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The Effect of Three Dimensional Virtual Environments and Augmented Reality Applications on The Learning Achievement: A Meta-Analysis Study *

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Abstract

The objective of the study is to analyze the effect of three dimensional (3D) virtual environment and augmented reality applications on learning achievement. In line with this purpose, experimental studies were considered and the effects of experimental and control groups on learning achievement analyzed. In the experimental group, the applications which were established through the 3D virtual environment and augmented reality technologies while control group consisted of face to face environment. In order to realize this aim, the meta-analysis method used in educational sciences was preferred. Key words for 3D virtual environments meta-analysis scanning are: '"3D virtual world" & achievement' and '"3D virtual environment" & achievement'. And the key word determined for the augmented reality meta- analysis scanning is '"augmented reality" & achievement'. Within the context of the research, the databases such as Science Direct, ERIC, Taylor & Francis, EBSCO, Emerald, JSTOR, SAGE, SpringerLink and Google Scholar were analyzed. The determined keywords were entered into the aforementioned databases and 4.682 articles published between 2010 and 2016 were controlled in terms of their conformity to the objectives of the research. After the initial analysis, 47 articles were determined on 3D virtual environment while 57 articles were on the augmented reality. Among the 47 articles on 3D virtual environments, 20 articles which conform to the inclusion criteria were determined and 24 articles among the 57 articles on augmented reality were employed for meta-analysis. The dependent variable of the research is learning achievement while independent variable is experimental and control groups. Education level was determined as the moderator variable in the research. According to the results

Keywords

3D virtual environment
Augmented reality
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Effect size

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of the research, it was found that 3D virtual environments had moderate levels of effect on learning achievement on behalf of the experimental group (d=0.32). similar to those results, augmented reality applications had also moderate level of effect on learning achievement on behalf of experimental group (d=0.46). According to the results of the moderator analysis conducted, it was determined that the selection of the study sample as undergraduate, primary school, high school and secondary school did not change the effect size of the 3D virtual environments on the learning success. Again, according to the results of the moderator analysis, it was determined that the selection of the study sample as a secondary school, primary school and graduate did not change the effect size of the augmented reality applications on the learning success.

Introduction

In order to make education more effective, attractive, and productive, it is a requirement of our age to utilize different teaching techniques and support those methods through computer technologies. The factors such as development and production of various technologies and modern devices, the increase in the quantity of the students and the rise in the awareness levels necessitate the integration of the compter technologies into education (Yücer, 2011). The researches conducted in recent years indicate that 3-dimensional (3D) virtual worlds (Dalgarno & Lee, 2010; Papachristos, Vrellis, Natsis, & Mikropoulos, 2014) and augmented reality technologies (Lee, 2012) have great potential for employing in education. Since 2012, the 3D virtual learning environments have attracted non-negligible attention and this interest have been updated nowadays through the applications such as Pokémon Go and SoundPacman which unite virtual and real world by using augmented reality (Chatzidimitris, Gavalas, & Dimitris, 2016; Serino, Cordrey, McLaughlin, & Milanaik, 2016).

The changes observed in computers and internet resulted in our introduction to the virtual worlds. Virtual worlds are the systems which can be accessed through a multiuser interface online and allow the users interact with both each others and the environment and conduct various transactions (Dinçer, 2008). It is a display which was established by computers and arouses the feeling of being within an environment although they are not there as well as allowing interaction with the environment (Schroeder, 1996). In other words, the virtual worlds give the users a strong feeling of readiness (existing there) and an opportunity to experience within the technological environment (Warburton, 2009). In another definition by Bainbridge (2007), the virtual worlds were specified as the electronic environments where individuals are represented by a virtual character, they conducted interactions with each other and the virtual objects and complicated physical fields are visually imitated. In the virtual worlds, it is technically possible to explore a different world out of our personal real life experiences, express ourselves through real-looking avatars and establish social connestions with other people beyond the different geographical borders (Fetscherin & Lattemann, 2008). The use of 3D virtual environments in education is important for increasing the quality of learning and learning experiences (Jarmon, Traphagan, Mayrath, & Trivedi, 2008; Squire & Jenkins, 2004), creating online communities (Riedl, Tashner, & Bronack, 2003) and providing collaborative environments (Erlandson, Nelson, & Wilhelmina, 2010). Researches have shown that 3D virtual environments support interaction, commitment, motivation, active learning, experiential learning and collaboration (Barab, Thomas, Dodge, Carteaux, & Hakan, 2005; Dickey, 2005b; De Jong, Van Der Meijden, & Von Berg, 2005; Minocha & Roberts, 2008; Omale, 2010). These environments also motivate students to learn by providing a safe and realistic learning atmosphere (Brasil et al., 2011; Dalgarno, 2002), supporting synchronous communication and social interaction (Barab et al., 2005; Delucia, Francese, Passero, & Tortora, 2009).

Today, the augmented reality technology is one of the popular instruments which are employed in the fields such as education, health, culture etc. In the New Media Consortium Horizon Report issued in 2016 (NMC Horizon Report: 2016 Higher Education Edition), it was stated that Higher Education Institutions had to keep up with the developing new technologies and the technologies of Augmented Reality (AR) and Virtual Reality, among the aforementioned technologies will be commonly employed in higher education institutions within two or three years. Although it was listed in the same category with virtual reality in the literature (Boud, Haniff, Baber, & Steiner, 1999), the augmented reality is a variation of virtual reality and a modified form of it (Azuma, 1997). The augmented reality (AR) means that a physical reality real world is combined to a complicated reality through connecting them to visual or haptical (tactual) stimulants created by a virtual computer (Lamata et al., 2010). Milgram and Kishino (1994) defined the AR as the combination of real and virtual data in a real-world environment while Azuma et al., (2001) focused on the qualifications of the augmented reality application. An application should involve some technical characteristics to make the environment AR, Azuma (1997) stated that: (a) the integration of virtual and real objects in real environment, (b) the alignment of the objects in the three dimensional environment, (c) the interaction between real and virtual objects in the real-timed environment.

Augmented reality applications are one of the promising technologies in education and technology integration as they can improve perceptions about the real world (İbili, 2013). Augmented reality can be used in the design of learning materials and learning environments integrated with reality or in the cooperation of dynamic and complex problems (Dunleavy & Dede, 2014) in learning teaching processes. Students can gain experience of learning on real objects in real environment with augmented reality applications (Cai, Wang, & Chiang, 2014), and can easily understand three-dimensional structures (Núñez, Quirós, Núñez, Carda, & Camahort, 2008). In addition, it is ideal for developing user-friendly learning environments and enables you to realize your learning experiences instantly (Gervautz & Schmalstieg, 2012).

The Problem Statement

The processes of development and change observed in the technology uncontrollably continue all over the world. Especially, the 3D virtual reality technology which is said to be employed within the following 2-3 years as stated in the Horizon K-12 report issued in 2016-2017 period is very popular nowadays. Virtual reality is a technology which allows individuals to interact with the objects in the environment as well as it gives the sense of being in a real environment in the mind of human beings through 3D objects, animations and technological devices (virtual eye glasses, the gloves with motion sensor etc.) (Kayabaşı, 2005). Rosemblum and Cross (1997) stated that three main components of virtual reality are immersion, interaction and visual realism.

The immersiveness is established through surrounding the user with a virtual 3D environment and making people feel as if he belongs to that environment. Depending on this immersive aspect of it, virtual reality technologies have several types. The augmented reality which was developed depending on the virtual reality technology and desktop virtual reality (virtual worlds) can be listed in the aforementioned technologies (Riva, 2006). Augmented reality contributes to the perception of reality more qualitatively and deeper through adding virtual information, explanations and visuals to the real environment htrough the support of technology (Babur, 2016). Dickey (2005a) defined virtual worlds as network-based desktop virtual reality where the users move and interact in the simulated 3D fields. Milgram, Takemura, Utsumi and Kishino (1994) pointed out that a transition from real environment to the virtual world using the diagram which they call "real virtual immersiveness" (Figure 1). On the very left of Figure 1, there is the real world environment while there is a completely artificial-digital virtual environment on the very right of the diagram

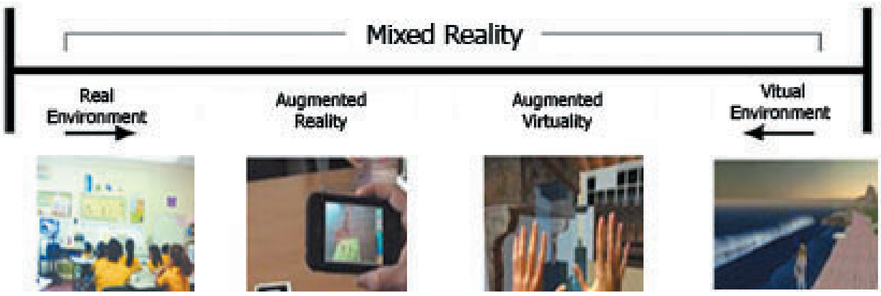

Figure 1. Reality-Virtuality Continuum

The transitions between two worlds were defined as "Mixed Reality" where real and virtual objects are presented together (Milgram et al., 1994). Augmented virtuality is obtained through adding real objects into virtual environment while augmented reality is obtained through adding virtual environments to real objects. When we progress from left of the figure towards the right, the quantity of virtual environment increases and the aspect of immersiveness also increase accordingly. Virtual reality takes place on the basis of both augmented reality and 3D virtual environment technologies. These two similar technologies differ from each other in the absence of reality element in 3D virtual worlds. In this study, it is planned to compare augmented reality technology where real environment element used more with the 3D virtual environments where a whole digital environment plays a part by means of learning achievement.

