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Review article

The Effect of Mobile Learning on Learning Performance: A Meta-Analysis Study

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Abstract

The importance of mobile technologies in the educational process has directed the attention of many researchers to this field and has created an important body of academic research. The main purpose of this study is to determine the effect of mobile learning on students' learning performance. In this study, the meta-analysis method was employed. The literature was reviewed through different databases in order to access the relevant researches within the scope of the study. After reviewing the literature, study aspects and inclusion criteria were applied. The studies to be included in the meta-analysis were examined, and 104 studies conducted between the years of 2009 and 2019 that met the inclusion criteria were subjected to a meta-analysis. Education level, course/subject and the implementation period of the studies were determined as moderating variables. The sample of the study consists of 7,568 participants. As a result of the analysis performed according to the random effects model, the mean effect size value was calculated as 0.85 with an error of 0.07. It was determined that there was no publication bias in the meta-analysis. According to the results of the moderator analysis, it was found that the effect of mobile learning on the learning performance of the students did not change according to the education level and the implementation period, but it changed according to the course/subject. In addition to the aforementioned research results, this article also contains descriptive analysis of the results of the studies included in the meta-analysis.

Keywords

mobile learning • mobile devices • academic achievement • meta-analysis • effect size

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The widespread use of technology, the constantly updated information, the need for people to access information everywhere and the individualization of the education have led the emergence of distance education, e-learning and mobile learning. Wireless communication technologies and mobile devices play an important role in the popularization of these concepts. In a world where there is a race against time, mobile technologies are not just a means of communication anymore, but they provide easy access to unlimited information at any time and place in the field of education with the applications developed. This helps students easily interact with information and enables the use of technology for educational purposes. As mobile technologies have become widespread, they have started to play an important role for teachers and learners with the advantages it offers in the field of education (Zengin, Şengel, & Özdemir, 2018). The concept of mobile learning has come to the forefront following the rapid developments in technology. The development of this concept brought about its integration into the educational process. Mobile learning, which is a concept developed on the basis of this idea and has gained a place in the literature, is a new way of learning in the contemporary education system.

Mobile learning, which can be briefly defined as learning through mobile technologies (Elçiçek, 2015), provides the learner's access to information at any time and place in line with their individual needs (Wagner, 2008). This concept, which has emerged as a result of the co-evaluation of mobile informatics and e-learning fields, can also be referred to as e-learning through portable application tools (Trifonova & Ronchetti, 2003). Mobile learning is the use of mobile technologies such as mobile phones, tablets and laptops in the learning process (Niazi, 2007). In the light of these data, mobile learning can be defined as the ability of learners to access information independently of time and space through mobile devices and to manage their own learning processes based on their individual differences and needs. Although there are different definitions of mobile learning in the relevant literature, it is noted that these definitions generally emphasize the elements of “space, time-independent”, “mobile devices” and “wireless technologies”. In addition, the concepts of portability, individuality and customizability are also emphasized within the definitions (Akın, 2014).

Mobile learning is an educational method supported by many learning theories. Naismith, Lonsdale, Vavoula, and Sharples (2004) classify mobile learning by the usage of mobile technologies in certain learning approaches. Accordingly, (i) Behavioral learning: Feedback can be given to the answers of the learners for the questions asked in the mobile learning environment over the system. (ii) Constructivist learning: It allows learners to construct new ideas and concepts around their previous knowledge. The learner becomes active in a simulation or three-dimensional dynamic mobile learning environment. (iii) Situational learning: With mobile learning, content can be adjusted to each learning situation and location. Content-sensitive mobile learning applications provide access to original content in its cultural environment. For example, content-sensitive mobile applications in centers such as museums and art galleries give visitors information about the exhibited works. (iv) Cooperative learning: It refers to the information exchange through social interactions on mobile devices in learning processes. Mobile learning facilitates and enhances interaction and collaboration among students. (v) Lifelong learning: With mobile learning, the learner can access information anytime, anywhere and without the need for another individual. Therefore, learning continues throughout life.

However, when the recent research on mobile learning is reviewed, it is seen that the theoretical structure of mobile learning is not only related to these learning approaches. It also suggests that mobile learning should be associated with new learning approaches such as activity, connectivity, navigation and location-based learning (Keskin & Metcalf, 2011). Within this scope, it is possible to find mobile education applications in many education areas from language (Chen, Chen, & Yang, 2019; Shadiev, Hwang, & Liu,

2018) to science (Jeno, Vandvik, Eliassen, & Grytnes, 2019; Nair, 2019), from mathematics (Fabian & Topping, 2019; Zheng, Warschauer, Hwang, & Collins, 2014) to information and communication technology (Çavuş Ezin, 2019; Oyelere, Suhonen, Wajiga, & Sutinen, 2018).

In mobile learning, virtual mobile learning environments are used as classrooms. The student is the focal point of this virtual learning environment. One can reach the school, curriculum and teacher by using the internet. With mobile information technologies, mobile learning enables access to the e-learning content independently of space. It can be used for distance learning or to support traditional learning.

The inclusion of mobile learning environments in educational programs has many advantages. The fact that mobile devices are portable, have lower costs and offer social and individual learning opportunities is among the main advantages they provide in terms of learning process and outcomes (Chinnery, 2006). Especially thanks to the widespread use of personal mobile devices, learners can now access learning contents, teachers and even their peers at any time and place. As a result, the student-student, student-teacher and student-content interactions in the classroom can be maintained outside the classroom as well (Corbeil & Valdes-Corbeil, 2007; Sharples, Arnedillo-Sánchez, Milrad, & Vavoula, 2009). Therefore, mobile learning will contribute to the individual's lifelong learning process. In addition, this learning environment, which supports student-centered education, provides learning according to individual differences and needs (Corbeil & Valdes-Corbeil, 2007). Therefore, it affects learning socio-culturally and cognitively (Pachler, 2009).

The use of mobile devices in education and the popularity of mobile courses have provided many benefits in terms of learning process and outcomes but also led to several problems. When the literature on mobile learning is reviewed, it is seen that mobile devices cause the majority of the problems in mobile learning. When we look at these problems in general, they can be classified under the following main headings: hardware and software problems caused by technologies, internet and infrastructure problems, screen, keyboard, battery problems of mobile devices (Akın, 2014; Kacetl & Klímová, 2019). Security and privacy issues and the high costs of functional mobile devices can be mentioned as other important problems (El-Hussein & Cronje, 2010; Hockly, 2012). As technology gets more sophisticated, it is believed that such problems will diminish. In addition to technical limitations, there are psychological and pedagogical problems as well (Lewis, 2013). According to Park (2011), the use of social media, messaging applications on mobile devices and the use of these devices for surfing the internet interrupt the learning activity.

