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The Effect of Augmented Reality Applications in the Learning Process: A Meta-Analysis Study*

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ABSTRACT

Purpose: The aim of this research is to investigate the effect of Augmented Reality (AR) applications in the learning process. **Problem:** Research that determines the effectiveness of Augmented Reality (AR) applications in the learning process with different variables has not been encountered in national or international literature. **Research Methods:** To determine the effect of AR in the learning process, experimental studies conducted in 2007-2017 on the use of AR in education were analyzed by the Meta Analysis Method. Analyzed articles were selected among the publications in the journals scanned in the Social Sciences Citation Index (SSCI). In this context, 16 studies were examined to identify the effect of AR applications in the learning process. **Findings:** Findings indicated that AR applications increase students' academic achievement in the learning process compared to traditional methods. **Implications for Research and Practice:** It was concluded that AR applications do not show significant differences in academic success in the learning process. For example, the "grade level" variable of the study does not show a significant difference compared to traditional methods. When assessing AR display devices, the largest effect size was related to the use of mobile devices, while the smallest effect size was in the use of webcam-based devices. When comparing sample size in the study, it was identified that the effect size of large sample groups was affected by AR on a medium level, while small samples were affected minimally.

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Introduction

The emergence of innovative technologies helps instructional designers develop learning environments that facilitate learning (Chang, Hsu, & Wu, 2016). Fast and widespread use of wireless communication networks and mobile devices has made access to innovative technologies such as Augmented Reality (AR) considerably easier and has provided significant advantages for technology-assisted learning (Ozdemir, 2017a). AR is a variation of virtual environments commonly called Virtual Reality (VR) (Azuma, 1997), which can be defined as a technology enabling virtual objects produced by computers to be placed on physical objects in real time (Zhou, Duh, & Billinghurst, 2008).

There are two types of AR, namely, image-based AR and location-based AR. In image-based AR, some markers are needed to fix the position of 3D objects onto real-world images (Ibanez, Di-Serio, Villaran-Molina & Delgado - Kloos, 2016). In application, an AR marker is matched with a 3D model or animation, and this marker is perceived by a camera to enable the model or animation to appear on a screen (Pasareti, Hajdin, Patusaka, Jambori, Molnar & Tucsanyi-Szabo, 2011). In location-based AR, the location information of users' mobile devices is used with the help of the global positioning system (GPS) or Wi-Fi-based positioning systems (Wojciechowski & Cellary, 2013). GPS determines the exact location of mobile devices and how far related objects can be exactly calculated from the target location (Pasareti et al., 2011). In both AR types, virtual objects are associated with real-world objects, and a 3D perception is presented to its user (Ke & Hsu, 2015). AR objects can be displayed on mobile devices, projection systems or head-mounted screens (for instance, Google Cardboard). AR helps to increase users' experiences with the real world as opposed to other computer interfaces that pull users away from the real world through the screen (Billinghurst, Kato & Poupyrev, 2001). Therefore, the use of AR technologies provides benefits in a number of fields, including engineering, entertainment and education (Zhou, Duh, & Billinghurst, 2008).

Augmented Reality in Education

AR provides students with the opportunity to practice their knowledge and skills by seamlessly combining digital information with the real-world environment (Wojciechowski & Cellary, 2013). In addition to the practicing real-world senarios, AR can also provide interactive learning environments through interactive activities (Chen & Wang, 2015). AR has the potential to save time and money in the case of high-cost educational needs (Gavish, Gutierrez, Webel, Rodriguez, Peveri, Bockholt & Tecchia, 2015). AR systems, which can be used to increase collaborative learning experiences (Billinghurst, Kato & Poupyrev 2001), enable the teaching of lessons in an innovative and interactive way by presenting information in 3D format, thereby facilitating students' skill acquisition (Wu, Lee, Chang, & Liang, 2013). Besides, AR systems positively affect students' motivation and cognitive learning (Sotiriou & Bogner, 2008). They help to develop their spatial (Kaufmann & Schmalstieg, 2003) and psychomotor-cognitive skills. AR can provide hints and feedback visually, auditorily or sensorially to improve students' experiences (Zhou et al., 2008). Through these features, AR systems can be integrated into teachers' lecture notes. Thus, the abstract information to be taught can be conveyed to the students in a concrete way. Because AR allows students to observe events that they cannot easily see in a natural environment (Wu Lee, Chang, & Liang, 2013). One of the most important advantages of AR in terms of education is helping to create a comprehensive, blended learning environment which facilitates the development of critical thinking, problem solving and mutually cooperative communicative skills by presenting digital and physical objects together in the same environment (Dunleavy, Dede & Mitchell, 2009). Following is a comparison of other analysis studies on the use of AR in the educational field with our research.