From the past to the present, these technologies have been practiced in many fields like; geometry (Hwang & Hu, 2013), mathematics (Christy & Fox, 2014), anotomy (Blum, Kleeberger, Bichlmeier, & Navab, 2012), engineering (Potkonjak et al., 2016) and language teaching (Taşkıran, Koral, & Bozkurt, 2015). In addition, many studies examining the effects of these technologies on learning achievement have been conducted (Ang & Wang, 2006; Bayırtepe & Tüzün, 2007; Chen, Chou, & Huang, 2016; Ibáñez, Di-Serio, Villarán, & Kloos, 2014; Mallory, 2012; Merchant et al., 2012; Sert, 2009; Topu, 2015; Tüzün, Yılmaz-Soylu, Karakuş, İnal, & Kızılkaya, 2009; Yıldırım & Şahin, 2015; Wang, Duh, Li, Lin, & Tsai, 2014). However, there is no study examining the effect size of these technologies on learning achievement in education has been found in the literature.

The preparation, implementation and evaluation process of these two technologies, which provide many pedagogical benefits in educational environments, are very challenging. Both the preparation and the implementation process require serious labor, time and money. Especially the applications to be prepared by using these technologies should be formed with a team and this preparation process takes a long time. It is also difficult to use such labor-demanding applications by researchers and teachers in education. At this point, it is a matter of wonder that which of these two similar technologies has a higher effect on learning achievement when used in accordance with the defined objectives. By this study, it is aimed to answer the question that which of these two technologies is more effective on learning success. Knowing which of these two technologies have a higher impact on the learning success in conditions where the target, content and learning environment are suitable for both technologies will save time, money, labor and human resources in the teaching process.

The Purpose and Significance of the Study

In this research, it was aimed to compare the augmented reality technology with more quantity of real environment factor to 3D virtual environments with completely digital environments in term of learning achievement. For that purpose, it was aimed to determine the size of the effects of augmented reality and 3D virtual environments on learning achievement. The objective of this research is to analyze the effects of the application which were established with 3-dimensional virtual environments, one of the popular technologies of today, and augmented reality on the learning achievement. When the experimental studies which analyze the effects of 3-dimensional virtual environment and augmented reality applications are compiled together in the study, an answer to the question "Is there a significant difference between the applications established through employing the aforementioned technologies and face to face environment in terms of learning achievement?" was sought.

For this general purpose, following questions were asked:

1. What is the effect of learning in 3-dimensional virtual environment on learning achievement when compared to learning in face to face environment?
2. What is the effect of learning through augmented reality technology on learning achievement when compared to face to face learning?

Unless the results of the conducted studies are separately evaluated instead of interpreting as a whole, it may sometimes cause wrong or deficient results. When the literature is analyzed, numerous studies which reveal the effects of 3D virtual environment and augmented reality applications on learning achievement through experimental studies were observed however there was no study which aforementioned studies were interpreted as a whole through employing meta-analysis. Accordingly, this study was conducted through compounding the studies which deal with the effects of 3D virtual environment and augmented reality applications on learning achievement and meta-analysis was conducted. For each individual study, the effect size was calculated in addition to the effect size of 3D virtual environments and augmented reality on learning achievement were revealed.

- For that reason, this study is *significant* since it gives a general result indicating the effects of uning the aforementioned technologies in education on learning achievement,
- It is *updated* since it deals with 3D virtual environment and augmented reality technology which are both popular and frequently employed technologies,
- It is *necessary* since it employs meta-analysis method which isn't frequently employed but strengthens the findings of the individual studies and increases the statistical significance,
- It is regarded as *distinctive* since no study was observed in the literature related to the effect size of 3D virtual environment and augmented reality technology on learning achievement.

Method

The Research Model

In this study, meta-analysis method, one of the systematically synthesizing methods, was employed. Meta-analysis is "the systematical summarization of a group of studies on a definitetopic through the help of statistical methods" (Göçmen, 2004, p.189). The purpose of meta-analysis is to obtain a general result through combining the results of different studies and to re-analyze the results of a definite study (Dinçer, 2014). While conducting a meta-analysis within the context of a research, the existence of *publication bias* should be analyzed. Publication bias is a significant factor which affects the results in meta-analysis method. If the number of the studies which is included in meta-analysis according to the inclusion criteria in a study or only studies which obtain significant findings on behalf of the method, the publication bias is inevitable related to that research. The publication bias beyond a definite level affcets the size of the average effect size to be calculated and causes higher values than expected (Borenstein, Hedges, Higgins, & Rothstein, 2009). For that reason, the researcher should be objective in determining the studies, sweepingly scan the related literature and include the reliable ones into the meta-analysis. Before revealing the effect size, it is crucially important to conduct necessary analysis for publication bias. The effect size is one of the techniques which is employed in calculating the size of the difference between the averages of two groups (Fraenkel, Wallen, & Hyun, 2012). The statistically significant difference between the groups obtained through the test doesn't mean that the calculated effect is significant and important; fot that reason, it is important to calculate the effect size in the studies (Field, 2009). Among the formulas employed in the calculation of the effect size, the most familiar one is Cohen d (Üstün & Eryılmaz, 2014). In the literature, a list of the most frequently employed effect size was given in Table 1 below.

Table 1. Classification of Effect Sizes

Effect Sizes			
(Cohen, 1988)	*(Cohen, Manion, & Morrison, 2007)*	*(Lipsey & Wilson, 2001, as cited in Ferrer-Wreder, 2003)*	*(Thalheimer & Cook, 2002)*
d= ≤0.20 low level effect	.00<d<0.10 weak effect	d ≤.30 low level effect	-0.15<d<0.15 weak level effect
d=0.50-0.80 moderate level effect	0.10<d<0.30 modest effect	d ≤.50 moderate level effect	0.15<d<0.40 low level effect
d> 0.80 high level effect	0.30<d<0.50 moderate effect	.67≥ d high level effect	0.40<d < 0.75 moderate level effect
	0.50<d <0.80 strong effect		0.75<d<1.10 high level effect
	d≥ 0.80 very strong effect		1.10<d<1.45 very high level effect
			1.45<d excellent level effect

Data Collection

Within the context of this research, the processes employed in the application of meta-analysis method were given in Figure 2 below and each of the processes was explained in sub-titles.

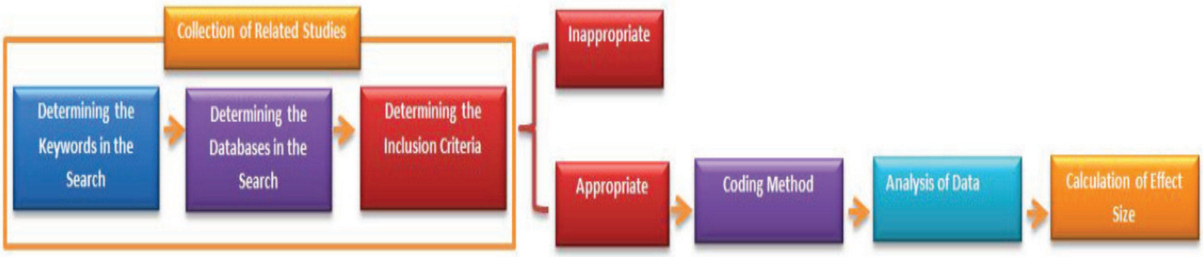

Figure 2. The Application Process of Analysis Method

When Figure 2 is analyzed, it is seen that the implementation of meta-analysis method starts with the step of collecting the related research (determining the keywords, determining the databases and determining the inclusion criteria). The studies in conformity with the inclusion criteria are coded through coding method and the effect size is determined by analyzing them. The studies which aren't in conformity with the inclusion criteria are kept out of the process of meta-analysis.

Determining the "Keywords" in the Search

Keywords were determined to be employed in the databases where the scanning will be conducted to access the related studies. The keywords which were determined to scan the 3-dimensional virtual environment were as follows: "3D virtual world" & achievement' and' "3D virtual environment" & achievement'. The keywords determined related to the scanning for augmented reality were as follows:' "augmented reality" & achievement'.

Determining the Databases in the Search

The databases where the scanning would be conducted were determined as "Science Direct", "ERIC", "Taylor & Francis", "EBSCO", "Emerald", "JSTOR", "SAGE", "SpringerLink" and "Google Scholar". The aforementioned databases were preferred since they are commonly employed in the field of education and all the published articles were shared in the electronic environment. Through using the determined keywords, the last scanning was conducted in those databases on the date of 26.09.2017. At the end of the first scanning with the keywords of '"3D virtual world" & achievement' without determining any criteria, 1.502 articles were found, 1.348 articles were found using the keywords '"3D virtual environment" & achievement', and 13.676 articles were found using the keywords '"augmented reality" & achievement'.

Determining the Inclusion Criteria

The criteria employed in the election of the included studies are as follows:

Criterion 1: The time interval of the studies which were included into meta-analysis: should be conducted between 2010 and 2016.

Criterion 2: Published resources of study: The articles which were published in the electronic and peer-reviewed environments.

Criterion 3: The conformity of research methods in the studies: In order to achieve the standardized effect size in the meta-analysis, the included researches should be experimental (should possess experimental and control groups), dependent variables should calculate learning achievement and the convenient technologies (3D virtual environments and augmented reality) should be employed as the independent variables.

