tokac, Novak and Thompson (2018) reported that articles were more effective than theses in a meta-analysis study. Ayaz, Sekerci, and Oral (2016) examined the effect of instructional technologies on the academic achievement of primary school students in their meta-analysis study and found no significant difference. However, they stated that the effect size of doctoral theses was higher than that of the master theses and article studies. In addition, Günhan and Açan (2016) did not find a significant difference depending on the type of the study in their meta-analysis study investigating the effect of using dynamic geometry software on the geometry achievement of students. When the results are examined, the reason for the higher effect size value in thesis and dissertations in terms of academic success can be explained by the application time sample size and the experience of the researcher.

The effect of the technology-based applications used in primary school mathematics classes on academic achievement was found to vary significantly depending on whether the study is conducted nationally or internationally. The effect size for the national studies (0.655) was found to be higher than that of international studies (0.071). This could be the result of the fact that the majority of analyzed studies were national rather than international because the national studies met the research inclusion criteria. Because of the technological reform in education that started in 2010 in Turkey, researchers have paid more attention to technology integration. Moreover, the data from 4th grade Mathematics scores in Trends in International Mathematics and Science Study (TIMMS) 2019 indicated that the Mathematics scores in Turkey were lower than the average of the countries, as well as the hours per year for mathematics instruction (International Association for the Evaluation of Educational Achievement (IEA), 2021). Therefore, the intervention studies conducted nationally might be more effective than internationally as the intervention affected the students with disadvantages. The reason why the comparison of the national and international studies was because of a newly-designed primary school curriculum involving aspects of 21st-century skills and a nationwide technology integration project called FATIH. Hence, the impacts of those nationwide attempts on the research findings were presented in this study.

This study illustrated the impacts of the use of technology in primary school grades. Therefore, it contributes to the literature on technology use in mathematics in primary education settings. In general, the meta-analysis studies conducted in this topic have focused on K-12 level. However, this study specifically aimed to investigate K-5 settings. The subcategories (grade levels, technology types, duration of the study, type of study, and national/international) provide better and in-depth insights compared to the relevant literature. Previous studies did not include recent studies (2018-2019 years) which are 7/22 of all studies. The findings provide insights to both researchers and practitioners about the potential of technology in teaching and learning mathematics in lower grades. However, the limitations of the study involved the criteria used to decide the studies included in the meta-analysis, such as grade levels, control and experimental group with pre- and post-test design, and the date of publication.

In light of the findings of the current study, following suggestions can be made:

- At lower grade levels of primary education (1st, 2nd, and 3rd grades), the use of technology in mathematics classes should be supported. More technological tools should be developed for these grade levels.
- There is a need for more studies that examine the effects on academic achievement of the students at lower primary grades.
- More research on technology's effect on students' mathematics achievement especially in the early primary (K–2) is needed.
- In the current research, studies investigating the use of technology in mathematics classes in primary level were analyzed. Future studies can investigate the effect of using technology in other school subjects.
- When the literature is reviewed, it is seen that studies investigating the use of technology in mathematics classes were generally conducted in secondary school level. Given that positive experiences gained at early ages are transferred to more advanced levels of schooling, more use of technology should be supported in primary schools.
- In the current study, the main focus was on the effect of technology on the academic achievement of primary school students in mathematics classes. Meta-analysis studies can be conducted on the motivation and attitude of students.

In order to increase the effectiveness of experimental studies, rather than keeping the time longer, it is necessary to keep the applications richer in pedagogical aspects considering the development of students, their readiness and intrinsic factors such as interest, attitude and motivation.

References

Abidin, Z., Mathrani, A., & Hunter, R. (2017). Student engagement with technology use in mathematics education: An Indonesian secondary school context. *Proceedings of PACIS 2017, 165*. https://aisel.aisnet.org/pacis2017/165/

Akar, H. (2020). The effect of smart board use on academic achievement: A meta-analytical and thematic study. *International Journal of Education in Mathematics, Science and Technology, 8*(3), 261-273. https://doi.org/10.46328/ijemst.v8i3.908

Ayaz, M. F., Şekerci, H., & Oral, B. (2016). The effect of using of instructional technology to elementary school students' academic achievement: A meta-analysis study. *Journal of the Faculty of Education, 17*(1), 35-54.