Meta- Analysis Studies Conducted for the Use of AR in the Educational Process

Using meta-analysis, Santos et al. (2014) examined 87 studies in the IEEE Xplore database, which were conducted for the use of AR at the K-12 level. Tekedere and Göker (2016) investigated 15 articles published in SCI/SSCI indexed journals between the years 2005 and 2015 by using the meta-analysis method. Finally, Yılmaz and Batdı (2016) examined the effects size of AR on academic success in 12 studies conducted in national and international areas through the meta-analysis method. The above-mentioned analysis studies are found to be limited when the results of their research--conducted to investigate the effectiveness of AR applications in the learning process in different environments and times is combined. Moreover, research that determines the effectiveness of AR applications in the learning process with different variables (e.g., education areas, educational situations, the use of AR display devices and sample sizes) has not been encountered in national or international literature. In this regard, it is considered that this research will contribute to the field in terms of these variables. The education areas that prefer to use AR technology for educational purposes differ. For this reason, it is considered important to investigate the effect of AR applications on achievement in terms of educational areas. AR technologies are more preferred as an educational tool in several science branches such as physics, chemistry, biology, mathematics and ecology (Ozdemir, 2017b). In these branches of science, teaching is easier when concepts which are abstract and difficult to understand are presented in a concrete way with the help of AR technologies (Ozdemir 2017b). AR also offers many activities that allow students to visualize some educational content (e.g., the magnetic field) that they will not see in the real world (Ibanez et al., 2014). On the contrary, the using of AR applications as an educational tool is much less frequently preferred in areas such as social sciences, business, administration and law (Ozdemir, 2017b). In addition, the analized studies emphasized that AR applications are an important factor in increasing student achievement at every level of education (Bacca at al., 2014; Ozdemir, 2017b). Experimental studies on the use of AR in education seem to have been made at various educational levels, such as secondary, undergraduate and primary education (Ozdemir, 2017b). In this framework, it can be said that the determination of the effect size of AR applications on the students' academic achievements at different educational levels is very important. Since the sample size is very important in determining the effectiveness of the method used for student achievement, it can be said that it should be considered as a variable in meta-analysis studies. Furthermore, current devices used to display AR applications (e.g., mobile phones, tablets and webcam-based) differ. Usefulness and efficiency of these display devices can be an effective factor in uncovering the success of AR in educational environments. From this point forward, this variable is taken into consideration in this study.

A number of the studies on the use of AR in education (Chen & Tsai, 2012; Gavish et al., 2015; Han, Jo, Hyun, & So, 2015; Huang, Chen, & Chu, 2016; Ibanez, Serio, Villaran & Kloos, 2014; Kamaraine et al., 2013; Ke & Hsu, 2015; Lin, Duh, Li, Wang & Tsai, 2013; Lin, Chen & Chang, 2013; Liou, Bhagat, & Chang, 2016; Sommerauer & Müller, 2014; Yang & Liao, 2014; Zhang, Sung, Hou, & Chang, 2014) indicated that AR applications have an impact on academic achievement. In this regard, grouping the findings of the different studies dealing with AR applications and combining the quantitative findings of these studies will reveal to what extent these applications are effective.

Purpose of the Research

The aim of the research is to investigate the effect of AR applications in the learning process. Therefore, this research aimed to combine the results of the independent studies dealing with the use of AR in education. Sixteen studies were examined to identify the effect of AR applications in the learning process, and this study aimed to answer the following questions:

1. What is the effect size of the AR applications on students' academic achievement?

2. Are there significant differences among the effect sizes of AR applications on students' academic achievement as regard to education areas (Natural Sciences and Social Sciences) addressed in studies?

3. Are there significant differences among the effect sizes of AR applications on students' academic achievement, when the grade levels (primary education, high school and undergraduate level) of students are taken into consideration?

4. Are there significant differences among the effect sizes of AR applications on students' academic achievement, when the display devices used by students (mobile devices, tablets, and webcam-based devices) are handled?

5. Are there significant differences among the effect sizes of AR applications on students' academic achievement as regard to the sampling size of the research?

Method

Research Design

The meta-analysis method was used to determine the effect of AR in the learning process. Meta-analysis is a statistical method that attempts to obtain a general conclusion by compounding findings of independent studies (Ergene, 2003). In the meta-analysis method, results of the findings of similar studies are collected according to certain criteria, analyzed and interpreted (Lipsey & Wilson 1993).

Data Collection

The studies revealing the effectiveness of AR applications on the learning process were included in the research. In this respect, the following phases were pursued:

Literature Review

In this study, experimental studies conducted on the use of AR in education between October 1st, 2007 and February 1st, 2017 were analyzed. In this regard, the articles that use AR applications in the experimental group and the traditional applications in the control group are discussed. In order to reach these articles, this study used a three-stage roadmap as follows: In the first stage, the articles were scanned in "educational research," "education scientific disciplines," "psychology education" and "special education" categories through the Web of Science search engine. The journals scanned in the Social Sciences Citation Index (SSCI) were selected. Keywords such as "augmented reality," "augmented reality system," "mixed reality," "virtual environments," "virtual reality," and "virtual learning environments" were used as search terms. As a result of scanning the journals, an academic journal list was obtained (100 journals in total). In the second stage, the first 15 academic journals in the Google Academic h5-index rank (in the Education Technologies category) were added to the list of journals to be considered for the study (Table 1). In the final stage, six journals were added to the list which were scanned in the first 100-journal list in Web of Science, were not available in the 15-journal list in the second stage but published most articles in respect to the subject matter (Table 2). As a result, 21 academic journals scanned in SSCI were determined for evaluation in the study.