Criterion 4: *Enough data should be available:* In order to calculate the effect sizes necessary for the meta-analysis activities, the descriptive statistics of experimental and control groups of the incuded studies are needed. For this purpose, the values listed below were included in the experimental and control groups:

1. Sample size (N)
2. Average ($\bar{x}$)
3. Standard Deviation (sd)
4. F value
5. t value
6. p value
7. Correlation coefficient (r)

After the scanning conducted in the aforementioned databases using the related keywords, the first inclusion criterion, limitation of time interval, was implemented and the numbers of articles to be analyzed were achieved. The numbers of obtained articles were given in Table 2.

Table 2. The Number of International Articles Achieved in the Databases after Time Limitation

Keywords	Databases*	Number of the Articles Achieved after Time Limitation
"3D virtual world"& achievement	Science Direct	34
	ERIC	7
	Taylor & Francis	56
	EBSCO	18
	Emerald	13
	JSTOR	1
	SAGE	33
	SpringerLink	23
	Google Scholar	805
Total		**990**
"3D virtual environment"& achievement	Science Direct	29
	ERIC	18
	Taylor & Francis	49
	EBSCO	17
	Emerald	12
	JSTOR	1
	SAGE	45
	SpringerLink	24
	Google Scholar	647
Total		**842**
"augmented reality"& achievement	Science Direct	303
	ERIC	25
	Taylor & Francis	555
	EBSCO	284
	Emerald	170
	JSTOR	16
	SAGE	313
	SpringerLink	202
	Google Scholar	982
Total		**2.850**

**The joint articles which were found in the databases after the conducted scanning weren't excluded from the given numbers.*

After the years of study was limited with the years of 2010-2016 as the first inclusion criterion, totally 4.682 articles were obtained. The aforementioned articles were reviewed one by one and analyzed for the other criteria (2-3-4). After the initial review, 47 articles were found convenient for 3D virtual reality environments while 54 articles were found in conformity with augmented reality. As a result of a detailed further analysis, 20 articles of the 47 studies related to 3D virtual environments and 24 of 54 articles related to augmented reality were found to fulfill all the necessary criteris and they were included into meta-analysis. The flow diagram showing the way to conduct the selections was given in Figues 3-4.

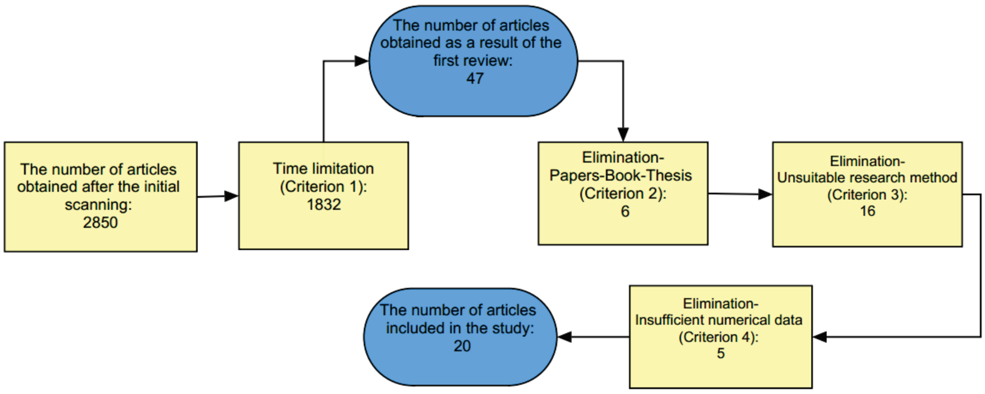

Figure 3. The Inclusion Process of the Studies into 3D Virtual Environment Meta-Analysis

When Figure 3 is analyzed, it is seen that 2850 articles were accessed after the initial scanning conducted using keywords determined for 3-dimensional environments. After that scanning, time limitation (the first criterion) was applied and 1832 articles were obtained. After that, the aforementioned 1832 articles were reviewed one by one and the number of the articles that might conform to the research was 47. When the articles were coded through the form which is developed by the researchers, 6 articles were excluded since they don't conform to Criterion 2, 16 articles weren't convenient for the criterion 3 and 5 articles were excluded due to its nonconformity to the criterion 4. In conclusion, the number of the articles found to be convenient for the research was 20. The list of the articles which were included in the research related to 3-dimensional virtual environments was given in Appendix-1. This is because three different results of analyses were obtained in the study conducted by Jong (2015) and this study was included into meta-analysis three times.

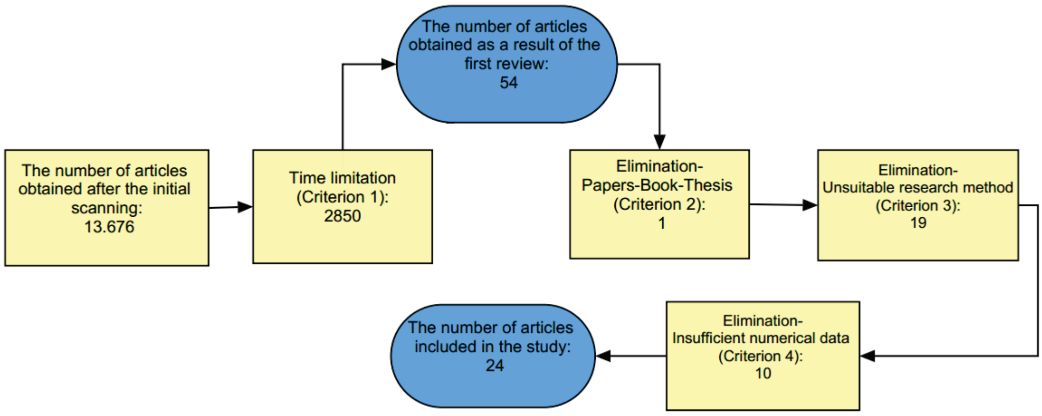

Figure 4. The Inclusion Process of the Studies into Augmented Reality Meta-Analysis

When Figure 4 is analyzed, it is seen that 13.676 articles were accessed through using the keywords determined related to the augmented reality. Following this scanning, time limitation (criterion 1) was implemented and 2850 articles were obtained. After that, the 2850 articles were reviewed one by one the numbers of the convenient articles were reduced to 54. When codification was started through using the form which is developed by the researchers, it was seen that 1 article was not convenient for criterion 2 while 19 of them were irrelevant to criterion 3 and 10 articles weren't found in conformity with criterion 4 and they were excluded from the research. In conclusion, the number of the articles which were found convenient for inclusion was 24. The list of articles which were included to the augmented reality meta-analysis was given in Appendix-2. There are 22 articles in Appendix-2. Because, the studies conducted by Zhang, Sung, Hou, and Chang (2014) and Chu, Chen, Yang and Lin (2016) achieved two different results of analysis which measure the dependent variant of learning achievement in the conducted studies and those studies were included in the meta-analysis twice.

Encoding the Studies

After the studies which are in conformity with the inclusion criteria in meta-analysis are determined, the afprementioned studies are codified according to a definite protocole. In order to do so, a codification form is needed. The codification form was employed in controlling the determined studies for their convenience for inclusion to meta-analysis and transforms the data employed in the studies which were included into meta-analysis through codifying. In the codification form employed in the research, there are three chapters such as the identity of the study, contents of the study, and data of the study (Table 3).

Table 3. Chapters of the Codification Form and It's Content

The Identity of the Study	**Contents of the Study**	**The Data of the Study** *Related to Experimental and Control Groups:*
Study code (According to the technology used)	Application Level	Sample Size (N)
The Title of the study	The country where the research was conducted	Mean ($\overline{X}$)
Author/Authors of the Sudy	Teaching method used in the experiment group	Standard deviation (sd)
Publication Year	Teaching method used in the control group	F value
Publication Type	Lesson	t value
	Duration of the study	p value
	Concepts used for learning success	Correlation coefficient (r)

The Reliability and Validity of the Research

These studies were coded by the first and third authors of the paper to ensure reliability in the analysis of the studies included in the meta-analysis. The coding form was prepared by the first author. During coding, the first author was named encoder1, while the third author was named encoder2. In order to analyze the consistency between the results obtained from the coders, Cohen's Kappa analysis was conducted. According to the results of kappa test conducted related to 3D virtual environment meta-analysis, the conformity between the codifiers was found as .929. According to the results of the kappa test conducted for the studies which were included in augmented reality analysis, the coherence between the codifiers was found as .907. According to the conformity criteria determined by Viera and Garret'in (2005), it shows a perfect conformity between the levels of .081 and .099. In that case, it may be concluded that there is a perfect conformity between the coders in codifying the studies included in the 3D virtual environment meta-analysis.

The validity of the united effect size calculated in meta-analysis depends on the validity of the other studies which were included in the analysis (Petitti, 2000 Cited In: Kış, 2013). For that reason, validity of all the studies which were included in the meta-analysis will make the conducted meta-analysis valid. Within the context of the research, 44 studies which were included in meta-analysis were seen to have validity. Accordingly, it can be concluded that this research is valid.

Moderators of the Research

The moderators of the study are the independent variables which are considered to have effect on the calculated effect size. The moderator of the study which may affect this research was determined as "education level". The analysis employed related to the moderator of the study was given in the chapter related to the findings.

