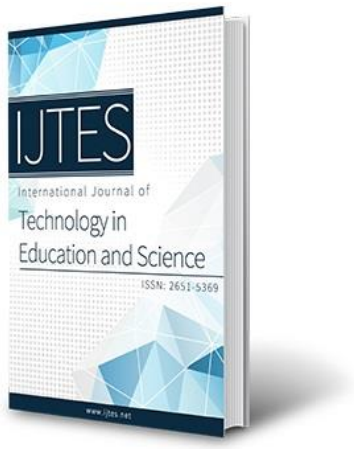

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Abstract

Changes in the lifestyles of human beings keep up with science and technology in tandem with the growth of science and technology. As in all fields, expectations are influenced by the advancement of science and technology for the use of emerging technologies in educational environments. By empowering the physical world with virtual information, Augmented Reality (AR) creates new opportunities for education. The impact of uncertainty and scientific advances in the field of application has modified the definition of "AR Technology" to "AR Environments". Within the scope of this study, it is aimed to analyze scientific studies on game-based learning and the use of AR in educational activities systematically. In this context, the "education area", "the level of education of the participant", "dependent variables", "data collection tools", "research methods used", "type of AR used", "software used in the development phase of the application", factors such as "advantages and limitations towards the use of AR in a learning environment" are taken into consideration. In line with the purpose of the research and the specified criteria, a total of 53 scientific studies, which were scanned from scientific journals published in Turkey and abroad between 2016 and 2020, were analyzed using the systematic literature review method. As a result, findings regarding the effects of the game and AR-based learning environments in the learning processes for students are discussed. In addition, several recommendations for the creation and use of new educational games and AR applications have been created, which will help the gaps in AR studies and students' learning processes in terms of potential study.

Introduction

The majority of researchers emphasize that games have been around since humans existed. It is shown that different games form the cultures of societies, and even in administrative circumstances, they benefit from games. In Ancient Egypt, in ancient Greece and India, the findings reveal that the history of games goes back to the time before Christ. Games are inherent activities of people and play an important role in their physical, cognitive, emotional, and social development**.** The game is an app with goals such as having fun, socializing and learning in a rules system and concentrating on those goals and outcomes such as winning and losing (Yılmaz,

2015). In addition, Syafii, Kusnawan & Syukroni (2020) pointed out that the game has huge potential to give practice in all the skills such as listening, speaking, reading and writing, and also it is very effective for teaching/learning performance and various types of communication such as criticizing, explaining, encouraging and agreeing. Huizinga (2013) describes the game as a phenomenon that excludes real life, has a limit called the magic circle, that the player is completely immersed in the game by forgetting the outside world, has rules, and gives freedom of action within the rules (Şahoğlu and Polat, 2018). The games also include experiences that allow students to learn by doing and experiencing, as well as being a tool for students to actively participate in and execute their actions individually. While the games increase the level of motivation of the student, it creates relaxation and motivation for the student by ensuring the interest in the content, maintaining the self-confidence and effectiveness regarding learning. Among the general results, the games also provide environments that encourage cooperation. Items covered by the games include players, the system, specific rules, challenge, feedback, emotional responses, interaction, and measurable outcomes.

Game and Gamification

Game and gamification are confusing concepts. The use of game elements in the design of non-game processes or contents is called gamification (Deterding, Dixon, Khaled & Nackle, 2011; Deterding, O'Hara, Sicart, Dixon & Nacke, 2011; Deterding, Sicart, Nacke, O'Hara, & Dixon, 2011; Werbach, 2014; Werbach & Hunter, 2012 ac. Samur & Özkan, 2019). Zichermann (2015) defines the concept of gamification as "a discipline in which game-related designs and game mechanics are added to a non-game process". Participants concentrate on the activities they need to do within the game dynamics with higher motivation in the player role.