Barbara, M. (2010) Technology and education change: Focus on student learning. *Journal of Research on Technology in Education, 42*(3), 285-307. https://doi.org/10.1080/15391523.2010.10782552

Battista, M. T. (2001). Shape makers: A computer environment that engenders students' construction of geometric ideas and reasoning. *Computers in the Schools, 17*(1-2), 105-120. https://doi.org/10.1300/J025v17n01_09

Borba, M. C., Askar, P., Engelbrecht, J., Gaganidis, G., Llinares, S., & Aguilar, M. S. (2016). Blended learning, e-learning and mobile learning in mathematics education. *ZDM, 48*, 589–610. https://doi.org/10.1007/s11858-016-0798-4

Byun, J. & Joung, E. (2018). Digital game-based learning for K–12 mathematics education: A meta-analysis. *School Science and Mathematics, 118*(3-4), 113-126. https://doi.org/10.1111/ssm.12271

Camnalbur, M. (2008). Bilgisayar destekli öğretimin etkililiği üzerine bir meta analiz çalışması (Yayınlanmamış yüksek lisans tezi). Marmara Üniversitesi, Eğitim Bilimleri Enstitüsü, İstanbul.

Chan, K. K. & Leung, S. W. (2014). Dynamic geometry software improves mathematical achievement: Systematic review and meta-analysis. *Journal of Educational Computing Research, 51*(3), 311-325. https://doi.org/10.2190/EC.51.3.c

Chang, W. L., Yuan, Y., Lee, C. Y., Chen, M. H., & Huang, W. G. (2013). Using Magic Board as a teaching aid in third grader learning of area concepts. *Educational Technology & Society, 16*(2), 163-173.

Cheung, A. & Slavin, R. E. (2013). The effectiveness of educational technology applications on mathematics achievement in K-12 classrooms: A meta-analysis. *Educational Research Review, 9*, 88-113. https://doi.org/10.1016/j.edurev.2013.01.001

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education* (6th ed.). Routledge.

Demir (2013). Bilgisayar destekli matematik öğretiminin (BDMÖ) akademik başarıya etkisi: Bir meta analiz çalışması (Yayımlanmamış yüksek lisans tezi). Gaziosmanpaşa Üniversitesi, Eğitim Bilimleri Enstitüsü, Tokat.

Dikmen, M. & Tuncer, M. (2018). Bilgisayar destekli eğitimin öğrencilerin akademik başarıları üzerindeki etkisinin meta-analizi: son 10 yılda yapılan çalışmaların incelenmesi. *Turkish Journal of Computer and Mathematics Education, 9*(1), 97-121.

Dinçer, S. (2014). Eğitim Bilimlerinde Uygulamalı Meta-Analiz. 1. Baskı; Pegem Akademi: Ankara.

Dowker, A. Cheriton, O. Horton, R. & Mark, W. (2019). Relationships between attitudes and performance in young children's mathematics. *Educational Studies in Mathematics, 100*(3), 211-230. https://doi.org/10.1007/s10649-019-9880-5

Eccles, S. J. (1999). The development of children ages 6 to 14. *The Future of Children*, *9*(2), 30-44. https://doi.org/10.2307/1602703

Franklin, T. & Peng, L. (2008). Mobile math: Math educators and students engage in mobile learning. *Journal of Computing in Higher Education*, *20*, 69-80. https://doi.org/10.1007/s12528-008-9005-0

Getenet, S. T. (2020). Designing a professional development program for mathematics teachers for effective use of technology in teaching. *Education and Information Technologies*, *25*, 1855-1873. https://doi.org/10.1007/s10639-019-10056-8

Glazer, E. (2001). *Using Internet primary sources to teach critical thinking skills in mathematics.* Greenwood Publishing Group.

Gündüz, S. & Kutluca, T. (2019). Matematik ve Fen Bilimleri Öğretiminde Akıllı Tahta Kullanımının Öğrencilerin Akademik Başarılarına Etkisi Üzerine Bir Meta-Analiz Çalışması. *Journal of Computer and Education Research. 7(*13), 183-204.

Higgins, K., Huscroft-D'Angelo, J., & Crawford, L. (2019). Effects of technology in mathematics on achievement, motivation, and attitude: A meta-analysis. *Journal of Educational Computing Research. 57*(2), 283-319. https://doi.org/10.1177/0735633117748416

Hilton, A. (2018). Engaging primary school students in mathematics: Can iPads make a difference? *International Journal of Science and Mathematics Education*, *16*, 145–165. https://doi.org/10.1007/s10763-016-9771-5

International Society of Technology in Education (ISTE). (2021). *ISTE Standards for Educators.* https://www.iste.org/standards/iste-standards-for-teachers

Kaya, A. & Öçal, M. F. (2018). Geogebra'nın öğrencilerin matematikteki akademik başarılarına etkisi üzerine bir meta-analiz. *Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi (EFMED)*, *12*(2), 31-59.

Kaya, A. & Öçal, M. F. (2018). A meta-analysis for the effect of GeoGebra on students' academic achievements in mathematics. *Necatibey Faculty of Education Electronic Journal of Science & Mathematics Education*, *12*(2), 31-59.