Data Analysis

In the research, group difference meta-analysis method was employed since the experimental and control groups were compared during the analysis of data. Through calculating the effect size of each research, Statistical Package Program Comprehensive Meta Analysis (CMA) 2.2 was employed for meta-analysis in order to compare the variances and groups. After the effect size of each study included in the meta-analysis in the research, the homogeneity test was conducted. After the aforementioned homogeneity test, it was decided to employ both fixed effect model and random-effects model in the meta-analysis. Primarily, the fixed-effect model was employed in the study and then the analysis was conducted using the random-effect model. The Cohen d statistics which define the differences between the standardized averages is applied in order to measure the effect size. Cohen d indicates that how many standard deviations, the averages separate from each other (Card, 2012; Borenstein et al., 2009 Cited In: Kış, 2013).

Related to the coder reliability test in the research, the Statistical Package for the Social Sciences (SPSS) 21.0 program was employed. The significance level for all the statistical calculatipns in the study was found .05.

Results

In this chapter, the findings obtained through meta-analysis method were given.

The Findings of Analysis of the Effect Size of Employing 3-Dimensional Virtual Environment on Learning Achievement

The first research question of the study was determined as follows: "What is the effect of learning 3-dimensional virtual environment on learning achievement when compared to learning in face to face environment?" In order to find answer to that problem, necessary analyses were conducted on the data related to the included in the research. At the end of the aforementioned analyses, the findings related to the publication bias, forest graphic, fixed-effects model, homogeneity test, random-effects model and moderator analysis were given below.

Publication Bias

Before starting meta-analysis, it is extremely important to test whether there is a publication bias (Kış, 2013). For that reason, three methods such as Funnel plots, Orwin's fail-safe N, and Egger test were employed to test the publication bias.

The Results of Funnel Plots Graph:

One of the results of the tests of meta-analysis for the publication bias is the funnel scatter plots. The funnel scatter plots show the standard error value (SE) of the study on the centerline of Y while it they show the effect size (ES) on the centerline of X. In order to access the conclusion of "there is no publication bias" according to this graphic, it is necessary to visually determine that the included studies were symmetrically distributed around the general effects size (the vertical middle line in the funnel) and the values of standard error were scattered towards zero points (upside of the graphic) more densely. The studies with lower levels of standard error value are gathered around the upper side of the figure of funnel and near the average effect size while the studies with higher ones are seen around the bottom of the graphic and aer gathered at only one section of the vertical line (Borenstein et al., 2009; Şad, Kış, Demir, & Özer, 2016). The results of funnel scatter plots of the study were given in Figure 5.

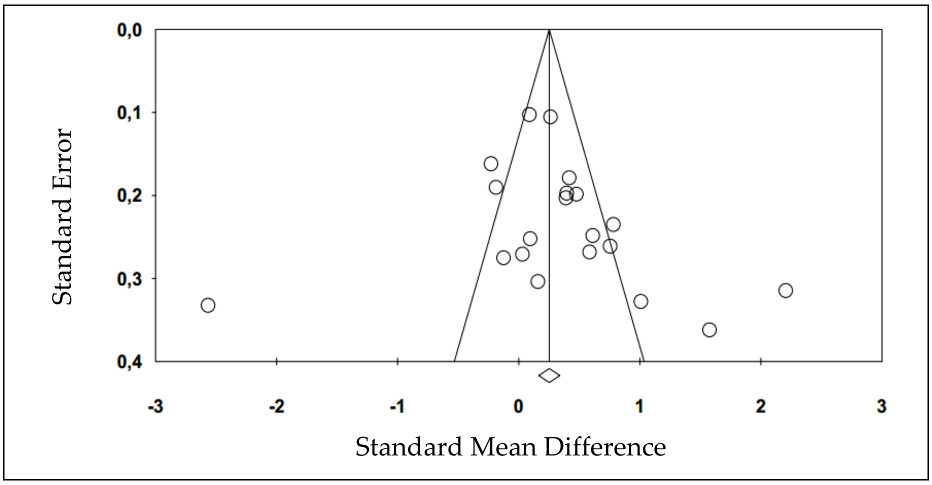

Figure 5. The Funnel Scatter Plots of the Studies Which Deal with the Effects of 3D Virtual Environments on Learning Achievement Related to their Publication Bias

According to this graphic, there is symmetry among the studies but there is localization in the middle of the graphic. This result strengthens the claim that there is no publication bias. However, this result also indicates that other analysis should be analyzed.

The Results of Orwin's Fail-Safe N (Orwin Fail-Safe N):

Another test for the publication bias of the results of the meta-analysis is *Orwin's Fail-Safe N.* The publication bias of the studies which deal with 3-dimensional virtual environments was analyzed through employing Orwin's Fail-Safe N. It is employed in calculating how many studies more are needed to decrease the general effect size (for fixed effects model, d=0,252) into ineffectiveness level (d=0,00). The result related to this study is 485 studies. It is suggested that this quantity should be 5-10 times more than the included studies. However, this result (485/20 = 24.25) is far more over than the aforementioned criterion. Except the studies included in the research, it was concluded that there is no publication bias in the research since it is impossible to access 485 studies through the determined criteria.

Results of Egger Test:

Another test for the publication bias of the results of the meta-analysis is *Egger test.* The publication bias of the studies which deal with 3-dimensional virtual environments on learning achievement was analyzed through Egger Test. The obtained findings were given in Table 4.

Table 4. The results of Egger test related to publication bias of 3-dimensional virtual environments on learning achievement

Intercept	1.48527
Standard Error	1.78191
%95 Lower Limit (2 tailed)	-2.25838
%95 Upper Limit (2 tailed)	5.22893
t-value	0.83353
sd	18.00000
p-value (1 tailed)	0.20774
p-value (2 tailed)	0.41547

The fact that p value of this analysis which test the asymmetry of the funnel plots isn't statistically significant gives the conclusion that funnel plots aren't also asymmetrical (p=0.42, p>.05). This result proves that there is no publication bias in the study.

The Uncombined Findings related to the Effect Size of 3D Virtual Environment on Learning Achievement

There is a need for the calculation of the effect size of each study while conducting the meta-analysis. The size effects of 3-dimensional learning environments, standard error and lower and upper limits according to the reliability interval of 95% from the highest size effect to the lowest size effect were all given in Table 5.

Table 5. The Effect Sizes of 3-dimensional Virtual Environments on Learning Achievement

Study Name (Author, Year)	Effect Size (d)	Standard Error	Variance	Lower Limit	Upper Limit	Z Value	P
Jong, 2015c	2,206	0,315	0,099	1,589	2,822	7,011	0,000
Ijaz, Bogdanovych and Trescak, 2016	1.576	0.362	0.131	0.866	2.285	4.353	0.000
Adamo-Vilani and Dib, 2012	1.009	0.328	0.107	0.367	1.651	3.079	0.002
Chee and Tan, 2012	0.781	0.235	0.055	0.321	1.242	3.324	0.001
Su and Cheng, 2013	0.755	0.261	0.068	0.243	1.266	2.891	0.004
Chung, 2012	0.612	0.248	0,062	0,125	1,098	2,463	0,014
Hwang and Hu, 2013	0,585	0,268	0,072	0,059	1,110	2,181	0,029
Chau et al. 2013	0,477	0,198	0,039	0,088	0,866	2,404	0,016
Sun, Lin and Wang, 2010	0,417	0,179	0,032	0,066	0,767	2,331	0,020
Jou and Liu, 2012	0,396	0,197	0,039	0,010	0,783	2,010	0,044
Jacobson, Taylor, and Richards, 2016	0,390	0,203	0,041	-0,008	0,788	1,922	0,055
Lee and Wong, 2014	0,262	0,105	0,011	0,055	0,468	2,485	0,013
Güzel and Aydin, 2016	0,159	0,304	0,092	-0,437	0,754	0,522	0,602
Jong, 2015b	0,095	0,252	0,064	-0,399	0,589	0,376	0,707
Merchant et al., 2013	0,088	0,103	0,011	-0,113	0,289	0,858	0,391
Tüzün and Özdinç, 2016	0,031	0,271	0,073	-0,500	0,561	0,113	0,910
Zaharias, Michael, and Chrysanthou, 2013	-0,125	0,275	0,076	-0,664	0,414	-0,456	0,648
Okutsu, DeLaurentis, Brophy and Lambert,2013	-0,188	0,190	0,036	-0,561	0,185	-0,988	0,323
Sun and Chan, 2013	-0,229	0,162	0,026	-0,546	0,088	-1,414	0,157
Jong, 2015a	-2,566	0,332	0,110	-3,217	-1,914	-7,719	0,000

According to the Table 5, the size effects of 3D virtual environment on learning achievement in 20 studies with 2180 participants (1078 in control group and 1105 in experimental group) varies between d=-2,566 and d= 2,206. Among those studies, 12 of them had statistical significance ($p<.05$) while the remaining 8 studies had no statistical significance ($p>.05$). Of the 20 studies, 16 of them aimed to reveal the learning achievement through a single dimensional assessment instrument. In remaining 4 studies, the employed assessment instruments had more than one sub-dimensions in order to analyze the effects of 3D on learning achievement.

The Findings of Size Effect Meta-Analysis of 3D Virtual Environment on Learning Achievement in Terms of Fixed Effect Model

The effect size of 3D virtual environments on learning achievement is given in Table 6 in terms of the average effect size, standard error and the reliability interval of 95% according to the fixed-effect model.