Especially increasing after 1990 and named as "digital natives" by Prensky (2001), the community has the characteristics of following technological developments tightly and adapting easily to all kinds of innovations from a very young age. Çetin and Özgiden (2013) state that digital natives have high learning potential in online applications and game environments. In the same study, it is emphasized that the rewards they receive in these environments have a motivating impact on digital natives. According to Norman (1993), digital games show that they are instructive and educational tools when a safe environment is created and the time situation is well adjusted. Durkin and Barber (2002) concluded that adolescents playing games are more positive in respecting their families and school management, participating in other entertaining activities, positive mental health, substance use, self-concept, obedience to parents, and friendship (Ocak, 2013). According to An (2020) using game elements or terms in learning process may be very effective in terms of getting students' attention, but it should be kept in mind that some gamifications which have poor design can have negative effects in terms of student motivation and learning.

Game-Based Learning

Several theories have been developed to overcome the monotony of traditional education. Educational games according to Demirel, Seferoğlu, and Yağcı (2003, p. 141) are "software that enables students to learn the course contents or develop their problem-solving skills by using the game format". In game-based learning theory,

which is inspired by the idea of learning by playing, there are versatile researches such as the use of cognitive tools in education, information and communication technologies, internet-based distance education. According to Shapiro (2014), while game-based learning is the application or approach of digital video games as an educational tool in learning environments, gamification is the use of game design elements in non-game contexts. In the learning process, games can be used in various ways. In this context, educators can integrate teaching content into existing games and include games in their lessons (Van Eck, 2006). According to the research results of Vu and Feinstein (2017), it was revealed that applying game-based activities in the learning process increased the academic performance of students in terms of exam scores and behaviors. As accepted in many parts of the world as well as in Turkey, game is the most appropriate learning method for children of early childhood. For that reason, all events, whether informal or formal, should be game-based. This situation is stated in the basic principles of pre-school education in force as in previous programs of the Ministry of National Education (2013).

The characteristics of digital natives have shown to educators and researchers that digital games can be actively used in educational environments. Greenfield (1996), in his study examining the effect of digital computer games on socialization and cognitive development, found that children playing digital computer games showed the development of adults for a long time, their thinking and decision-making skills in games in a shorter period of time (Ocak, 2013). According to Prensky (2003) and Zin, Jaafar & Yue (2009), "Digital Game-Based Learning" (DGBL) is the use of games in the learning environment by integrating learning content into existing digital games or following the learning objective (Samur and Özkan, 2019). Today, there are many applications used educationally using augmented reality and virtual reality.

Augmented Reality

The first thoughts about augmented reality can be seen in "Frank's Key (Master Key)", published in 1901 by L. Frank Baum (Baum, 1901). Thomas Caudell and David Mizell are the names that first introduced the term "Augmented Reality (AR)" in 1992. Caudell and Mizell designed a guide for the cable connections of workers and technicians to the aircraft utilizing the head-mounted digital viewer they developed for the company Boeing in the early 1990s (Sung, 2011). The idea of AR, led by Ivan Sutherland in 1960, came to life thanks to the A.B.D Air Force project launched at Harvard University in 1970 (Milgram and Kishino, 1994). In this context, as a result of the development and change of technology, different concepts in the literature are gaining importance day by day. One of these concepts met with interest is the concept of "augmented reality". Despite the increasing number of studies on augmented reality (AR) in recent years, the definitions and terms used in this area vary. When the literature on AR is examined, the definition of AR made by Milgram and Kishino (1994) is expressed as the most general definition that "digital media products are used instead of real-world objects". According to Azuma (1997), AR is defined as a technology that connects the real world with virtual objects and enables interaction between real and virtual objects. That is, augmented reality is derived from virtual reality and includes virtual environment technologies in which the existing reality is supported. The concept of reality technology is two separate areas: virtual reality and augmented reality. Although virtual reality (VR) is frequently used in three-dimensional games developed in line with computer-based visual design