It is important to know the positive and negative aspects of mobile learning before conducting any studies in this field. If these positive and negative aspects are not considered, several problems may appear while executing studies for developing contents and learning materials or designing a learning environment. Learning content developed by knowing and benefiting from the positive aspects of mobile learning can be more efficient and useful for learners (Gülcü, 2015).

Purpose and Importance of this Research

Especially with the widespread use of mobile devices and wireless internet technologies, mobile learning has started to be applied in educational environments. It has been observed that the application studies which have examined the effect of this kind of learning on some outcomes such as academic achievement, attitude and motivation have increased in recent years. However, there is limited comprehensive information about the effectiveness of mobile learning in education since different results have been obtained in the aforementioned studies. It can be said that there is a need for meta-analysis studies that will contribute to the holistic interpretation of the study findings. Hence, it is believed that the current reviews in this field will shed light on new studies to be carried out on the topic. Therefore, it is important to find out how effective the use of mobile technologies in education in terms of learning performance is.

Furthermore, the necessity of making use of meta-analysis, which strengthens the findings of individual studies and increases statistical significance, can be pointed out here. As a result, it can be considered up to date in terms of addressing mobile learning, which is one of the popular and frequently used methods in today's education.

The literature contains studies that investigated the effect of mobile learning on academic achievement via the meta-analysis method (Avcı, 2018; Kim & Park, 2019; Sung, Chang, & Liu, 2016; Sönmez & Çapuk, 2019; Tingir, Cavlazoğlu, Çalışkan, Köklü, & Intepe-Tingir, 2017). However, Sönmez and Çapuk (2019) included 40 studies conducted only in Turkey between 2009 and 2018 in the meta-analysis. Moreover, Avcı (2018) included 16 studies conducted on the effect of mobile learning on academic achievement between 2008 and 2018 in the meta-analysis. Tingir et al. (2017) reviewed 14 studies conducted on the effect of mobile devices on the student's success in science, math and reading in grades K12 between 2010 and 2014. Sung, Chang, and Yang (2015) included studies that analyzed the usage of mobile instruments in language training between 1993 and 2013 in the meta-analysis. Likewise, Sung et al. (2016) reviewed the studies published between 1993 and 2013. Kim and Park (2019) includes 10 studies in the meta-analysis in order to evaluate the effect of smart phone-based mobile learning on nursing education. This study also aimed at making significant contributions to the literature by performing moderator analysis as well as determining the level of the effect of mobile learning on the learning performance of learners between 2009 and 2019.

In this study, it is aimed to determine the effect of mobile learning on the learning performance by gathering the related studies in the light of certain criteria. In other words, the findings of the research about mobile learning were analyzed in a comprehensive and holistic way, and the findings were re-analyzed using the meta-analysis method. According to the data obtained, it was found that examining the effectiveness of mobile learning according to its sub-objectives would be useful for forming a general idea about the field and answers to the following questions: (i) What is the size of the effect of mobile learning on learning performance? (ii) What is the size of the effect of mobile learning on learning performance in terms of education level? (iii) What is the size of the effect of mobile learning on learning performance in terms of implementation period? (iv) What is the size of the effect of mobile learning on learning performance in terms of course/subject?

Methods

The meta-analysis method was adopted in the study. Meta-analysis is the implementation of statistical procedures used for synthesizing and interpreting the individual studies. In other words, meta-analysis is a literature review method used to combine and reinterpret the results of similar studies conducted individually in a specific field (Hunter & Schmidt, 1990). In this study, the meta-analysis method was used since it was aimed to examine the effect of mobile learning on learning performance and to make comments from a holistic point of view by making use of the findings of previous independent studies, and also because of the need to look back on the criticism made. In addition, the moderator analysis of some variables that are thought to affect the results of the study on mobile learning was conducted. This also served the purpose of determining the extent of their effect.

Moderators of the Research

The moderators of the research are the independent variables which are thought to have effect on the observed effect size. The moderators of this research are determined as follows: (i) Education level

(*Primary School; Secondary School; High School; University*); (ii) Implementation period (*≤ 4h; >1 day and ≤ 7 days; >1 week and ≤ 4 weeks; >1 month and ≤ 2 months; >2 months and ≤ 3 months; >3 months*); (iii) Course/Subject (*Science; Social Sciences; Foreign Language; Math; Computer and Information Technology (CIT); Medical Sciences*)

Literature Search Procedure

To find answers to the research questions, firstly, databases and inclusion and exclusion criteria in the data collection process were determined. In the research, the databases to be searched were determined as "Web of Science", "ERIC (EBSCO)", "Scopus (A&I)", "Taylor & Francis Online", "Science Direct", "Springer LINK", "Wiley Online Library Full Collection", "Google Scholar", "ProQuest Dissertation & Thesis Global" and "Higher Education Council National Thesis Centre". In order to reach the relevant research, the following concepts were used as keywords in databases: (i) *mobile device terms* (i.e., mobile, cell phone, smartphones, hand-held, tablets, iPad, mobile device, mobile technology, mobile application, mobile learning, m-learning, ubiquitous learning, seamless learning, context-aware ubiquitous learning); (ii) *learning-related keywords* (i.e., learning, teaching, training, lectures). In these searches, studies in Turkish and English were chosen. A search was conducted on these databases on 19.08.2019 using the selected keywords.

Inclusion and Exclusion Criteria

The criteria used in the selection of the studies included in the research are as follows: (i) *Time interval* - To be conducted between the years 2009-2019. This time frame was determined because of the high number of studies conducted on mobile learning thanks to technological developments (i.e., widespread use of fast internet and smartphones, access to cheap internet in smartphones, development of Wi-Fi networks). (ii) *Study resources* - The articles published in refereed and electronic academic journals and master's and doctoral theses were determined as the sources of the study. (iii) *Appropriate research method in the studies* - In order to obtain the standard effect size in the meta-analysis studies, the following was sought: the included studies had experimental-control group, the dependent variable was able to measure the learning performance, and the independent variable was the use of mobile devices in education. (iv) *To contain sufficient numerical data* - In order to calculate the effect size required in the meta-analysis, the descriptive statistics (sample size [*N*], average [$\overline{X}$], standard deviation [*SD*]) in the experimental and control groups were included.