Criteria for the Inclusion of Articles and Determination of the Studies

The articles which were published by February 2017 were analyzed in the current study. In the study, symposium and conference proceedings, book reviews, book chapters, editorial writings, meeting abstracts, biographical items, master's theses and PhD theses written at national and international levels, and the studies published in other languages except in English were excluded. In the journals determined in accordance with the above criteria, this study found a total of 75 articles published on the use of AR in education until February 2017 from October 2007. Of the examined 75 articles, the articles involving the application of pre-tests, post-tests and comparisons among the groups were selected by focusing on the experimental studies. In terms of meta-analysis, studies that do not contain sufficient data to calculate effect sizes were excluded from the analysis. As a result, 16 articles were analyzed in the study according to the determined criteria.

Table 1

15 Journals at the Top List of h5-Indexed Ranking in Google Scholar Metrics, Which Were Obtained as a Result of Scanning the Web of Science Search Engine.

Academic Journal Name	h5-index* (06.02.2017)	Number of articles published on AR
Computers & Education	88	18
British Journal of Educational Technology	48	8
The Internet and Higher Education	43	1
Journal of Educational Technology & Society	41	6
Journal of Computer Assisted Learning	40	3
Intern. Review of Research in Open and Dist. Learning	38	-
Educational Technology Research and Development	32	4
Australasian Journal of Educational Technology	32	-
Intern. Journal of Computer-Supported Collaborative Learning	31	3
IEEE Transactions on Learning Technologies	28	4
Distance Education	27	-
Language, Learning & Technology	26	1
Recall	26	-
Computer Assisted Language Learning	25	-
Journal of Educational Computing Research	25	2
	Total	50

** h5-index means that h article is cited at least h times each in the last five years.*

Table 2

Unavailable Journals in the List of the h5-Indexed Ranking of Google Scholar Metrics, Having Most-Published Articles in Respect to the Use of AR in Education

Academic Journals	Number of articles published on AR in education
Interactive Learning Environments	10
Journal of Science Education and Technology	8
Education and Science	3
Comunicar	2
Teachers College Record	1
Environmental Education Research	1
Total	25

Evaluation Criteria

The studies conducted with students were examined in terms of the AR applications. Furthermore, the studies involving the post-test results of the experimental and control groups were analyzed. In this regard, this research examined studies including the values for sample size (n), arithmetic mean ($\overline{X}$), standard deviation (sd) and possibility (p) to calculate effect sizes in the experimental group. In this context, studies that do not give values to calculate the effect size were excluded from the scope of the study. In studies involving more than one AR application, data from any randomly selected test were analyzed.

Coding Stage

Coding must be conducted to reflect the general characteristics of the studies covered in the meta-analysis method. In this study, the data were grouped under three main sections, as follows: The first section was called "study identity." In this section, the names and number of the studies, the countries where they were conducted, the place where they were applied, and the time and author information were included. The second section was called "study content." This section presents data including grade level, educational area, and AR display devices being used. The third section was called "study data." This section gives information about the values used in meta-analysis calculations such as sample size (n), arithmetic mean ($\overline{X}$), standard deviation (sd) and possibility (p).

Variables

In the study, the effect sizes for the usefulness of AR applications in the learning process in the articles included in the meta-analysis were treated as dependent variables. Effect sizes are defined as standardized values for different-scale instruments in every study (Tarım, 2003). The study characteristics, which are expressed as independent variables of the study, are defined as "educational areas," "grade levels," "AR display devices used," and "sampling size".

Data Analysis

Comprehensive Meta-Analysis (CMA), the MetaWin package program and the Excel program were utilized to analyze the data in the study. CMA and MetaWin programs are used to calculate effect sizes. The primary purpose of this method is to calculate the mean differences in the experimental studies between the experimental and control groups (Hunter & Schmidth, 2004), expressed in the formula: d = (Xe – Xc) /Sd. In the field of educational sciences, different meta-analysis studies (Batdı, 2014; Batdı, 2017; Gözüyesil & Dikici, 2014; Günay, Kaya & Aydın, 2014) show that the *d* coefficient is used to determine the effect value. Hedge's *d* expresses coefficients used in the calculations of effect sizes in meta-analysis applications (Hedges & Olkin, 1985), where, *d* is calculated by dividing the differences between experimental and control groups with total standard deviation (Cooper, 1989; Şahin, 2005). The following classification is used to evaluate the obtained effect sizes in this study (Thalheimer & Cook, 2002):

- -0.15 < effect size < 0.15 insignificant
- 0.15 < effect size < 0.40 small
- 0.40 < effect size < 0.75 medium
- 0.75 < effect size < 1.10 large
- 1.10 < effect size < 1.45 larger
- 1.45 < effect size < very good

Since this meta-analysis study is an analysis of previously conducted studies, there is no limit to the number of studies to be included in the analysis. If the effect size of any study for meta-analysis is to be achieved, at least two studies are needed (Dinçer, 2014). When the databases identified by the criteria in the study were considered, 16 studies were analyzed in this study.