principles, it can be considered as an environment that causes the user to play this game to completely disappear from the real world. In other words, VR is a real environment where real objects or environments are digitally built-in 3D with computer technologies and the user can use this digital simulation through control units (joystick, keyboard, mouse, data-glove, kinect, etc.). Augmented Reality (AR) allows the user to interact with the real world. It is also expressed as an environment where multi-media features such as text, image, sound, video, animation, hologram can be integrated into real and virtual objects, as well as 2-dimensional (2D) or 3-dimension (3D) features. AR is a real environment where data such as audio, video, graphics, animation, and GPS location information are blended (Somyürek, 2014) and creates a common experience area in which real and virtual world objects are simultaneously combined. Azuma (1997) pointed to three basic features such as integrating virtual and real objects in a real physical environment, arranging objects in a three-dimensional environment, and interacting real and virtual objects simultaneously for any environment or application to have the characteristics of AR. In other words, AR is a virtual reality application where users interact with the real environment and interact with virtual objects in the real world (Zhu, Owen Li, & Lee, 2004). In many studies in the literature review, it is emphasized that the sense of reality felt by the user increases with the integration of designed virtual objects and real-world objects. According to another definition, AR is the environment where the real world meets the virtual world in real-time and reaches the user in the same sensory area (Özarslan, 2011). Considering the definitions in the literature regarding the AR concept, augmented reality can be defined as the environment in which real worlds are enriched by using virtual objects and usage diversity is provided with the features integrated into these objects.

Dunleavy and Dede (2014) state that AR provides convenience in terms of its motivation-enhancing effect, the design approaches that develop pedagogical competencies for educators, the ability to expand multi-faceted thinking and perspective, and the problem-solving opportunity to use different methods. However, they state that students are cognitively overloaded and the difficulty of managing AR technologies for teachers and designers is their limitations. Hamilton and Olenawa (2010) argue that AR technology provides personalized education opportunities according to individual learning speed. The use of augmented reality technology in education has motivational effects for students and there are many studies on this subject. In these studies, it has been determined that students spend less effort on the achievements they want to achieve and thus indicate that augmented reality technology helps them learn (Ibáñez, Di Serio, Villarán & Kloos, 2014, Kerawalla et al., 2006). Özdemir (2017) emphasizes that it is suitable for the constructivist approach and it will be an indispensable part of the teaching process soon due to the advantages of using AR technologies in education and providing a flexible learning environment to the individual regardless of time and place in the learning process.

The number of studies that are related to evaluating the use or effectiveness of gamification and augmented reality applications in education is increasing day by day. In the light of this information, it is possible to say that all experts, especially researchers and designers in the education and software sector, have increased interest in-game technology and augmented reality applications used in education. At this point, Çakır, Güven & Çelik (2021) emphasize that augmented reality is a technological application that is used not only in theoretical education but also in interesting informal teaching environments. Many of these studies deal with the questions necessary to determine the impact of games and AR technologies on educational activities, their contribution to

learning, the convenience and difficulties they bring, and the appropriate academic level. However, systematic review studies in which the results obtained from these studies are compiled and the common results are shown are not sufficient.

In this context, this study was planned to analyze the studies conducted to examine the use of augmented reality in education, especially based on the game-based learning approach, and to present concrete data to researchers. Based on the findings of many studies from the past to date, it is suggested that the innovations brought by game and AR technology together with the benefits of providing a flexible and individual learning environment to the individual regardless of time and place in the learning process will enable significant changes in educational environments in the near future. Determining variables such as motivation, achievement, attitude, and motivation of the learner profile regarding AR applications and game technologies, which are predicted to provide a wide range of benefits to educational processes, is important for researchers and educators who are willing to develop AR technologies and game environments and integrate them into their lessons.

Purpose of the Research

With this research, it is aimed to make examinations according to the sampling method related to academic studies including the use of AR and game technologies in education published in national and international academic journals between 2016 and 2020. In this context, some factors have been taken into account to analyze the effects of games and AR on learning processes. Among the factors considered in the studies examined are features such as the field of education, sample numbers, target audience, dependent variables, a game model used and augmented reality technology, the benefits, and limitations of this technology.

Research Questions

In studies conducted for game-based learning and the use of AR in education;

1. What are the fields of education, target audience, keywords used, dependent variables, data collection tools, and research methods used in the studies considered?
2. What is the type of application of AR technology and the software used in education?
3. What are the benefits and limitations of AR technology detected in practice?

Method

The "systematic review" method was used in the study. The systematic review is a literature review method. The general purpose of systematic literature reviews is to define all researches related to the specified subject. Therefore, the method of a systematic review is quite extensive. In other words, using this method means making a detailed evaluation and interpretation by reaching a wide variety of research sources related to a particular research question or subject area (Kitchenham, 2004).