The studies that were excluded from the meta-analysis study were the theses which were not within the limits of the research, were not available due to lack of access permission, studies with qualitative data and all the studies without sufficient data for analysis. In addition, if the studies of the same author and subject comprised both articles and a thesis, the article was included in the meta-analysis. It was determined that some of the studies obtained from the scanning process were registered to more than one database and only the data in one database was used. In addition, experimental studies with no experimental part or single group were excluded.

At the beginning, the titles and abstracts of all the studies identified according to inclusion and exclusion criteria were examined, and then, the full texts of the selected publications were evaluated. Furthermore, non-parametric tests were not included in the meta-analysis. The PRISMA flow diagram (Moher, Liberati, Tetzlaff, Altman, & Prisma Group, 2009) showing the process of obtaining the studies included in the meta-analysis during the literature review stage is given in Figure 1.

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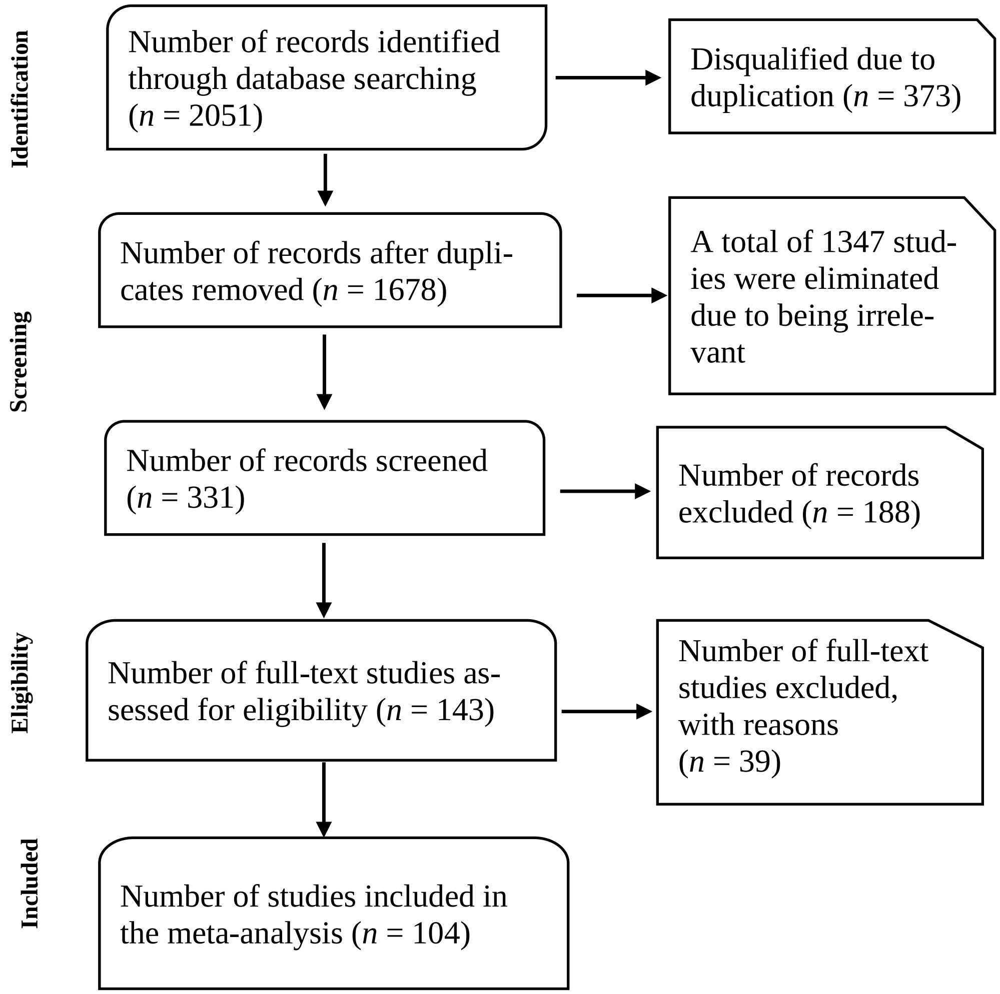

Figure 1. *Flow chart for selection of studies (flow diagram)*

When Figure 1 is examined, it can be seen that a total of 2051 records have been reached as a result of the review of the above-mentioned databases in order to determine the effect of mobile learning on learning performance. Then, the studies found were reviewed one by one. Since 373 of the studies were duplicates and the title and content of 1347 studies reviewed were found to be irrelevant, it was decided to exclude them from the research. After this review, 331 studies remained. Upon examining these studies within the context of inclusion criteria, 188 of them were eliminated. When the remaining 143 studies were evaluated in terms of suitability and quality, it was decided to exclude 39 studies that were not suitable for the meta-analysis, in other words, which did not contain sufficient data, and which were found to be low in quality. As a result, it was decided to include 104 studies that met all criteria in the meta-analysis.

Coding Method

Within the scope of the study, a coding form was created in accordance with the purpose of the study to compare the characteristics of the studies included in the meta-analysis and to convert the information contained in these studies into numerical data. The aforementioned coding form consists of three parts as shown in Table 1.

Table 1. *Chapters of the codification form and its content*

The identity of the study	*Contents of the study*	*The data of the study*
The Title of the study	Education level	Sample size (*N*)
Author/Authors of the study	Implementation period	Mean ($\bar{X}$)
Publication year	Course/Subject	Standard deviation (*SD*)
Publication type		
Publication database		

For the reliability of the research, the studies selected for meta-analysis were examined by two independent evaluators. The evaluators were experienced enough to participate in the coding process as they had PhD degrees in educational sciences and had many qualitative studies. The evaluators shared ideas after the coding process and reached common decisions on different opinions. In this process, the reliability among coders was also calculated and the compliance value was found to be 0.89. This value reveals that there is excellent compatibility between coders (Viera & Garret, 2005).

Data Analysis

The data obtained during the data collection stage were coded and processed into a Microsoft Excel document and related findings were calculated as frequency and percentage. Comprehensive Meta-Analysis 2.0 (CMA) software was used for data analysis and the effect sizes, heterogeneity test and publication bias calculations were performed through these programs. Although the classification of effect sizes varies, the values of the effect sizes commonly used in the literature are given in Table 2 below.