The reliability calculation of the coding form was conducted by two coders. In this respect, the inter-rater reliability formula--Reliability = Consensus / (Consensus + Disagreement) by Miles and Huberman (1994)--was conducted to ensure the reliability of the coding form. In this regard, the reliability of the study was found to be 100%.

Findings

Research Questions (RQ)

RQ-1: What is the Effect Size of the AR Applications on Students' Academic Achievement?

When all 16 studies involving the use of AR in the learning environment and the use of traditional methods in the learning environment were taken into account, the experiment group contained 506 students, and the control group contained 435 students. The frequency (f) and percentage (%) values of the different variables of the research such as “grade levels,” “educational areas,” and “AR display devices” are presented in Table 3.

Table 3

Different Variables of the Research

Variable	(f)	(%)
Grade Level		
Primary education	8	50
High school	5	31.25
Undergraduate level	3	19.75
Educational Area		
Natural Sciences	12	75
Social Sciences	4	25
AR Display Device		
Mobile devices	6	38.5
Tablet	5	31.25
Webcam-based devices	5	31.25

When Table 3 is examined in terms of "educational status," it is seen that half of the studies were carried out in the primary-education level (50%). The other half of the studies was conducted with the participants in high schools (31.25%) and the undergraduate level (19.75%). When the “educational area” variable is considered, the studies were predominantly carried out in Natural Sciences (75%) and then in Social Sciences (25%). When the AR display devices are examined, six studies were conducted with mobile devices (38.25%), five studies with tablets (31.25%), and five studies with webcam-based devices (31.25%) respectively.

The homogeneity values, mean effect values and confidence intervals in the effect sizes of the studies were included in the meta-analysis according to a Fixed-Effects Model (FEM) and Random-Effects Model (REM), as displayed in Table 4.

Table 4

The Homogeneity Values, Mean Effect Values and Confidence Intervals in the Effect Sizes of the Studies Included in the Meta-Analysis According to the Effects Models

Type of Model	N	Z	Total Heterogeneity Value (Q)	Average Effect Size (ES)	Mean Confidence Interval for Impact Size	
					Lower Limit	Upper Limit
FEM	16	7.509	53.99	0.508	0.375	0.640
REM	16	3.933	55.018	0.517	0.259	0.775

When Table 4 is examined, it is found that the effect of AR applications on academic success in the learning process is positive, with a 0.508 effect size in FEM. According to the homogeneity test, *Q* and *p* values were found to be 55.018 and 0.00, respectively. When the chi-square table is considered, the critical value was 24.996 at a 95% significance level and 15 degrees of freedom. At this point, *Q* values (55.018) are recognized to be higher than the critical value (24.996). Therefore, the homogeneity test for the distribution of the effect sizes was accepted in REM. In other words, the distribution can be thought to be heterogeneous.

Because of the heterogeneous nature of the study, the analyses were performed according to REM. In this respect, when the 16 studies comparing the effect of a learning environment supported by AR and the effect of a traditional learning environment not supported by AR on academic success were analyzed according to the Random-Effects Model, the upper and lower limits of a 95 confidence interval turned out to be 0.775 and .259, respectively, and the effect value was found to be .517. Therefore, the effect size was at a medium level (.517). It was concluded that AR applications positively affect academic success in the learning process.

RQ-2: Are there significant differences among the effect sizes of AR applications on students' academic achievement in various areas of education (Natural Sciences and Social Sciences) addressed in studies?

The studies conducted to reveal whether there are significant differences in academic success when using AR applications within various educational areas are displayed under two main headings, namely "Natural Sciences" and "Social Sciences" in Table 5.

Table 5

Effect Values with Regard to Educational Areas

			95% Confidence Interval	
Educational Area	N	ES	Lower Limit	Upper Limit
Natural Sciences	12	0.562	0.288	0.836
Social Sciences	4	0.409	0.212	1.031

When Table 5 is examined, it is recognized that the Natural Sciences effect sizes (0.562) is higher than the Social Sciences value (0.409). The *Q* value was found to be 0.195 according to the homogeneity test. When a 95% significance level and 1 degree of freedom is considered in chi-square table, the *Q* value turns out to be 3.841. As *Q* (0.195) is lower than the critical value (3.841). In this study, the homogeneity test for the effect sizes was implemented according to REM. In this respect, it can be stated that there is not a significant difference among the groups with regard to the effect sizes (QB = 0.195, p = 0.659). Therefore, it can be stated that the educational area does not affect AR applications. In other words, AR applications did not differ according to educational area.