Table 6. The Findings of Meta-Analysis for the Effect Size of 3D Virtual Environment on Learning Achievement in Terms of Fixed-Effects Model

Study	Effect Size (d)	Standard Error	Variance	Lower Limit	Upper Limit	Z Value	*p*
Fixed Effect Model	0.252	0.044	0.002	0.165	0.339	5.693	0.00

In Table 6, the data of studies which deal with the effects of 3D environments on learning achievement according to fixed effect model is given. According to the result of this model, the value for average effect size is d=0.25, standard error of the average effect size is SH=0.044, and the upper limit and lower limit of the reliability interval of the average size effect is 0.33 and 0.16, respectively. When the statistical significance is assessed according to Z test, the value of Z=5.693 (p=0.00, p<.05) has been found significant.

The data in the 20 studies included in meta-analysis displays that the level of learning achievement according to fixed effect model is higher on behalf of experimental group. When the value of effect size is considered, the level of 0.25 shows a moderate level according to the classification of Cohen (1988). According to the other classifications, lower levels of effect has been obtained (Cohen, Manion, & Morrison, 2007; Lipsey & Wilson, 2001; Thalheimer & Cook, 2002).

Homogeneity Test, Q and I^2 Statistics

In case the individual studies included in meta-analysis are found to be homogeneous as a result of the conducted test, fixed effects model is implemented. For that reason, the homogeneity test was conducted in order to test the convenience of continuing the research through the fixed effects model. The results of the conducted test were given in Table 7.

Table 7. The Results of the Homogeneity Test for the Effects of 3D Virtual Environments on Learning Achievement in Terms of Size Effect Distribution

Q value	df (Q)	*p*	I^2 value
164,459	19	0.00	88.447

According to the result of the homogeneity test between the effect size showing the effects of 3-dimensional virtual environments on learning achievement, a significant diffecerence was obtained (Q=164,45; p<.05). In that case, it was concluded that the distribution isn't homogeneous (heterogeneous).

The I^2 test which is the complement of the Q test isn't influenced from the number of studies on the contrary to the Q test. Cooper, Hedges and Valentine (2009) found that the I^2 value around the level of 25% was low levels of heterogeneity, moderate at about 50% and high at about 75%. In this research, the average effects size obtained according to fixed effects model (the I^2 value for 0.25) displays high levels of heterogeneity with the value of 88%. According to the obtained data, the averages of the size effects of the studies selected for meta-analysis conducted in order todetermine the effects of 3-dimensional virtual environments on learning achievement display an asunder and heterogeneous distribution.

Accordingly, the random-effects model was applied in the research since the individual studies included in the study displayed a heterogeneous distribution.

Findings of Meta-Analysis for the Effect Size of 3D Virtual Environment on Learning Achievement

The effect size of 3D virtual environments on learning achievement according to random-effects model, the standard error and upper and lower limits according to the reliability interval of 95% were all given in Table 8.

Table 8. Findings of Meta-Analysis for the Effect Size of 3D Virtual Environment on Learning Achievement According to Random-Effects Model

Study	Effect Size (d)	Standard Error	Variance	Lower Limit	Upper Limit	Z Value	*p*
Random Effect Model	0.327	0.137	0.019	0.059	0.595	2.390	0.017

According to Table 8, the data in the 20 studies included in meta-analysis gave the following results according to random-effect model; 0.137 standard error, the upper limit of 95% reliability interval at the level of 0.595 and the lower limit at the level of 0.059 and the value of effects size was 0.327. In terms of statistical significance, the z value according to the z test was 2.390, p value was 0.017 (p<.05).

It means that the study is statistically significant. The results of the conducted analysis displayed that the level of learning achievement was higher on behalf of the experimental group. Namely, the effect of 3-dimensional virtual environment on learning achievement in the experimental group is higher than the control group. According to the classfications of effect size conducted by Cohen (1988), Cohen et al. (2007) and Lipsey and Wilson'un (2001), the value of effects size obtained in the study had moderate levels of effect. As to the classification of Thalheimer and Cook (2002), the obtained effect size can be listed in the low levels of effect size.

In Figure 6, the effect sizes of experimental and control groups according to their learning achievement were given through the forest plots according to the fixed and randoms effect models.

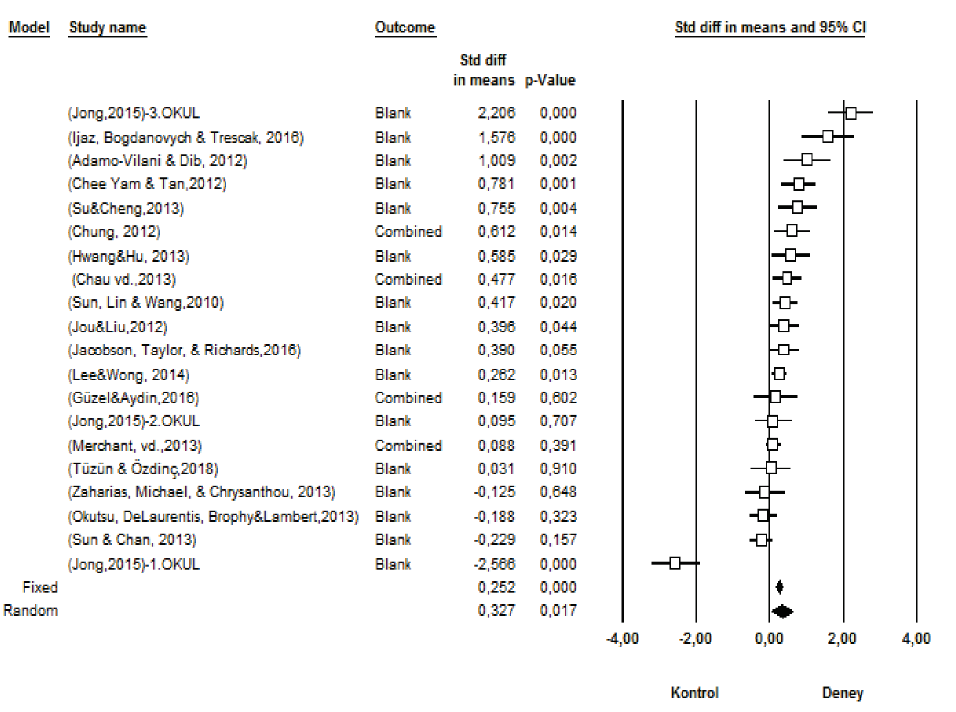

Figure 6. The Forest Plots of Effect Sizes of Experimental and Control Groups on Learning Achievement According to Fixed and Random Effects Model

When Figure 6 is analyzed, it is observed that the effect size associated in both fixed and random effect models is on behalf of experimental group and have a moderate level of effect in both fixed and random effect models. According to the result of meta-analysis, the last 4 studies resulted in favor of control group while the remaining 16 studies ended up on favor of experimental group. In addition, only one among the four studies had statistical significance while the remaining three had no statistical significance.

The Moderator Analysis of the Effect Size of 3D Virtual Environments on Learning Achievement According to the Application Levels

One of the reasons for the difference between the effect sizes may be the moderator variables of the studies included in meta-analysis. For that reason, the sample level was determined in the research as the moderator variants and analyzed. The studies which deal with the effects of 3-dimensional virtual environments on learning achievement and were included in meta-analysis were classified in four categories such as primary school, undergraduate, high school and secondary school according to the application level. Ten studies which consist of data of average effect size related to the application level moderator chose undergraduate level, 4 studies preferred primary school level and 2 of them employed secondary school level as the application level (Table 9).

Table 9. The Results of Analysis for Application Level Moderator Related to the Variant of Learning Achievement

				%95 CI				Heterogeneity		
Application Level	**N**	**Mean ES**	**SE**	**Lower Limit**	**Upper Limit**	**z**	**p**	**Q**	**df**	**P**
Undergraduate	10	0.433	0.138	0.163	0.703	3.139	0.002			
Primary School	4	0.151	0.206	-0.253	0.555	0.733	0.464			
High School	4	0.006	0.702	-1.369	1.381	0.009	0.993			
Secondary School	2	0.568	0.195	0.186	0.949	2.914	0.004			
Total Between								2.572	3	0.462
Overall	20	0.395	0.098	0.203	0.587	4.039	0.000			

As seen in Table 9, the average values of effect size among the application level groups for as follows; 0.433 (CI 0.163-0.703, p<.05) for the group of undergraduate level, 0.151 (CI -0.253-0.555, p>.05) for the group of primary school, 0.006 (CI -1.369-1.381, p>.05) for the participants at the high school level and 0.568 (CI 0.186-0.949, p<.05) for the group of secondary school. The variance between the studies in terms of application level moderator isn't statistically significant (QB= 2.572, p>.05). it was determined that chosing the levels of education such as underfraduate education, primary school, high school and secondary school didn't change the effect size of 3-dimensional virtual environments of learning achievement.

The Findings of Analysis Related to the Effects of Augmented Reality Applications on Learning Achievement

The second research question of the study was determined as follows; "What is the effect of learning through augmented reality on learning achievement when compared to learning in the face to face environment?". In order to find an answer to that problem, the related data in the studies which were included in meta-analysis were analyzed. As a result of that analysis, the obtained publication bias, the forest plots, the fixed effects model, homogeneity test, random effects model and moderator analysis were given below.

Publication Bias

Before starting meta-analysis, it is vitally significant to test the fact that whether there is a publication bias (Kış, 2013). For that reason, three methods such as Funnel plots, Orwin's fail-safe N and Egger test.