Table 2. *Classification of effect sizes*

	Effect Sizes	
(Cohen, 1988)	(Lipsey & Wilson, 2001)	(Thalheimer & Cook, 2002)
d = 0.20-0.50 small	d =.15 low	-0.15< d < 0.15 negligible
d = 0.50-0.80 medium	d =.45 middle	0.15 < d < 0.40 small
$d \geq$ 0.80 large	d =.90 top	0.40 < d < 0.75 medium
		0.75 < d < 1.10 large
		1.10 < d < 1.45 very large
		1.45 < d huge

In the study, Hedges' *g* coefficient was used to calculate the effect sizes. Hedges' *g* effect size is usually classified as Cohen´s *d* shown in Table 2. The confidence interval was 95% in all the calculations. Interpretation of the effect sizes of the studies that were analyzed was conducted according to the classification of Thalheimer and Cook (2002). During the study, the effect size of each study included in the meta-analysis was calculated, and then, a homogeneity test was performed. If the effect sizes present a homogeneous distribution according to the results of this test, it is said that a fixed effects model can be used. If the effect sizes do not present a homogeneous distribution, a random effects model should be used (Ellis, 2010). Typically, *Q*-tests are used to assess whether the studies included in the meta-analysis constitute a heterogeneous structure. The *Q* statistic is used to test the zero-hypothesis claiming that all studies included in the meta-analysis share a common effect, by χ^2 distribution (Borenstein, Hedges, Higgins, & Rothstein, 2013). Accordingly, if the *Q* value obtained from the heterogeneity test is smaller than the *Q* value shown in the χ^2 table, the condition of homogeneity is considered as fulfilled, and if it is greater, the condition of heterogeneity is considered as fulfilled (Dinçer, 2014). The fact that the *Q* statistic calculated in this test is significant ($p < .05$) suggests that the studies are heterogeneous. Therefore, random effects model was taken as a basis for calculating the overall effect size in this study. Furthermore, the values obtained according to the fixed effects model are given in the results. The reliability of the study was found to be 98% by calculating the inter-rater reliability level formula *[number of agreements/(number of agreements+ disagreements) x 100]* (Miles & Huberman, 1994).

Results

In this part, the findings of the meta-analysis are described. Thus, descriptive information about meta-analysis is primarily provided. Then, the calculated effect size values and changes in subcategory groups are examined.

Descriptive Statistics of the Included Studies

Descriptions examined in this research consist of education level, implementation period, publication type, study year, course/subject and sample size. The descriptive statistics of these variables are presented in Table 3.

Table 3. *The number and percentage values of the studies*

Variables	*k*	*%*
Education Level		
Primary School	23	22.1
Secondary School	11	10.6
High School	15	14.4
University	52	50.0
Other	3	2.9
Study Year		
2009/2010	3/5	2.9/4.8
2011/2012	7/6	6.7/5.8
2013/2014	12/10	11.5/9.6
2015/2016	12/12	11.5/11.5
2017/2018	15/13	14.4/12.5
2019	9	8.7
Implementation Period		
≤ 4h	14	13.5
> 1, ≤ 7 days	4	3.8
> 1, ≤ 4 weeks	28	26.9
> 1, ≤ 2 months	29	27.9
> 2, ≤ 3 months	8	7.7
> 3 months	7	6.7
Not mentioned	14	13.5
Course/Subject		
Science	22	21.2
Social Sciences	13	12.5
Language Education	40	38.5
Math	3	2.9
CIT	13	12.5
Medical Sciences	8	7.7
Other	5	4.8

Publication Type		
Articles	75	72.1
Master's Thesis	21	20.2
Doctoral Thesis	8	7.7
Sample Size		
Small sample (between 1-49)	31	29.8
Medium sample (between 50-99)	56	53.8
Large sample (100 and above)	17	16.3

Considering Table 3, half of all the studies included in the meta-analysis were conducted at the university level. The least number of studies was performed in the secondary school. The number of studies has increased after 2013. The implementation periods of the studies vary between 1 to 2 months. Apparently, the implementation period was not specified in 14 studies. Last but not least, the highest number of studies was conducted in the field of language education with 40 studies, followed by science education with 22 studies. It was determined that the lowest number of studies was conducted in the field of Mathematics. Most of the studies included in the meta-analysis were journal articles. Doctoral theses included in the analysis were less frequent. When the sample sizes were examined, it was found that 31 studies were based on small samples, 56 were based on medium samples and 17 were based on large samples. In the studies included in the meta-analysis, the total number of participants in the experimental-control group was 7,568.

Findings of the Studies on Learning Achievement in Terms of Effect Size

Table 4 presents the mean effect size values of the studies included in the analysis. When we look at Table 4, it can be seen that the *p* value is .000. In the χ^2 table, χ^2 was found to be 128.804 at the level of 95% significance and 104 degrees of freedom. According to the heterogeneity test, the *Q*-statistical value (145.314) was found to be greater than the critical value (128.804). Therefore, it can be stated that the distribution was heterogeneous. As a result of the analysis performed according to REM, mean effect size (Hedges' *g*) value was calculated as $g = 0.85$ with 0.07 standard error. The lower limit of the 95% confidence interval was 0.72 and the upper limit was 0.99.

Table 4. *Studies' overall effect sizes, heterogeneity distribution value according to effects model, and confidence intervals*

Type of Model	*k*	*Z*	*p*	*Q*	*df*	*g*	*SE*	*% 95 CI*	
								Lower	Upper
Fixed Effects	104	30.439	0.000	797.656	103	0.75	0.03	0.704	0.801
Random Effects	104	12.128	0.000	145.314	103	0.85	0.07	0.716	0.992

Note. *k* = number of effect sizes; *df* = degrees of freedom; *g* = Hedges' *g; SE* = standard error; *CI* = confidence of interval for the average value of ES.

As can be seen in Table 4, $g = 0.85$ value was evaluated according to Thalheimer and Cook (2002) classification in terms of the effect size classification and found to be a large effect size. Therefore, it can be stated that mobile learning has a positive effect on learning performance and is highly effective. The individual effect sizes of the studies included in the meta-analysis in terms of learning performance are included in Appendix. On the other hand, funnel plot is given in Figure 2 with the intent of determining whether there is a bias in favor of the studies with significant differences among the studies included in the research.