RQ-3: Are There Significant Differences Among the Effect Sizes of AR Applications on Students' Academic Achievement, When the Students' Grade Levels (Primary Education, High School and Undergraduate) Are Taken into Consideration?

The studies conducted to reveal the effects of AR applications on academic success according to grade level are displayed under three main headings, namely "primary education," "high school," and "undergraduate" in Table 6.

Table 6

Effect Sizes Regarding Grade Level

			95% Confidence Interval	
Grade Level	N	ES	Lower Limit	Upper Limit
Primary Education	8	0.303	0.002	0.604
High School	5	0.623	0.359	1.319
Undergraduate	3	0.839	0.189	1.057

According to Table 6, the largest effect of AR applications on academic achievement in the learning process turned out to be with the students in undergraduate levels (0.839). Furthermore, it is seen that the effect sizes of AR applications in high schools (0.623) is higher than that in primary education (0.303). The *Q* value was 3.876 according to the homogeneity test. When 95% significance level and 2 degrees of freedom (df) are considered in the critical-interval value of the chi-square table, this value turned out to be 5.991. In this regard, *Q* value (3.876) is understood to be lower than the critical value (5.991). Therefore, the homogeneity test with regard to the distribution of effect sizes was accepted in REM. This indicates that the distribution is heterogeneous and there is not a significant difference among the groups in terms of the effect values (QB = 3.876, p= 0.144).

RQ-4: Are there significant differences among the effect sizes of AR applications on students' academic achievement in regard to the display devices used by students (mobile devices, tablets, and webcam-based devices)?

The studies conducted to reveal whether there are significant differences in academic success when using AR applications on various display devices are presented in Table 7 under three main headings, namely, "mobile devices," "tablets," and "webcam-based devices."

Table 7

Effect Values with Regard to AR Display Devices

			95% Confidence Interval	
AR Display Devices	N	ES	Lower Limit	Upper Limit
Mobile Devices	6	0.686	0.180	1.192
Tablets	5	0.667	0.419	0.916
Webcam-based Devices	5	0.159	0.171	0.488

When Table 7 is considered, it was recognized that the largest effect size (0.686) is found among students using mobile devices and the smallest effect (0.159) with those using webcam-based devices. As a result of the homogeneity test, the *Q* value was identified as 6.371. When 95% significance level and 2 degrees of freedom (df) are considered in the critical-interval value in the chi-square table, this value is seen to be 5.991. In this regard, it is seen that the *Q* value (6.371) is higher than the critical value (5.991). Therefore, the homogeneity test related to the distribution of effect sizes was implemented according to FED. Thus, it was revealed that the distribution is homogenous and there is a significant difference among the groups with regard to the effect sizes (QB = 6.371; p= 0.0041) based on the display devices being used. In other words, it can be stated that the effect of AR applications on academic success in the learning process is positive when related to the display-devices variable.

RQ 5: Are There Significant Differences Among the Effect Sizes of AR Applications on Students' Academic Achievement in regard to the Sampling Size of the Research?

The studies conducted to reveal whether there are significant differences in academic success when using AR applications in various sampling sizes are provided in Table 8 under two main headings, namely "small sampling" (1-49) and "large sampling" (50 and over).

Table 8

Effect Sizes with Regard to Sampling Size

			95% Confidence Interval	
Sampling Size	N	ES	Lower Limit	Upper Limit
Large (50 and over)	10	0.647	0.306	0.988
Small (1-49)	6	0.262	0.042	0.565

Table 8 indicated that the average effect size for the use of AR applications in a large sampling is 0.647, and the effect size in a small sampling is 0.262. According to the critical-interval value in a chi-square table with a 95% significance level and 1 degree of freedom (df), this value turned out be 3.841. In this case, the Q value (2.734) was understood to be lower than the critical value (3.841). The homogeneity test with regard to the distribution of effect sizes was conducted according to FEM. When the effect size of the groups, which were classified based on sampling size, was examined, it was concluded that the sampling size variable is not an effective variable.

Result, Discussion and Recommendations

Researchers need to test prototypes of AR in the learning process in terms of their benefits and user-friendliness (Santos et al., 2014). The research conducted to investigate the effectiveness of AR technology on students' learning process will give insight into the role of AR for instructional designers and educators.