Li, Q. & Ma, X. (2010). A meta-analysis of the effects of computer technology on school students' mathematics learning. *Educational Psychology Review*, *22*, 215-243. https://doi.org/10.1007/s10648-010-9125-8

Murphy, D. (2016). A literature review: The effect of implementing technology in a high school mathematics classroom. *International Journal of Research in Education and Science*, *2*, 295-299. https://doi.org/10.21890/IJRES.98946

Musti-Rao, S., & Plati, E. (2015). Comparing two classwide interventions: Implications of using technology for increasing multiplication fact fluency. *Journal of Behavioral Education*, *24*, 418–437. https://doi.org/10.1007/s10864-015-9228-x

Namkung, J. M., Peng, P., & Lin, X. (2019). The relation between mathematics anxiety and mathematics performance among school-aged students: A meta-analysis. *Review of Educational Research*, *89*(3), 459–496. https://doi.org/10.3102/0034654319843494

National Council of Teachers of Mathematics (NCTM). (2015). *Calculator Use in Elementary Grades.* https://www.nctm.org/uploadedFiles/Standards_and_Positions/Position_Statements/Calculator%20Use%20in%20Elementary%20Grades%20July%202015.pdf

National Council of Teachers of Mathematics (NCTM). (2014). *Principles to actions: Ensuring mathematical success for all.* NCTM.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics.* NCTM.

Ok, M. W., & Bryant, D. P. (2016). Effects of a strategic intervention with iPad practice on the multiplication fact performance of fifth-grade students with learning disabilities. *Learning Disability Quarterly, 39*(3), 146–158. https://doi.org/10.1177/0731948715598285

Peker, Ö. (1985). Ortaöğretim kurumlarında matematik öğretiminin sorunları, matematik öğretimi ve sorunları, Ankara : TED Yayınları,

Perienen, A. (2020). Frameworks for ICT integration in mathematics education: A teacher's perspective. *Eurasia Journal of Mathematics, Science and Technology Education, 16(*6), em1845. https://doi.org/10.29333/ejmste/7803

Philipp, R. A. (2007). Mathematics teachers' beliefs and affect. In F.K. Lester (Ed.), *Second Handbook of Research on Mathematics Teaching and Learning*, (pp. 257–315). Information Age Publishing.

Pilli, O., & Aksu, M. (2013). The effects of computer-assisted instruction on the achievement, attitudes and retention of fourth grade mathematics students in North Cyprus. *Computers & Education, 62*, 62-71. https://doi.org/10.1016/j.compedu.2012.10.010

Robinson, R., Molenda, M., Rezabek, L. (2008). Facilitating learning. In: A. Januszewski, M. Molenda (Eds). *Educational technology: A definition with commentary* (pp. 15-48), Lawrence Erlbaum Associates.

Sung, Y. T., Chang, K. E., & Liu, T. C. (2016). The effects of integrating mobile devices with teaching and learning on students' learning performance: A meta-analysis and research synthesis. *Computers & Education, 94*, 252-275. https://doi.org/10.1016/j.compedu.2015.11.008

Tabachnick, B. G. & Fidell, L. S. (2013). *Using multivariate statistics* (6th ed.). Pearson.

The International Association for the Evaluation of Educational Achievement (2021). *TIMSS 2019 International Results in Mathematics and Science.* https://timssandpirls.bc.edu/timss2019/international-results/classroom-contexts/#classroom-math-curriculum

Tingir, S., Cavlazoglu, B., Caliskan, O., Koklu, O., & Intepe-Tingir, S. (2017). Effects of mobile devices on K–12 students' achievement: a meta-analysis. *Journal of Computer Assisted Learning, 33*(4), 355-369. https://doi.org/10.1111/jcal.12184

Tokac, U., Novak, E., & Thompson, C. G. (2018). Effects of game based learning on students' mathematics achievement: A meta analysis. *Journal of Computer Assisted Learning, 35*(3), 407-420. https://doi.org/10.1111/jcal.12347

Xie, C., Cheung, A. C. K., Lau, W. W. F., & Slavin, R. E. (2020). The effects of computer-assisted ınstruction on mathematics achievement in mainland China: A meta analysis. *International Journal of Education, 102.* https://doi.org/10.1016/j.ijer.2020.101565

Viberg, O., Grönlund, Å., & Andersson, A. (2020) Integrating digital technology in mathematics education: a Swedish case study. *Interactive Learning Environments.* https://doi.org/10.1080/10494820.2020.1770801

Yang, D. C., & Tsai, Y. F. (2010). Promoting sixth graders' number sense and learning attitudes via technology-based environment. *Educational Technology & Society, 13*(4), 112–125.

Young, J. (2017). Technology-enhanced mathematics instruction: A second-order meta-analysis of 30 years of research. *Educational Research Review, 22*, 19-33. https://doi.org/10.1016/j.edurev.2017.07.001

Yüksel-Şahin, F. (2008). Mathematics anxiety among 4th and 5th grade Turkish elementary school students. *International Electronic Journal of Mathematics Education, 3(*3), 179-192.

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