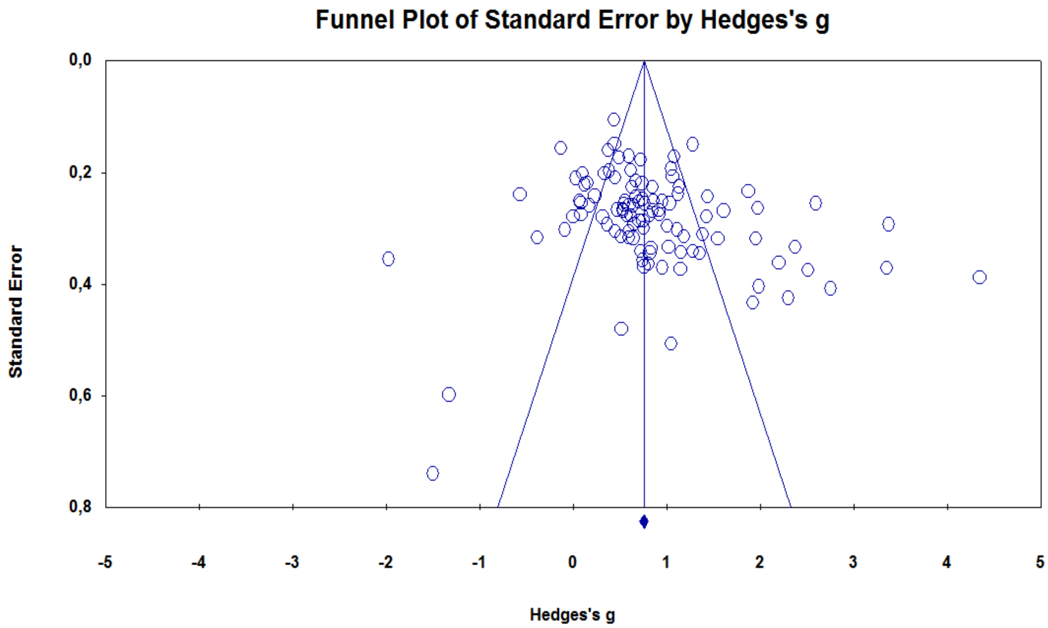

Figure 2. *Funnel plot of the dissemination bias status of the studies included in the research*

When Figure 2 is examined, it is understood that the studies do not have an asymmetric distribution around the overall effect size. In other words, distribution is not concentrated on one side. The fact that the distribution was not an asymmetric batch at a single point revealed that the study sample was not biased in favor of mobile learning. In order to support the findings obtained from the funnel plot, Rosenthal fail-safe number (FSN) value was also calculated. The obtained findings are included in Table 5.

Table 5. *Rosenthal's fail-safe number calculations*

Z-value for observed studies	31.38885
p-value for observed studies	0.00000*
Alpha	0.05000
Tails	2
Z for alpha	1.95996
Number of observed studies	104
Fail-safe *N*	26,570

*Note. *p < .05*

As a result of the analysis, the FSN was calculated as *N* = 26,570. If more studies with negatively or neutrally significant differences are included in the analysis and the number of these studies is equal to the aforementioned value, then it will be possible to say that the significant effect can decrease to zero. This value is well above the 5k+10 limit and is too high to be reached. This information was accepted as another indicator suggesting that there was no publication bias and the results of the meta-analysis were reliable.

The Effect Sizes of the Studies According to Moderators

As a result of the study, it was found that the education level, course/subject and the implementation period of the studies included in the study were different from one another. Hence, it was aimed to examine whether the effect size values of the studies differed according to the variables mentioned. Table 6 shows the results of the moderator analysis according to the education level, course/subject and the implementation period of the studies included in the meta-analysis.

Table 6. *The effect sizes of studies on including moderators in relation to learning performance*

	Variables	*k*	*g*	*95% CI*		Q_B	*Z*	*df*	*p*
				Lower	Upper				
Education Level	Primary School	23	0.793	0.575	1.010	1.571	14.52	4	0.814
	Secondary School	11	0.928	0.333	1.523				
	High School	15	0.690	0.125	1.254				
	University	52	0.893	0.736	1.049				
	Other	3	1.136	0.456	1.816				
	Overall	104	0.862	0.743	0.982				
Implementation Period	≤4h	14	0.887	0.533	1.242	7.370	12.858	6	0.288
	>1, ≤7 days	4	0.539	0.180	0.899				
	>1, ≤4 weeks	28	0.666	0.367	0.965				
	>1, ≤2 months	29	1.085	0.732	1.439				
	>2, ≤3 months	8	0.994	0.594	1.394				
	>3 months	7	0.849	0.419	1.279				
	Not mentioned	14	0.695	0.494	0.896				
	Overall	104	0.777	0.658	0.895				
Course/Subject	Science	22	0.713	0.568	0.859	15.560	13.985	6	0.016
	Social Sciences	13	1.019	0.422	1.615				
	Language Education	40	0.999	0.715	1.284				
	Math	3	-0.015	-0.637	0.606				
	CIT	13	0.518	0.261	0.775				
	Medical Sciences	8	1.103	0.660	1.546				
	Other	5	0.838	0.477	1.200				
	Overall	104	0.740	0.636	0.844				

Note. *k* = number of effect sizes; *g* = Hedges' *g*; *df* = degrees of freedom*; CI* = confidence of interval for the average value of ES.

According to Table 6, in terms of *education level*, the intergroup homogeneity test value was found as Q_B= 1.571. In the table, χ^2 was found as 9.488 and its significance level was found as 95% at 4 degrees of freedom ($\chi^2_{(0.95)}$= 9.488). Since the Q_B statistical value is found less than the critical value of χ^2 distribution with 4 degrees of freedom, it can be stated that the distribution is homogeneous. When the studies were reviewed according to the education level, it was found that there is no significant difference between the sizes of the effect of mobile learning on students' learning performance (Q_B= 1.571, $p > .05$). On the other hand, it can be stated that the overall effect size ($g = 0.86$) of the level of teaching corresponds to the large effect size according to Thalheimer and Cook's (2002) classification.

According to Table 6, in terms of *implementation period,* the homogeneity test value was found as Q_B= 7.370. In the table, χ^2 was found as 12.592 and its significance level was found as 95% at 6 degrees of freedom ($\chi^2_{(0.95)}$= 12.592). Thus, since the Q_B statistical value is less than χ^2, there is homogeneity between the effect sizes. In this case, it can be stated that the effect of mobile learning on learning performance does not change according to implementation periods ($p > .05$). Learning performance is also independent of the implementation period in the courses where mobile learning is used. On the other hand, it can be revealed that the overall effect size value is $g = 0.78$, and according to Thalheimer and Cook (2002), it is a large effect size. When it comes to interpreting this finding, it is possible to say that mobile learning has a positive effect on the learning performance.