The findings of the current study indicated that AR applications increase students' academic achievement in the learning process compared with the use of traditional learning methods. This result shows consistencies when the studies zoned in on students in different grade levels (Chiang, Yang, & Hwang, 2014; Gavish et al., 2015; Hsiao, Chang, Lin, & Wang, 2016; Hwang, Wu, Chen, & Tu, 2016; Ibanez, Di Serio, Villaran, & Kloos, 2014; Liou et al., 2016; Liu, 2009; Lin et al., 2015; Sommerauer & Müller, 2014; Yang & Liao, 2014; Lin et al., 2013; Yang & Liao, 2014; Yoon, Elinich, Wang, Steinmeier, & Tucker, 2012; Zhang et al., 2014).

There may be a number of reasons why learning applications supported with AR positively influence students' academic achievement. For example, Chiang et al. (2014) stated in their studies on AR that AR enables students to practice what they are learning in an entertaining environment. In another study, Hsiao et al. (2016) indicated that AR provides better understanding, recall, concentration, interaction, and more-attractive learning environments compared with traditional learning environments.

Likewise, Ibanez et al. (2014) reported that AR increases concentration and facilitates improved subject comprehension. Liou et al. (2016) studied the benefits of AR from various dimensions, thereby revealing that teachers can more-easily and quickly convey concepts to their students who study the learning materials supported by AR prior to their lessons. In another study, Lin et al. (2013) stated that AR is a supportive instrument for constructing students' own knowledge in a way that clarifies the relations among theoretical concepts or principles.

The results of the findings of the 16 studies examined according to meta-analysis indicated that the effect size of AR for Natural Sciences is higher than that for Social Sciences. However, it was determined that the effect sizes for both educational areas were at a medium level and were therefore positive. On the other hand, it was concluded that AR applications do not show significant differences in academic success during the learning process in respect to educational areas. The subjects taught in Natural Sciences courses such as physics, chemistry, biology and mathematics involve predominantly abstract concepts. However, almost all the subjects in social-science courses such as economics, political sciences, psychology and sociology, require abstract thinking. "…by integrating the digital information with real-world assets simultaneously, AR helps to concretize abstract concepts, enables the use of all senses, and enhances the sense of reality, which in turn is a huge contribution to learning" (Ozdemir, 2017a). One of the reasons why the effect sizes of AR among Natural-Science courses are higher than those of Social-Science courses is that the abstract concepts in Natural-Science courses can be concretized more easily in an AR learning environment compared with those in Social Science courses.

The effect sizes for grade level, which is a variable of the study, do not show a significant difference. Nevertheless, the effect sizes for high schools are higher than for other grade levels according to a study by Thalheimer and Cook (2002).

Display devices were studied as one of the variables in the effect of AR. According to the findings of the comparison, the largest effect size was observed with mobile devices, with the smallest effect being with desktop applications displaying webcam-based devices. Therefore, a significant difference among the effect sizes was recognized. At this point, it can be thought that "AR display devices" used for AR applications is an important variable affecting students' academic achievement in the learning process. It was found in a number of studies that the use of mobile devices to display AR applications increased the students' academic success in the learning process in comparison to the use of traditional learning methods (Chiang et al., 2014; Gavish et al., 2015 ; Hsiao et al; Hwang et al., 2016; Ibanez et al., 2014; Lin et al., 2013; Liou et al., 2016; Liu, 2009; Sommerauer & Müller, 2014; Zhang et al., 2014). On the other hand, in some studies (Chang, Chung, & Huang, 2016; Chen & Tsai, 2012) that preferred webcam-based devices to display AR applications, a significant difference was not observed in academic success. With regard to the effect sizes of sampling size in the study, it was identified that the effect value of a large sampling group was at medium level and that of a small sampling group was at a minimal level. Therefore, it was concluded that in regard to the use of AR applications in the learning process, sampling size is not an effective variable to influence academic achievement.

This study dealt with the effect of AR applications in the learning process in respect to academic success. Different research could be conducted to study the effect of AR applications in the learning process as it affects variables such as attitude, anxiety, motivation, etc. Different independent variables such as age or gender could be investigated apart from the independent variables of the current study. Master's and PhD theses related to AR studies conducted at national and international levels could be considered to examine larger sampling sizes.

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Öğrenme Sürecinde Artırılmış Gerçeklik Uygulamalarının Etkililiği: Bir Meta-Analiz Çalışması

Atıf:

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Özet

Problem Durumu: AR'nin eğitim ortamlarında kullanımına yönelik analiz çalışmalarına rastlamak mümkündür. Fakat AR uygulamalarının öğrenme sürecindeki etkisini belirlemeye yönelik farklı ortamlarda ve zamanlarda gerçekleştirilen araştırmaların birleştirilmesini öngören kapsamlı araştırmaların sınırlı olduğu ortaya çıkmaktadır. Bunun yanı sıra, AR uygulamalarının öğrenme sürecindeki etkililiğini farklı değişkenler (ders alanları, eğitim durumları, kullanılan görüntüleme aygıtları) ile belirleyen araştırmalara gerek yurt için de gerekse yurt dışında rastlanmamıştır. Bu çerçevede araştırmanın bu değişkenler bakımından alana katkıda bulunacağı düşünülmektedir.