The Results of Funnel Distribution Plots:

One of the tests for the results of meta-analysis is the funnel scattering plots. The funnel scattering plots display the value of standard error (SE) of the study on the axis of Y and the effect size (ES) on the axis of X. According to this graph, there is a need for visually determining that the included studies are distributed around the general effect size (a vertical line in the middle of the funnel) and the value of standard error is densely scattered around the zero point (about the top of the graphic). The results of funnel scattered plots related to the research were given in Figure 7.

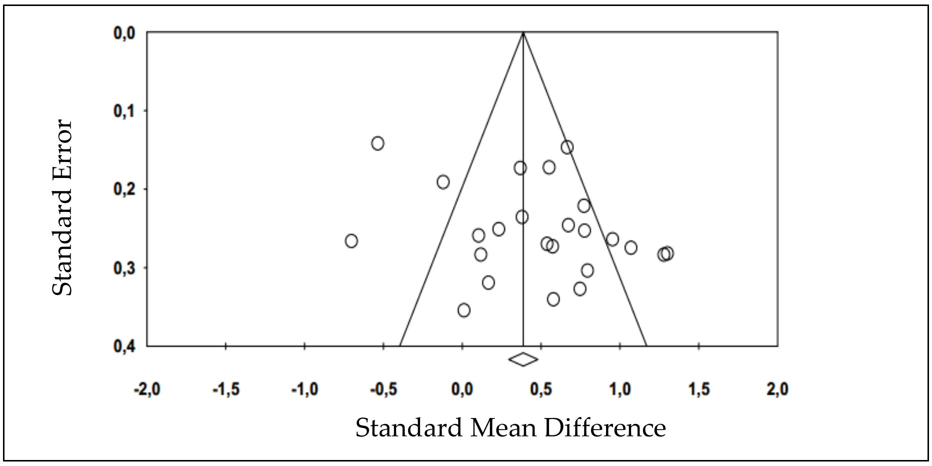

Figure 7. The Funnel Scattered Plots Related to the Publication Bias of the Studies Which Deal with the Effect of Augmented Reality Applications on Learning Achievement

According to this graph, it is observed that there is symmetry in the studies but there is a condensation in the middle of the graphic. This result strengthens the conclusion that there is no publication bias. However, this result reveals the necessity for examining other analysis, too.

The Results of Orwin's Fail-Safe N:

One of the other tests for the publication bias of the results of meta-analysis is *Orwin's Fail-Safe N.* The publication bias of augmented reality applications on leraning achievement was analyzed through Orwin's Fail-Safe N test. Another test which is employed for the publication bias of meta-analysis results is Orwin's Fail-Safe N. This test is employed in order to calculate the number of the studies neded for decreasing the general effect size (d=0,387 for fixed effects model) into the level of ineffectiveness, d=0,00. This result is 905 studies related to this research. It is suggested that the number of the studies included in this research should be fivefold or 10 times more than present. However, this result (905/24 = 37,70) is much more beyond this criterion. Except the studies included in the research, it is impossible to access 905 studies more and this was accepted as the indicator of the absence of publication bias in the study.

The Results of Egger Test:

One of the other tests for the publication bias of the results of meta-analysis is *Egger test.* The publication bias of augmented reality applications on leraning achievement was analyzed through Egger test. The obtained findings were given in Table 10.

Table 10. The Results of Egger Test Related to the Publication Bias of the Studies Analyzing the Effects of Augmented Reality Applications on Learning Achievement

Intercept	2.89286
Standard Error	1.68180
%95 Lower Limit (2 tailed)	-0.59498
%95 Upper Limit (2 tailed)	6.38070
t-value	1.72010
sd	22.00000
p-value (1 tailed)	0.04973
p-value (2 tailed)	0.09945

The fact that p value of the result of this analysis which test whether the funnel plots are asymmetrical or not isn't significant gives the conclusion that the funnel plots aren't asymmetrical (p=0.099, p>.05). This result is another proof of the lacking of publication bias in the study.

The Uncombined Findings of the Analysis for the Effect Size of Augmented Reality on Learning Achievement

While conducting meta-analysis, it is necessary to calculate the effect size of each study. The effect size of augmented reality applications on learning achievement, the ranking of the effect size from highest one to the lowest one, standard error and the upper and lower limits according to the confidence interval of 95% were given in Table 11.

Table 11. The Effect Sizes of Augmented Reality Applications on Learning Achievement

Study Name (Author, Year)	Effect Size (d)	Standard Error	Variance	Lower Limit	Upper Limit	Z Value	P
Solak and Çakır, 2016	1,301	0,282	0,079	0,749	1,854	4,616	0,000
Chang and Liu, 2013	1,279	0,283	0,080	0,724	1,834	4,513	0,000
Yang, Hwang, Hung, and Tseng, 2013	1,071	0,275	0,075	0,532	1,609	3,898	0,000
Liu and Chu, 2010	0,954	0,264	0,070	0,437	1,471	3,615	0,000
Gutierrez and Meneses Fernandez, 2014	0,794	0,304	0,092	0,199	1,390	2,617	0,009
Zhang, Sung, Hou, and Chang, 2014b	0,776	0,253	0,064	0,280	1,271	3,068	0,002
Chang et al., 2014	0,772	0,221	0,049	0,339	1,206	3,491	0,000
Lin, Duh, Li, Wang, and Tsai, 2013	0,747	0,327	0,107	0,106	1,388	2,284	0,022
Küçük, Kapakin, and Göktaş, 2016	0,673	0,246	0,060	0,191	1,155	2,739	0,006
Ferrer-Torregrosa, Torralba, Jimenez, Garcia, and Barcia, 2015	0,666	0,147	0,021	0,378	0,953	4,539	0,000
Chu, Chen, Yang, and Lin, 2016a	0,579	0,340	0,116	-0,088	1,245	1,700	0,089
Tarng, Lin, Lin, and Ou,2016	0,573	0,273	0,074	0,038	1,108	2,100	0,036
Gopalan, Zulkifli, and Abubakar, 2016	0,551	0,172	0,030	0,214	0,889	3,201	0,001
Chiang, Yang, and Hwang, 2014	0,538	0,270	0,073	0,009	1,066	1,994	0,046
Zhang, Sung, Hou, and Chang, 2014a	0,380	0,235	0,055 -	-0,082	0,841	1,613	0,107
Jee, Lim, Youn, and Lee, 2014	0,368	0,173	0,030	0,029	0,708	2,128	0,033
Hsiao, Chang, Lin, and Wang, 2016	0,232	0,251	0,063	-0,260	0,724	0,924	0,355
Yoon, Elinich, Wang, Steinmeier, and Van Schooneveld,2012	0,166	0,319	0,102	-0,459	0,792	0,521	0,602
Cai, Chiang, and Wang, 2013	0,118	0,283	0,080 -	-0,438	0,673	0,416	0,678
Ibáñez, Di Serio, Villarán, and Kloos, 2014	0,104	0,259	0,067	-0,404	0,612	0,402	0,688
Chu, Chen, Yang, and Lin, 2016b	0,011	0,354	0,125	-0,683	0,705	0,031	0,975
Chen and Tsai,2012	-0,121	0,191	0,036	-0,495	0,253	-0,633	0,526
Hsiao, Chen, and Huang, 2012	-0,535	0,142	0,020	-0,813	-0,258	-3,777	0,000
Tarng, Ou, You, Liou, and Liou, 2015	-0,703	0,266	0,071	-1,224	-0,181	-2,641	0,008

According to Table 11, the standardized effect sizes of augmented reality applications on learning achievement in the 24 studies with 1937 participants (1000 experimental group and 937 control group) varies between d=-0,703 and d= 1,301. Among those studies, 16 of them had statistical significance ($p<.05$) while remaining 8 studies didn't display statistical significance ($p>.05$). The 20 studies of the 24 studies aimed to reveal the learning achievement through a single dimensional assessment instrument. The remaining 4 studies more than one dimensional assessment instrument was employed and the effect of augmented reality on learning achievement was analyzed.

Findings of Meta-Analysis of Augmented Reality Applicatins on Learning Achievement According to Fixed Effects Model

The effect size of augmented reality applications on learning achievement, the average effect size according to fixed effect model and the upper and lower limits according to the confidence interval of 95% were given in Table 12.

Table 12. Findings of Meta-Analysis of Augmented Reality Applicatins on Learning Achievement According to Fixed Effects Model

Study	Effect Size (d)	Standard Error	Variance	Lower Limit	Upper Limit	Z Value	*p*
Fixed Effect Model	0,387	0.047	0.002	0.294	0.480	8.159	0.00

In Table 12, the values of the studies related to the effect size of augmented reality applications on learning achievement according to the fixed effects model were given. According to the result of this model, the average value of effect size is d=0.387, the standard error of the average size effect is SH=0.047 and the upper limit for the average effect size is 0.48 while the lower limit is 0.29. When the statistical significance is calculated according to z test, it was found that z=8.159 value is significant (p=0.00, p<.05).

Data in the 24 studies included in meta-analysis was found higher on the favour of experimental group according to the fixed effects model. When the value of effect size is considered, a moderate level of effect of 0.38 was obtained according to the classification by Cohen (1988), Cohen et al. (2007) and Lipsey and Wilson (2001). According to the classification by Thalheimer and Cook (2002), there is a low level of effect.