According to Table 6, in terms of *course/subject*, the homogeneity test value was found as $Q_B = 15.560$. In the table, χ^2 was found as 12.592 and its significance level was found as 95% at 6 degrees of freedom ($\chi^2_{(0.95)} = 12.592$). Since the Q_B statistic value is greater than the critical value of χ^2 distribution with 6 degrees of freedom, the distribution is heterogeneous. According to these results, it can be argued that learning performance changes in terms of course/subject because mobile learning positively affects learners' performance and contains significant differences ($p < .05$). In the same table, it is determined that the greatest value of the effect size is in the fields of Medical Sciences (1.103) and Social Sciences (1.019) while the lowest effect size value is in the Mathematics field (-0.015).

Discussion

The main purpose of using different technologies in education is to facilitate the achievement of teaching objectives and enrich learning by rendering it efficiently. The contemporary understanding of education is a new approach to education that does not see students as an information-laden entity, and rather puts them at the center, gives importance to individual differences and helps them become individuals with an analyzing and synthesizing capability. This understanding has also affected the technological developments and has enabled the methods and techniques used in education to change and develop. Therefore, there is a transition to modern learning methods using wireless technologies in the learning-teaching environment. Considering that wireless technologies provide the opportunity to access information at the desired time and place, mobile devices have the potential to contribute to the courses during the education process. Mobile learning, which is a concept that has been developed based on this idea and which has been studied since the 2000s, emerges as one of the most important advancements that increase the efficiency and effectiveness of learning.

In this study, in order to determine the effectiveness of mobile learning on learning performance, the studies on the topic were analyzed using the meta-analysis method. To serve the purpose of the study, 104 studies were included in the meta-analysis.

Within the scope of the research, the data of the studies included in the meta-analysis were examined primarily, and it was understood that the studies were generally conducted at the university level, in form of articles and on language education. On the other hand, it was found that the number of studies increased after 2013 and intensified over a 1-2-month period; studies were conducted over medium samples. As a result of the analysis, it was discovered that mobile learning had a positive and broadly significant effect on learning performance. This result shows that mobile learning positively affects students' learning performance. As a matter of fact, in the literature, there are many studies (Al-Temimi, 2017; Arain, Hussain, Rizvi, & Vighio, 2018; Elfeky & Masadeh, 2016; Jeno et al., 2019; Kalınkara, 2017; Oyelere et al., 2018) showing that mobile learning positively affects learning performance. In this case, it can be put forward that the result of the study is consistent with the relevant literature and the aforementioned method has a positive effect on the learning performance of the students. On the other hand, there are also studies comparing mobile learning to other methods and stating that there is no significant increase in learning performance or there are no significant differences (Chou, Chang, & Lin, 2017; Fabian & Topping, 2019; Guillén-Gámez, Álvarez-García, & Rodríguez, 2018). The reason for obtaining different results in these studies in the literature may be the implementation of mobile learning in different ways, the type and quality of mobile devices used during the implementation, and the differences in the activities performed during the course. Another reason for this difference may be that the teacher executing the implementation managed and planned the process in a different way. In addition, participants' adoption of mobile learning, their attitudes and motivation towards the course may lead to different results. Hence, it is possible to state that the courses designed for mobile learning should be planned well.

The reason that mobile learning positively affects learning performance can be listed as follows: it provides learning anywhere, anytime, supports student-centered education and provides learning according to individual differences and needs (Corbeil & Valdes-Corbeil, 2007). Mobile learning takes education out of the classroom. By doing so, education taking place in fixed areas within a certain period is avoided, and students are provided with the opportunity to continue their education in social life (Corbeil & Valdes-Corbeil, 2007; Gülcü, 2015). In addition, the fact that each learner learns at his own pace, can be connected to distance education platforms via mobile devices and constantly update their knowledge with new generation technologies (Elçiçek, 2015) contributes positively to students' learning performance. In this respect, mobile learning offers the same advantages of e-learning and computer-assisted learning, especially distance education. Besides, the fact that mobile learning supports different learning approaches such as lifelong learning, unconscious learning, on-time learning, learning independent of time and space, and learning adjusted to space and conditions (Bulun, Gülnar, & Güran, 2004) contribute positively to students' learning performance. Mobile learning environments provide enriched learning contents and address visual and auditory intelligence simultaneously (Gülcü, 2015).

In the study, employing the moderator analysis, it was examined whether the effect of mobile learning on learning performance changes according to education level, course/subject and the implementation period. When the related results were examined, it was understood that mobile learning did not change according to the education level and implementation period but changed according to the course/subject. In conclusion, it can be stated that mobile learning differs according to the course/subject. In the study, no problems occurred when calculating the publication bias that showed the reliability of the meta-analytical study and showed that the effect sizes of the studies presented a normal distribution. This result indicates that the analyses are reliable.

In the literature, meta-analyses, which were conducted on the effects of mobile learning on learning performance by making use of several technologies, have also been found. For example, in the meta-analysis of Sung et al. (2015), the use of mobile devices in language education was examined. Forty-four studies published between 1993 and 2013 were found to be in accordance with the criteria of this meta-analysis. As a result of the analysis, the effect size value for the use of mobile devices in language education was found as 0.55 and moderate. It was determined that mobile devices had a positive effect on language education. Similarly, in the study conducted by Sung et al. (2016), 110 studies published between 1993 and 2013 were subjected to a meta-analysis in order to examine the effect of integrated mobile devices in teaching and learning. In this study, the effect size was determined to be 0.523 and moderate. Sönmez and Çapuk (2019) also examined the effect of mobile learning on students' academic achievement by conducting a meta-analysis. In this study, it was aimed to gather 40 scientific studies executed on mobile learning in Turkey between the years 2009 and 2018 and to determine the overall effect size. As a result of the analysis, the size of the effect of mobile learning on academic achievement was found as 1.055. The calculated effect size was found to have a high positive effect and to be statistically significant. As for Kim and Park (2019), they conducted a meta-analysis to evaluate the impact of smartphone-based mobile learning on nursing education. The data of 10 studies that met the inclusion criteria from different databases were analyzed. It was determined that smartphone-based mobile learning has a significant effect on nursing students' knowledge, skills, confidence in performance and learning attitudes.