Araştırmanın Amacı: Bu araştırmanın amacı AR uygulamalarının öğrenme sürecindeki etkisini belirlemektir.

Araştırmanın Soruları: 1. Artırılmış gerçeklik uygulamalarının öğrencilerin akademik başarıları üzerindeki etkisi nedir? 2. Araştırmaların gerçekleştirildiği ders alanları (Doğa Bilimleri ve Sosyal Bilimler) incelendiğinde, artırılmış gerçeklik uygulamalarının etki büyüklükleri arasında akademik başarı açısından anlamlı bir fark var mıdır? 3. Öğrencilerin eğitim durumları (ilköğretim, lise ve lisans) bakımından artırılmış gerçeklik uygulamalarının etki büyüklükleri arasında akademik başarı bakımından anlamlı bir fark var mıdır? 4. Öğrencilerin kullandığı görüntüleme aygıtları (mobil, tablet ve web) bakımından artırılmış gerçeklik uygulamaları arasında akademik başarı bakımından anlamlı bir fark var mıdır? 5. Araştırmanın örneklem büyüklükleriyle artırılmış gerçeklik uygulamalarının etki büyüklükleri arasında akademik başarıya göre anlamlı bir fark var mıdır?

Araştırmanın Yöntemi: AR uygulamalarının öğrenme sürecindeki etkisini belirlemek amacıyla gerçekleştirilen araştırmada meta analiz yöntemi kullanılmıştır.

Araştırma Verilerinin Toplanması: Araştırmaya artırılmış gerçeklik uygulamalarının öğrenme sürecindeki etkisini ortaya koyan çalışmalar dahil edilmiştir. Bu çerçevede şu aşamalar izlenmiştir:

Literatür Taraması: 1 Ekim 2007 ile 1 Şubat 2017 arasında eğitimde AR kullanımına yönelik yurtiçinde ve yurtdışında gerçekleştirilen nicel çalışmalar araştırmaya dâhil edilmiştir. Bu çerçevede araştırmada deney grubunda AR uygulamalarını kullanan, kontrol grubunda ise geleneksel uygulamaları kullanan makaleler ele alınmıştır. Bu makalelere ulaşmak için üç aşamalı bir yol izlenmiştir; Birinci aşamada, analiz edilecek makaleler Web of Science arama motoru yardımı ile eğitim araştırmaları, eğitim bilimsel disiplinleri, psikoloji eğitimi ve özel eğitim kategorilerinde taranmıştır. Makalelerin yayınlandığı dergiler Social Sciences Citation Index (SSCI) tarafından tarananlar arasından belirlenmiştir. Tarama terimleri olarak "augmented reality", "augmented reality technology", "augmented reality system", "mixed reality", "virtual environments", "virtual reality" ve "virtual learning environments" şeklindeki anahtar kelimeler kullanılmıştır. Taramalar sonucunda bir akademik dergi listesi elde edilmiştir (toplam 100 adet). İkinci aşamada, birinci aşamada belirlenen dergilerin içerisinden, Google Akademik h5-endeks sıralamasında (Eğitim teknolojileri" kategorisinde) ilk 15'de yer alan akademik dergiler çalışma için değerlendirilmiştir (Tablo 1). Üçüncü ve son aşamada ise Web of Science taramasında elde edilen ilk 100 dergi arasında yer alıp da ikinci aşamada belirlenen 15 dergi arasında yer almayan fakat çalışma konusu ile ilgili en fazla makale yayınlayan altı dergi yine çalışma için ele alınacak dergiler listesine eklenmiştir (Tablo 2). Sonuç olarak SSCI tarafından taranan toplam 21 akademik dergi çalışmada değerlendirmek üzere belirlenmiştir.

Makaleleri Seçme Kriterleri ve Çalışmaların Belirlenmesi: Çalışmada analiz etmek üzere Ekim 2017'den Şubat 2017'ye kadar yayınlanmış SSCI makaleleri ele alınmıştır. Tarama sırasında sempozyum ve kongre bildirileri, kitap incelemesi, kitap bölümleri, editör yazıları, toplantı özetleri, biyografik öğeler, ulusal ya da uluslararası alanda yer alan yüksek lisans ve doktora tezleri ve İngilizce dışındaki dillerde yayınlanmış çalışmalar inceleme dışı bırakılmıştır. Yukarıda belirlenen kriterler doğrultusunda, belirlenen dergilerde Şubat 2017'ye kadar eğitimde AG kullanımı üzerine yayınlanmış olan toplam 75 makaleye ulaşılmıştır. İncelenen 75 makale içinden deneysel çalışmalara odaklanılarak özellikle ön–test ve son–test uygulanan ve gruplar arasında karşılaştırma yapılan makaleler ilgili çalışma için seçilmiştir. Meta-analiz çalışmaları için etki boyutunu hesaplamak üzere yeterince veri içermeyen araştırmalar analiz dışı bırakılmıştır. Sonuç olarak belirlenen ölçütlere göre araştırmada 16 makale analiz edilmiştir.