In a systematic review; the purpose of the research should be clearly explained, the academic studies included in

the research should be selected according to the determined criteria, the main features of the selected articles should be determined, and the information and findings obtained from the articles should be inferred (Alkan, 2005). Unlike traditional reviews, a more rigorous and well-defined approach is used to review the literature in a particular field to bring explanatory and enlightening answers to research questions to be focused on with systematic reviews (Cronin, P. et al.2008). Besides, as a result of the screening, many researchers discussing the systematic analysis emphasize that the methods to be focused on during the determination of the researches to be covered in the subject study should be well defined during the literature review and that this method is extremely important to be applied in future studies.

The study in question is based on a three-step method compiled by Bacca et al. (2014) from the study of Kitchenham (2004) as the main source. With this method, the steps of planning, examining, and reporting the studies reached were applied in detail:

- Planning, which is the first stage, includes the selection of the databases to be examined, the establishment of important criteria to determine whether the studies accessed in the selected databases will be included in the study, and the determination of the categories after the content is reached according to the appropriate criteria.
- In the second stage, the work to be examined is determined.
- In the last stage, the process of reporting the findings is applied.

The methodological steps of the three-step method applied in this systematic literature review are given in Figure 1 as a flow diagram. As shown in Figure 1, the systematic literature review was carried out in 3 general steps:

- In the first step, database selections were made, and 302 articles were reached with 3 keywords and by restriction methods such as year, source type, and language selection in the selected databases.
- In the second step, the articles to be included in the research were selected as a result of the searches made with keywords, and the analysis process of 53 articles was performed.
- In the last step, comments were made and reported according to the findings.

Data Collection and Analysis

The following criteria were considered in the selection of the articles to be included in the study:

- ✓ The research must evaluate the effects and results of the use of games and augmented reality in education
- ✓ Journals must be published nationally and internationally and generally include studies related to "educational technologies",
- ✓ The articles must be published between the years of 2016-2020,
- ✓ Access to the full text of the article must be provided,
- ✓ The articles must be accessed by using the keywords "game-based learning and augmented reality", "augmented reality in education", "gamification".