Homogeneity Test, Q and I^2 Statistics

As a result of the conducted test, the fixed effects model is applied in case the individual studies included in meta-analysis are homogeneous. For that reason, the homogeneity test was implemented in order to determine the conformity of the research for fixed effects model. The results of conducted homogeneity test were given in Table 13.

Table 13. The Results of the Homogeneity Tests for the Distribution of Effect Size Related to the Effect of Augmented Reality Applications on Learning Achievement

Q Value	df (Q)	*p*	I^2 value
116,900	23	0.00	80.325

According to the homogeneity test conducted in order to determine whether fixed effects model is convenient for this meta-analysis study (Q=116.90; p<.05), significant differences were found between the studies. In that case, it was concluded that the distribution isn't homogeneous (it is heterogeneous).

The I^2 test which is the complement of the Q test isn't influenced from the number of studies on the contrary to the Q test (Kış, 2013). Cooper et al. (2009) found that the I^2 value around the level of 25% was low levels of heterogeneity, moderate at about 50% and high at about 75%. In this research, the average effects size of 0.387 obtained according to fixed effects model (the I^2 value for 0.25) displays high levels of heterogeneity with the value of 80%. According to the obtained data, the averages of the size effects of the studies selected for meta-analysis conducted in order to determine the effects of augmented reality applications on learning achievement display an asunder and heterogeneous distribution.

Accordingly, the random-effects model was applied in the research since the individual studies included in the study displayed a heterogeneous distribution.

Findings Meta-Analysis for Effect Size of Augmented Reality Applications on Learning Achievement According to Random Effects Model

The effect size of augmented reality applications on learning achievement, the average effect size according to random-effect model and the upper and lower limits according to the confidence interval of 95% were given in Table 14.

Table 14. Findings Meta-Analsysis for Effect Size of Augmented Reality Applications on Learning Achievement According to Random Effects Model

Study	Effect Size (d)	Standard Error	Variance	Lower Limit	Upper Limit	Z Value	*p*
Random Effect Model	0,461	0.110	0.012	0.245	0.676	4.196	0.000

According to Table 14, the data of 24 studies included in meta-analysis was found as follows according to random-efefcts model: the value of 0.110 for standard error, the lower limit of confidence interval of 95% is 0.676 while the lower limit is 0.245. When the statistical significance is assessed according to z test, the z value was found as 4.196 while the p value is 0.000 (p<.05); thus, it means that the study is statistically significant. As a result of the conducted analysis, it was observed that learning achievement is higher on favor of experimental group. Namely, the effects of learning through augmented reality applications in experimental group are bigger when compared to learning in face to face environment in the control group. According to the classification of effect size by Cohen (1988), Cohen et al. (2007), Lipsey and Wilson (2001) and Thalheimer and Cook's (2002), the value for the effect size obtained at the end of the research have a moderate level of effect.

In Figure 8, the forest plots of the effect size of experimental and control groups according to fixed and random-effect models were given.

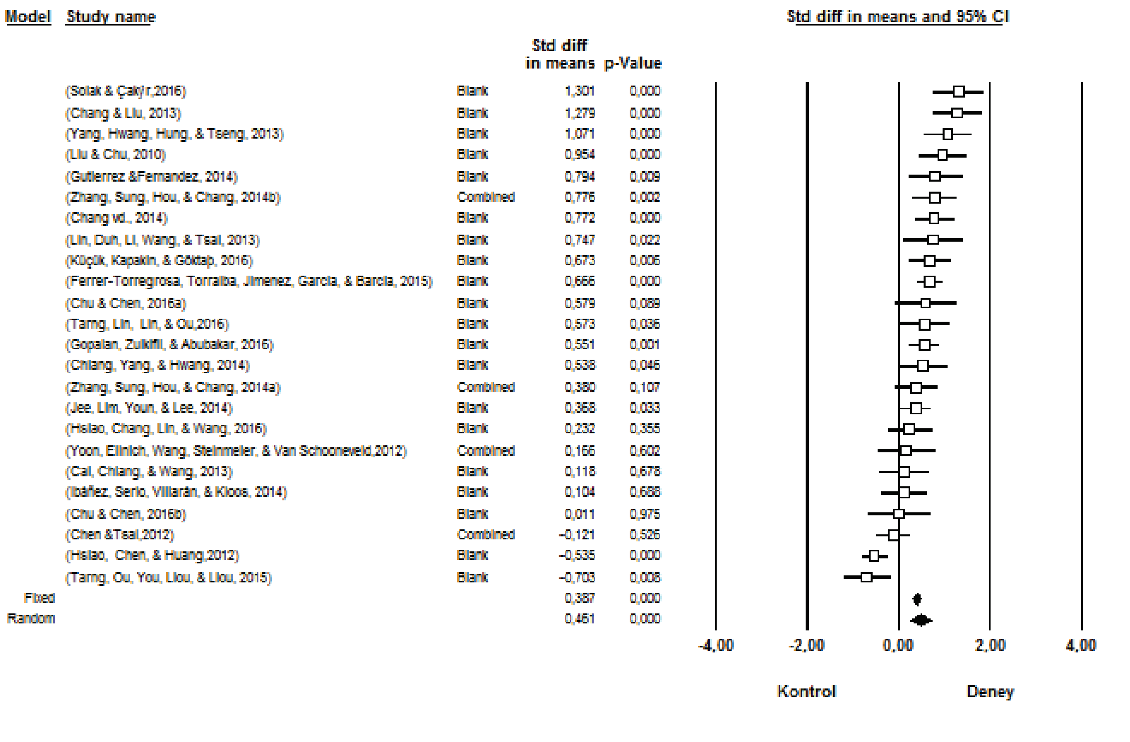

Figure 8. The Forest Plots of Effect Size of the Experimental and Control Groups According to their Learning Achievement in the Fixed and Random-Effect Models

When Figure 8 is analyzed, it may be seen that the size of effects combined in both fixed and random effects model had a moderate level in favor of the experimental group. According to meta-analysis, only last for studies resulted in favour of the control group while remaining 20 studies resulted in favour of the experimental group. Moreover, only 2 of the aforementioned 4 studies have statistical significance while remaining 2 studies haven't statistically significant.

The Moderator Analysis Results of the Effect Size of Augmented Reality on Learning Achievement According to the Application Levels

One of the reasons for the difference in effect sizes may be the moderator variables of the studies included in meta-analysis. For that reason, the application level was determined as the moderator variable and it was analyzed. The studies which were included in meta-analysis and deal with the effects of augmented reality applications on learning achievement were classified into three groups such as primary school, undergraduate education and secondary school according to the application levels. Eleven studies which employ the data of average effect size for the application level moderator were in the group of secondary school, 6 studies were at primary school level and 5 studies had the undergraduate application level. In the moderator analysis, the number of sub-groups should be between 2 and 8 (Pincus et al., 2011). For that reason, one study which dealth with post-graduate level (Chang & Liu, 2013); and another study which dealt with high school level (Ibáñez et al., 2014) were excluded from the research (Table 15).

Table 15. The Analysis Results of Application Moderator Related to the Variable of Learning Achievement

				%95 CI				Heterogeneity		
Application Level	**N**	**Mean ES**	**SE**	**Lower Limit**	**Upper Limit**	**z**	**p**	**Q**	**df**	**P**
Secondary School	11	0,448	0,194	0,068	0,828	2,311	0,021			
Primary School	6	0,207	0,196	-0,178	0,592	1,055	0,292			
Undergraduate	5	0,709	0,098	0,516	0,901	7,216	0,000			
Total Between								5,787	2	0,055
Overall	22	0,581	0,080	0,424	0,738	7,262	0,000			

As seen in Table 15, the values of average effect size for the application level groups are as follows: 0.448 (CI 0.068-0.828, p<.05) for the group of secondary school, 0.207 (CI -0.178-0.592, p>.05) for the group at the level of primary school and 0,709 (CI 0.516-0.901, p<.05) for the undergraduate level. The variance for the application level moderator isn't statistically significant in the studies (QB= 5.787, p>.05). It was found that choosing the sampling of the study as secondary school, primary school and undergraduate level didn't affcet the efefct size of the augmented reality applications on learning achievement.