The use of mobile technologies, which can be used independently of time and space, is increasing day by day. These technologies should be integrated into education; students, teachers and administrators should be informed about this matter, and mobile learning awareness should be raised. Rather than prohibiting the use of mobile devices in education, technological infrastructure and technical support in learning activities should be brought to a sufficient level. Moreover, curriculums should be reviewed to make sure that they include mobile learning, and the use of mobile learning to support formal education should be supported and increased.

In this study, an attempt was made to determine the effect of mobile learning on students' learning performance by using the meta-analysis method. In future studies, the applicability and effectiveness of mobile learning can be examined in more detail by performing subgroup analyses according to the subject, implementation period, sample size, age and gender considering the variables such as attitude, motivation and permanence. In the following years, new study findings about mobile learning can be added for the purpose of repetition and comparison. Nowadays with rapidly increasing knowledge, it is recommended to use research techniques such as the meta-analysis method, which allows for interpretation of different results obtained from similar individual studies, in the studies more often.

The digital generations of the digital age seem to be ready for mobile learning both psychologically and in terms of knowledge and skills. Educational institutions should somehow organize their learning environments, education programs and learning-teaching processes in accordance with the needs of the new generation, changing learning styles and emerging new teaching technologies. As mobile technologies are present in the learning environment today, learning methods, techniques and strategies should be selected to support mobile learning. Moreover, policy makers need to make investments and strategic decisions to encourage utilization of mobile technologies in the field of education in order to generalize mobile learning and increase its effectiveness. Improving the compatibility of learning environment and learning materials with mobile technologies, making the necessary definitions with respect to mobile learning in the curricula of governments and updating these definitions with advancing technology would be important steps to increase the effectiveness of mobile learning.

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Appendix

Table 1. *Individual effect sizes of the studies addressing mobile learning and learning performance according to Hedges' g*

Author & Year	*Effect Size (g)*	*Standard Error*	*Variance*	*95% Lower Limit*	*95% Upper Limit*	*Z Value*	*p*
Aygül (2019)	0.601	0.259	0.067	0.093	1.106	2.320	0.020
Ağca (2012)	0.749	0.300	0.090	0.160	1.337	2.494	0.013
Ahmed & Parsons (2013)	0.371	0.161	0.026	0.056	0.687	2.308	0.021
Akın (2014)	0.000	0.279	0.078	-0.547	0.547	0.000	1.000
Alemi, Sarab, & Lari (2012)	0.449	0.306	0.093	-0.150	1.048	1.468	0.142
Alkhezzi & Al-Dousari (2016)	0.594	0.317	0.100	-0.027	1.215	1.874	0.061
Al-Temimi (2017)	1.001	0.296	0.088	0.421	1.581	3.383	0.001
Arain et al. (2018)	1.275	0.150	0.023	0.981	1.569	8.487	0.000
Bakay (2017)	0.830	0.336	0.113	0.171	1.483	2.469	0.014
Basal et at. (2016)	1.381	0.311	0.097	0.772	1.990	4.443	0.000
Başoğlu (2010)	0.171	0.260	0.067	-0.338	0.679	0.657	0.511
Bruce-Low et al. (2013)	0.817	0.277	0.077	0.274	1.360	2.950	0.003
Cak (2014)	-0.086	0.303	0.092	-0.680	0.507	-0.285	0.776
Carr (2012)	0.386	0.197	0.039	-0.000	0.772	1.958	0.050
Chang, Chang, & Shih (2016)	0.230	0.243	0.059	-0.245	0.706	0.950	0.342
Chang, Chen, & Hsu (2011)	3.349	0.371	0.138	2.621	4.077	9.017	0.000
Chen (2013)	1.045	0.508	0.258	0.050	2.040	2.059	0.039
Chen, Chen, & Yang (2019)	0.360	0.293	0.085	-0.215	0.935	1.228	0.219
Chen, Huang, & Chou (2019)	0.702	0.253	0.064	0.207	1.198	2.777	0.005
Chen, Hwang, & Tsai (2014)	0.916	0.268	0.072	0.390	1.442	3.413	0.001
Chiang, Yang, & Hwang (2014)	0.531	0.266	0.071	0.009	1.052	1.995	0.046
Chin, Wang, & Chen (2019)	1.428	0.280	0.078	0.879	1.976	5.103	0.000
Chou et al. (2010)	0.919	0.275	0.076	0.380	1.459	3.342	0.001
Chou, Chang, & Lin (2017)	-1.974	0.356	0.126	-2.671	-1.276	-5.549	0.000
Çavuş Ezin (2019)	1.112	0.303	0.092	0.519	1.705	3.672	0.000
Çelik & Yavuz (2018)	1.974	0.264	0.070	1.456	2.492	7.464	0.000
Çevik et al. (2017)	0.952	0.370	0.137	0.227	1.678	2.572	0.010
Dehmenoğlu (2015)	0.071	0.251	0.063	-0.421	0.562	0.282	0.778
De-Marcos et al. (2010)	0.337	0.202	0.041	-0.058	0.733	1.671	0.095
Doğan (2016)	1.353	0.345	0.119	0.677	2.029	3.923	0.000
Doğan (2017)	3.369	0.293	0.086	2.794	3.943	11.494	0.000
Elçiçek (2015)	1.133	0.225	0.051	0.691	1.575	5.025	0.000
Elfeky & Masadeh (2016)	1.545	0.318	0.101	0.921	2.169	4.853	0.000
Fabian & Topping (2019)	-1.327	0.598	0.358	-2.500	-0.154	-2.217	0.027
Guillén-Gámez et al. (2018)	0.314	0.280	0.078	-0.235	0.863	1.121	0.262
Gülcü (2015)	2.199	0.362	0.131	1.490	2.909	6.076	0.000
Gürkan (2019)	1.872	0.234	0.055	1.413	2.331	7.991	0.000
Hayati, Jalilifar, & Mashhadi (2013)	1.922	0.433	0.188	1.073	2.772	4.436	0.000
Hou et al. (2014)	1.019	0.334	0.112	0.364	1.675	3.049	0.002
Huang & Chiu (2015)	1.075	0.172	0.029	0.739	1.412	6.263	0.000
Huang, Lin, & Cheng (2010)	1.145	0.373	0.139	0.414	1.877	3.069	0.002
Hwang & Chang (2011)	0.635	0.260	0.067	0.127	1.144	2.448	0.014
Hwang & Chen (2013)	2.370	0.334	0.112	1.715	3.026	7.090	0.000
Hwang et al. (2013)	0.534	0.269	0.072	0.007	1.061	1.984	0.047
Hwang et al. (2014)	0.844	0.269	0.072	0.317	1.370	3.140	0.002
Hwang et al. (2018)	1.062	0.207	0.043	0.656	1.468	5.126	0.000
Hwang Wu, & Ke (2011)	0.755	0.368	0.136	0.033	1.477	2.050	0.040