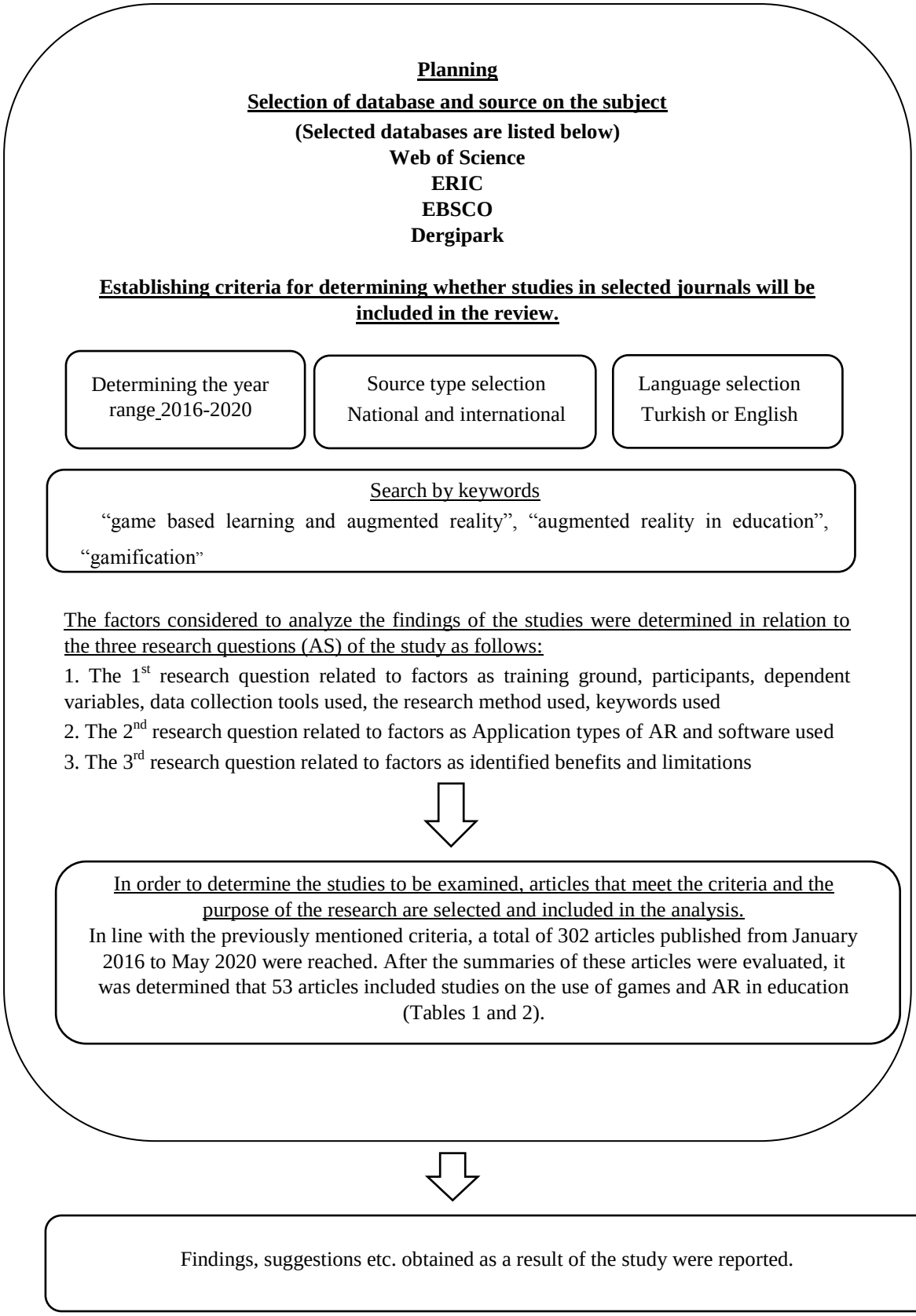

Figure 1. Flowchart of Methodological Steps

Sample of the Study

Web of Science, ERIC, EBSCO, Ulakbim-Dergipark, and Google Scholar search engines and databases were used to reach relevant articles in the systematic literature review on the use of game-based learning and AR technologies in education. The search was carried out using these databases, mostly in the categories of education, educational research, educational technology, instructional design, and computer sciences. The date range is determined as 2016-2020.

Full-text article search in journals containing relevant studies in the national and international academic literature review was carried out using the keywords "game-based learning and augmented reality", "augmented reality in education", "gamification". During the screening, “book chapters, papers, reviews, news items, and discussions” were not taken into consideration. A total of 53 studies from the articles that meet the research criteria constitute the sample of the review.

Findings

Reviewed Studies According to Inclusion Criteria

In line with the specified criteria, a total of 302 articles published in January 2016 to May 2020 were reached. After reviewing the abstract parts of these articles, it was found that only 53 articles were developed on game-based learning and AR use in education (see Table 1).

Tablo1. Distribution of Studies Determined According to the Inclusion Criteria, by Databases and Years

Databases	2016	2017	2018	2019	2020	Total (f)	(%)
Web of Science	5	7	6	14	3	35	66
ERIC	2	2	2	-	1	7	13
EBSCO	-	1	2	2	1	6	11
DergiPark	-	1	3	1	-	5	10
TOTAL	7	11	13	17	5	53	100

As shown clearly in Table 1, more studies were conducted following the determining criteria in 2017, 2018, and 2019 compared to the other years. Also, it is seen that these studies are mostly published in the Web of Science (35%) database. This is followed by Eric (13%), Ebsco (11%), and DergiPark (10%) databases.

Reviewed Studies According to Educational Field, Participants, Data Collection Tools and Research Methods

As can be seen in Table 2 in the articles about game-based learning and AR usage in education, most of the academic studies are distributed in Science (26.42%) and foreign language (16.98%) branches. In addition to this, there are also studies with a high rate of 24.53%, in which no branch is specified.