Araştırmanın Bulguları ve Sonuçları: Araştırmada elde edilen bulgular ile, AR uygulamalarının öğrenme sürecinde öğrencilerin akademik başarılarını geleneksel öğretime göre artırdığı sonucuna ulaşılmıştır. Bu sonuç farklı öğretim kademelerinde öğrenim gören öğrencilerle yapılan araştırma sonuçlarıyla tutarlılık göstermektedir. AR destekli öğrenme uygulamalarının öğrencilerin akademik başarılarını olumlu yönde etkilemelerinin altında yatan birçok neden olabilir. Meta-analiz kapsamında incelenen 16 araştırma bulgularının sonucu, araştırmanın gerçekleştiği eğitim alanlarına göre Doğa Bilimlerinin etki büyüklüğü Sosyal Bilimlere göre daha yüksek düzeyde ortaya çıktığını göstermektedir. Bununla birlikte her iki eğitim alanının etki büyüklüğünün orta düzeyde olduğu ve pozitif değerler aldığı belirlenmiştir. Ayrıca artırılmış gerçeklik uygulamalarının öğrenme sürecindeki akademik başarıyı eğitim alanı bakımından anlamlı olarak farklılaştırmadığı sonucuna ulaşılmıştır. Hem Doğa bilimlerinde (örn., fizik, kimya biyoloji ve matematik) anlatılan derslerde genellikle soyut kavramlar ağırlıklıdır. Fakat sosyal bilimlerde (örn., Ekonomi, Siyaset Bilimi, Psikoloji ve Sosyoloji vb.) anlatılan derslerin neredeyse tamamı soyut düşünmeyi gerektirmektedir. Meta-analiz kapsamında, Doğa Bilimlerinin etki büyüklüğünün Sosyal Bilimlere göre daha yüksek düzeyde çıkmasının olası nedenleri arasında, AR teknolojisi ile Doğa Bilimlerindeki soyut kavramların Sosyal bilimlere göre daha kolay somutlaştırılabiliyor olması yer alabilir. Araştırmanın diğer bir değişkeni olan öğretim kademesine göre etki büyüklüklerinin anlamlı bir farklılık göstermediği belirlenmiştir. Araştırmada etki büyüklükleri bakımından karşılaştırma yapılan değişkenlerden biri de görüntüleme aygıtlarıdır. Buna göre en yüksek etki büyüklüğü mobil aygıtlarda, en düşük etki büyüklüğü ise web kame tabanlı görüntüleme sistemlerinde gözlemlenmiştir. Bununla birlikte söz konusu etki büyüklükleri arasında anlamlı bir fark bulunmuştur. Bu noktadan hareketle artırılmış gerçeklik ile ilgili uygulamalarda kullanılan görüntüleme aygıtlarının öğrencilerin öğrenme sürecindeki akademik başarılarını etkileyen önemli bir değişken olduğu düşünülebilir. Öyle ki AR uygulamalarını görüntülemek için mobil aygıtların kullanıldığı çoğu çalışmada AR uygulamalarının öğrenme sürecinde öğrencilerin akademik başarılarını geleneksel öğretime göre artırdığı sonucuna ulaşılırken, AR uygulamalarını web kamerası ile görüntüleyen bazı çalışmalarda ise akademik başarıda anlamlı bir farklılık gözlenmemiştir. Araştırmada ele alınan çalışmalarda büyük örneklem gruplarının etki büyüklüğünün orta düzeyde, küçük örneklem gruplarının etki büyüklüğünün küçük düzeyde olduğu bulgusuna ulaşılmıştır. Böylece örneklem büyüklüklerinin AR uygulamalarının öğrenme sürecindeki akademik başarıyı etkileyen önemli bir değişken olduğu sonucuna ulaşılmamıştır.

Araştırmanın Önerileri: Bu çalışma artırılmış gerçeklik uygulamalarının öğrenme sürecindeki etkililiğini akademik başarı değişkeni bakımından ele almıştır. Farklı araştırmalar artırılmış gerçeklik uygulamalarının öğrenme sürecindeki etkililiğini tutum, kaygı, motivasyon gibi farklı değişkenler bakımından ele alınabilir. Araştırma kapsamında ele alınan bağımsız değişkenler dışında farklı bağımsız değişkenler (yaş, cinsiyet vb.) dikkate alınarak çeşitli araştırmalar gerçekleştirilebilir. Artırılmış gerçeklik çalışmaları ile ilgili ulusal ve uluslararası alanda yer alan yüksek lisans ve doktora tezleri dikkate alınarak daha büyük örneklem grupları incelenebilir.

Anahtar Kelimeler: Akademik başarı, yenilikçi öğrenme ortamları, tematik analiz