Jeno et al. (2019)	1.182	0.315	0.099	0.565	1.800	3.754	0.000
Jou, Lin, & Tsai (2016)	0.736	0.220	0.048	0.305	1.166	3.345	0.001
Kalınkara (2017)	0.821	0.344	0.119	0.146	1.496	2.383	0.017
Khansarian-Dehkordi & Ameri-Golestan (2016)	1.121	0.239	0.057	0.654	1.589	4.700	0.000
Khrisat & Mahmoud (2013)	0.486	0.315	0.099	-0.130	1.103	1.546	0.122
Kılıç (2015)	1.049	0.194	0.037	0.669	1.428	5.416	0.000
Kim et al. (2011)	0.119	0.222	0.049	-0.316	0.553	0.536	0.592
Körlü (2017)	1.148	0.344	0.118	0.474	1.822	3.339	0.001
Köse (2017)	0.742	0.358	0.128	0.041	1.443	2.075	0.038
Kuo, Chu, & Tsai (2017)	0.640	0.318	0.101	0.016	1.263	2.011	0.044
Küçük, Kapakin, & Göktaş (2016)	0.666	0.243	0.059	0.189	1.142	2.739	0.006
Lin & Lin (2016)	2.297	0.425	0.181	1.464	3.131	5.402	0.000
Lin (2014)	1.435	0.243	0.059	0.959	1.911	5.907	0.000
Liu, Tan, & Chu (2009)	1.609	0.269	0.072	1.082	2.136	5.982	0.000
Martin & Ertzberger (2013)	-0.569	0.240	0.057	-1.039	-0.099	-2.375	0.018
Meriçelli (2015)	0.083	0.255	0.065	-0.416	0.583	0.327	0.743
Nair (2019)	0.465	0.267	0.071	-0.059	0.988	1.739	0.082
Nikou & Economides (2013)	0.492	0.174	0.030	0.151	0.832	2.828	0.005
Nikou & Economides (2018)	0.614	0.196	0.038	0.231	0.998	3.140	0.002
Okumuş Dağdeler (2018)	0.953	0.252	0.063	0.460	1.447	3.787	0.000
Oyelere et al. (2018)	0.592	0.171	0.029	0.258	0.926	3.471	0.001
Ozdal & Ozdamli (2017)	0.153	0.219	0.048	-0.276	0.583	0.699	0.485
Özel Erkan (2016)	0.845	0.226	0.051	0.402	1.287	3.740	0.000
Poyraz (2014)	-0.129	0.157	0.025	-0.437	0.178	-0.825	0.410
Sandberg, Maris, & de Geus (2011)	-1.500	0.740	0.548	-2.951	-0.050	-2.027	0.043
Saran (2009)	0.804	0.365	0.133	0.090	1.519	2.205	0.027
Saran, Seferoglu, & Cagıltay (2009)	0.516	0.481	0.232	-0.427	1.460	1.072	0.284
Saran, Seferoglu, & Cagıltay (2012)	0.720	0.341	0.117	0.051	1.389	2.109	0.035
Sell (2018)	4.345	0.389	0.151	3.582	5.107	11.168	0.000
Shadiev et al. (2015)	-0.401	0.354	0.126	-1.095	0.294	-1.130	0.258
Shadiev, Hwang, & Liu (2018)	0.569	0.276	0.076	0.028	1.111	2.060	0.039
So (2016)	0.539	0.258	0.066	0.035	1.044	2.095	0.036
Sönmez (2018)	0.761	0.256	0.066	0.259	1.263	2.973	0.003
Su & Cheng (2013)	0.741	0.248	0.062	0.255	1.227	2.987	0.003
Su &Cheng (2015)	0.856	0.251	0.063	0.365	1.348	3.415	0.001
Su (2017)	1.032	0.256	0.065	0.531	1.533	4.037	0.000
Sung et al. (2014)	0.747	0.287	0.082	0.185	1.309	2.604	0.009
Sung, Hwang, & Chang (2016)	0.616	0.277	0.077	0.073	1.160	2.222	0.026
Sur (2011)	0.027	0.210	0.044	-0.385	0.439	0.128	0.898
Suwantarathip & Orawiwatnakul (2015)	0.626	0.227	0.051	0.181	1.070	2.757	0.006
Şad & Akdağ (2010)	2.592	0.255	0.065	2.092	3.093	10.150	0.000
Tanır (2018)	1.949	0.319	0.102	1.325	2.574	6.115	0.000
Vaishnav & Sinha (2017)	0.704	0.287	0.082	0.142	1.267	2.453	0.014
Wang, Fang, & Miao (2018)	0.671	0.215	0.046	0.250	1.092	3.121	0.002
Wardaszko & Podgórski (2017)	0.717	0.177	0.031	0.370	1.064	4.050	0.000
Wikinson & Barter (2016)	0.441	0.149	0.022	0.149	0.733	2.963	0.003
Wu (2014)	2.509	0.375	0.140	1.774	3.243	6.695	0.000
Wu et al. (2011)	0.653	0.292	0.085	0.080	1.225	2.236	0.025
Wu et al. (2012)	2.752	0.408	0.167	1.953	3.552	6.745	0.000
Yallıhep (2018)	1.980	0.405	0.164	1.187	2.773	4.894	0.000
Yang et al. (2013)	0.552	0.252	0.063	0.059	1.046	2.193	0.028
Yeşil (2015)	0.083	0.276	0.076	-0.458	0.624	0.301	0.763
Yıldırım (2017)	0.445	0.209	0.044	0.036	0.854	2.131	0.033

Yıldırım (2018)	0.097	0.202	0.041	-0.298	0.492	0.480	0.631
Zare Bidaki et al. (2013)	0.593	0.306	0.094	-0.007	1.193	1.937	0.053
Zengin Ünal (2015)	1.279	0.341	0.117	0.610	1.948	3.748	0.000
Zheng et al. (2014)	0.437	0.106	0.011	0.229	0.645	4.123	0.000