Discussion, Conclusion and Suggestions

The first sub-problem determined in this study is "*What is the effect of learning in 3-dimensional virtual environment on learning achievement when compared to face to face learning?*". In order to find an answer to that question, meta-analysis of 20 studies were conducted. First of all, fixed effects model was employed in the meta-analysis. According to the result of this model, the average value of effect size was found as d=0.25 then, the homogeneity test was conducted to see if employing this model is convenient for the research or not. According to the results of the homogeneity test, a significant difference was found and it was concluded that the distribution is heterogeneous, namely not homogeneous, (Q=164,45; p<.05). Cooper et al. (2009) found that the I^2 value at low levels around 25%, moderate levels at about 50% and high levels at about 75% and over means that there is high level of heterogeneity. The level of 88% I^2 value obtained from the study means high levels of heterogeneity. For that reason, random-effects model was preferred instead of fixed effects model. The average of the effect size of the studies included in meta-analysis according to random-effects model was found 0.32. According to the size effect classifications by Cohen (1988), Cohen et al. (2007) and Lipsey and Wilson

(2001), the value of effect size found at the end of the research was determined to have a moderate level of effect. According to the classification of Thalheimer and Cook (2002), the observed value of effect size is in the category of low level of effect. The result of the conducted analysis displayed that learning achievement showed that learning achievement level is higher in the experimental group. Namely, it was concluded that learning in the experimental group through a 3D virtual anvironment has bigger effects on learning achievement when compared to learning in the control group. When the literature is analyzed, it seems that some other studies with the similar results to the findings of the current study. Also in those studies, the experimental group where 3D virtual environment is applied had higher levels of learning achievement when compared to the control group where traditional teaching is conducted (Arici, 2008; Chau et al.,2013; Chee & Tan,2012; Chung, 2012; Hwang & Hu, 2013; Ijaz, Bogdanovych & Trescak, 2016; Jacobson, Taylor, & Richards,2016; Jou & Liu,2012; Ketelhut, Dede, Clark, & Nelson, 2006; Lee & Wong, 2014; Papachristos et al., 2014; Phungsuk, Viriyavejakul, & Ratanaolarn, 2017; Su & Cheng,2013; Sun, Lin & Wang, 2010; Tüzün et al., 2009). In their study, Bakar, Tüzün and Çağıltay (2008) pointed out that the students preferred the three-dimensional, multi-user environment which they use in the course of social sciences to the traditional teaching method. On the other hand, results of some other studies revealed that there was no significant difference between the students who employ 3 dimensional virtual environment and students who receive traditional education (Adamo-Vilani & Dib, 2012; Bayırtepe & Tüzün, 2007; Güzel & Aydin, 2016; Mallory, 2012; Merchant et al.,2013; Okutsu, DeLaurentis, Brophy, & Lambert,2013; Sert,2009; Sun & Chan, 2013; Tüzün & Özdinç, 2016; Wrzesien & Raya, 2010; Zaharias, Machael, & Chrysanthou, 2013).

The second sub-problem determined in this research is "*What is the effect of learning through augmented reality applications on the learning achievement when compared to face to face learning?*". In order to find an answer to this problem, 24 studies were analyzed. First of all, fixed effects model was implemented in meta-analysis. According to the result of this model, the average effect size was calculated as d=0.387. Afterwards, the homogeneity test was conducted to see whether this model is convenient for the research. According to the results of the homogeneity test, a significant difference was found and it was concluded that the effect size of the studies was heterogeneous, namely it wasn't homogeneous (Q=116,9; p<.05). Cooper et al. (2009) found that the I^2 value at low levels around 25%, moderate levels at about 50% and high levels at about 75% and over means that there is high level of heterogeneity. The level of 80% I^2 value obtained from the study means high levels of heterogeneity. For that reason, random-effects model was preferred instead of fixed effects model. The average of the effect size of the studies included in meta-analysis according to random-effects model was found 0.46. According to the size effect classifications by Cohen (1988), Cohen et al. (2007), Lipsey and Wilson (2001), and Thalheimer and Cook (2002), the value of effect size found at the end of the research was determined to have a moderate level of effect. The result of the conducted analysis displayed that learning achievement showed that learning achievement level is higher in the experimental group. Namely, it was concluded that learning in the experimental group through an augmented reality anvironment has bigger effects on learning achievement when compared to learning in the control group. When the literature is analyzed, it seems that some other studies with the similar results to the findings of the current study. Also in those studies, the experimental group where augmented reality environment is applied had higher levels of learning achievement when compared to the control group where traditional teaching is conducted (Chang & Liu, 2013; Chang et al., 2014; Chiang, Yang, & Hwang, 2014; Ferrer-Torregrosa, Torralba, Jimenez, Garcia, & Barcia, 2015; Gopalan, Zulkifli, & Abubakar, 2016; Gutierrez & Meneses Fernandez, 2014; Hsiao, Chang, Lin, & Wang, 2016; Ibáñez et al., 2014; Küçük, Kapakin, & Göktaş, 2016; Lin, Duh, Li, Wang, & Tsai, 2013; Liu & Chu, 2010; Solak & Çakır,2016; Tarng, Lin, Lin, & Ou,2016; Yang, Hwang, Hung, & Tseng, 2013; Yoon, Elinich, Wang, Steinmeier, & Van Schooneveld,2012). On the other hand, results of some other studies revealed that there was no significant difference between the students who employ augmented reality applications and students who receive traditional education (Baysan, 2015; Cai, Chiang, & Wang, 2013; Chen & Tsai,2012; Chu et al., 2016; Erbaş, 2016; Hsiao, Chen, & Huang,2012). In the study conducted by Tarng, Ou, Yu, Liou and Liou (2015), the experimental group learned the unit of the life of butterflies through augmented reality application while control group learned about butterflies through observing them in their home. As a result of the experimental application, the learning effectiveness of the control group was found significantly higher than the experimental group.

When the literature is analyzed, the meta-analysis of the studies which deal with the effects of the applications prepared through numerous technologies on learning achievement was found (Sitzmann, 2011; Vogel et. al., 2006; Güzeller & Üstünel, 2016; Sung, Chang, & Liu, 2016; Merchant, Goetz, Cifuentes, Keeney-Kennicutt, & Davis, 2014). Sitzmann (2011) and Vogel et al., (2006) analyzed the effects of computer based games and simulations on learning achievements through conducting meta-analysis. At the end of the analysis, they pointed out that the aforementioned technologies had positive effects on learning achievements. Güzeller and Üstünel (2016) analyzed the effects of mobile learning on academic achievement. The experimental studies related to issue were determined and analyzed. As a result of the meta-analysis conducted in 10 studies, it was determined that mobile learning has positive effects on learning achievement. At the end of the analysis, the effect size of mobile learning on academic achievement was found as 0.84. According to the classification of Cohen (1988), this value shows the existence of a high level effect. Sung, Chang and Liu (2016) conducted meta-analysis on 110 experimental and semi-experimental studies in order to analyze the effect of mobile devices (laptop, mobile phone, pda etc.) on teaching and learning. At the end of the research, the effect size was found as 0.52. In their meta-analysis study, Tekedere and Göker (2016) analyzed the use of augmented reality applications in education. Of the 171 studies conducted between 2005 and 2015, 15 of them were found to be convenient for the criteria of the research. In the meta-analysis conducted with the aforementioned studies, the effect size related to the use of augmented reality in education was 0.677. According to the classification of Thalheimer and Cook (2002), the study had moderate effect size. At the end of the research, it was found that the use of augmented reality applications in education had positive effect on students. In a study by Merchant et al. (2014), they analyzed the use of games, simulations and virtual world technologies at K-12 or high school levels through meta-analysis. Of the 3081 studies related to games, 13 of them were accepted convenient for the criteria while 29 studies among the 2553 studies related to simulation were in conformity with the criteria and they were included in meta-analysis. 2798 studies related to 3D virtual environments were analyzed and 27 of them were found to be convenient for the criteria of the study and meta-analysis was conducted. At the end of the research, the effect size of games on learning achievement was found d=0.51 according to random-effects model. The size effect of simulation and 3D virtual environments on learning achievement was found as d=0.41 according to random-effects model. According to the results of the research, the gaming technology has higher effects on learning achievements when compared to simulations and virtual worlds. Similarly, it was concluded at the end of this research that augmented reality technology had higher effects (d=0.46) on learning achievement when compared to 3D virtual environment (0.32). In augmented reality, there is an environment where 3D objects are included in the real objects while there is a complete artificiality (virtuality) in 3D virtual environments. Learning activities are conducted in actual environments in the augmented reality applications while 3D virtual environments are completely conducted in virtual environments (Abdüsselam, Beşikdüzü, & Karal, 2012). Since augmented reality allows the opportunities of simultaneous interaction and face to face education, it may be one of the reasons of this result.

According to the meta-analysis results, it was seen that 3D virtual environments had a medium effect size (d = 0.32) on the learning success in favor of the experimental group. Similar to this result, it was found that augmented reality applications had a moderate level of effect (d=0.46) on learning achievement in favor of experimental group. Depending on this result, it was also seen that augmented reality technology had higher effects on learning achievement than 3D virtual environment. This result indicates that augmented reality is more effective in achieving/providing the learning achievement when compared to 3D virtual environment. However, it can be stated that augmented reality provides a more effective solution when proper conditions (labor, money human resources, time etc.) although there is no general evaluation has been conducted related to other variant and since only learning achievement is analyzed in this study. It is considered that the reason for this is the relationship between augmented reality and real environment due to its nature/structure. As to face to face education, augmented reality may be more effective than 3D virtual environments when the support of actual environment and its size effct are considered.

When those two environments are considered together, augmented reality may be preferred if learning conditions require that individuals are supported according to the objects and locations in the real environments while designing education or it may provide better conditions; however, 3D virtual environments may be preferred unless learning conditions require them or it can't provide them. Although the selection of one of those technologies is important, the objectives of learning also should be considered. Thus, it was revealed that the augmented reality should be preferred if learning conditions can provide both of the status since augmented reality has bigger effect sizes. Considering the results of the research, following suggestions were given:

1. Since effect sizes of augmented reality applications are higher than 3D virtual environments in terms of learning achievement, augmented reality technology may be implemented if traditional classroom conditions are available.
2. A limited number of the experimental studies which deal with the effects of 3D virtual environments and augmented rality technologies on learning achievement. In addition, it was found that technologies have moderate effects on learning achievement. For that reason, further experimental studies related to the issue may be conducted.
3. Starting from the fact that 3D virtual environments and augmented reality applications have moderate level of effects on learning achievement, the aforementioned technologies may be applied at all levels of education, especially in the groups with lower levels of learning achievement.

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