Table 2. Educational Fields Covered in the Reviewed Articles

Educational Fields (Branches)	Number of the Studies (f)	%
Science	14	26.42
Math	1	1.89
Native Language	1	1.89
Foreign Language (English)	9	16.98
Informational Technologies – Computer Science	2	3.77
History - Geography - Astronomy	3	5.66
Health - Medicine	3	5.56
Engineering - Architecture	2	3.77
Educational Sciences – Instructional Design	2	3.77
Special Education	1	1.89
Communication	2	3.77
Unspecified	13	24.53
TOTAL	53	100

Considering the articles obtained regarding the use of games and augmented reality in education, the number of studies in which the educational status of the participants was clearly stated was determined as 35, 18 studies (33.33%) did not make any explanation about the educational status of the participants (see Table 3). As shown in Table 3, it has been determined that the primary education level (31.48%) and undergraduate students (16.67%) are the majority among participants. Besides, dependent variables discussed in the reviewed studies include factors such as motivation, attitude, learning performance, interest, spatial ability (concretizing abstract concepts), self-efficacy, and self-learning. Almost all of the studies argue that the use of game-based learning and augmented reality in education is effective and efficient in terms of those variables.

Table 3. Educational Levels of the Participants in Reviewed Studies

Educational Level	Number of the Studies (f)	%
Preschool	3	5.56
Primary Education (Primary School + Middle School)	17	31.48
Secondary Education (High School)	1	1.85
K12 Education (Primary + Secondary)	3	5.56
Undergraduate	0	0.00
Graduate	9	16.67
Postgraduate (Master + PhD)	2	3.70
Unspecified	18	33.33
Total	53	100

As a result of the data presented in Table 4, the data collection tools observed to be frequently used in the articles included in the study were determined as questionnaires (31.34%), observation and video recordings (20.89%), and interview forms (17.91%). At this point, it is noteworthy that more than one data collection tool

can be used in a study. The research methods used in the reviewed articles are quantitative (45.28%), qualitative (28.30%), and mixed (18.86%) methods (see Table 4). The mixed research method is the method that involves the use of quantitative and qualitative methods together in a single research project (O'Reilly, Thorkelsson, Nobert, & McLaughlan, 2009). According to another definition by Johnson and Christensen (2008), mixed-method research is achieved via using qualitative and quantitative research methods or paradigms together. Quantitative research is a type of research that presents events and their results in an observable, measurable, and numerically expressible way by objectifying them. Qualitative research, on the other hand, is a type of research that uses qualitative data collection methods such as observation, interview, and resource scanning, and the results are analyzed and reported holistically.

Table 4. Data Collection Tools and Research Methods Addressed in Reviewed Studies

Data Collection Tools	Number of the usage	%	Research Methods	Number of the usage	%
Observation / Video Recording	14	20.89	Quantitative	24	45.28
Achievement Test	8	11.94	Qualitative	15	28.30
Questionnaire	21	31.34	Mixed	10	18.86
Interview Form	12	17.91	Unspecified	4	7.54
Scale	2	2.98			
Unspecified	10	14.92			
Total	67	100	Total	53	100

Application Type of AR Technology and Software Used in Reviewed Studies

The types of AR used in the studies examined are shown in Table 5. Although it is emphasized that the number of articles that contain location-based augmented reality technology (33.96%) is much higher than sign-based augmented reality applications (16.98%), the number of studies in which AR application type is not clearly stated is respectively high (49.05%).

Table 5. Augmented Reality Application type Used in the Reviewed Studies

Application Type	Number of usages (f)	%
Marker-Based	9	16.98113208
Location-Based	18	33.96226415
Markerless	-	-
Unspecified	26	49.05660377
Total	53	100

Table 6 includes the software used in the reviewed studies. Most of the studies (30%) did not mention the software they used while developing AR applications. Only 37 studies mentioned the software they used (Aurasma Studio, Vuforia SDK, Unity 3D, Wikitude, Metaio Creator, Layar, etc.). Among this software, Unity 3D (22.64%) was determined as the most preferred compared to the others.

Table 6. The Software used for AR Development in Reviewed Studies

Software Used	Number of usages (f)	%
Aurasma Studio	5	9.43
Vuforia SDK	8	15.09
Unity 3D	12	22.64
Wikitude	1	1.88
Metaio Creator	1	1.88
Aris-ArKit	3	5.66
Quiver	1	1.88
Other	6	11.32
Unspecified	16	30.18
Total	53	100

Benefits and Limitations of the AR in Reviewed Studies

Almost all the studies examined state that the use of game-based learning and augmented reality in education is effective and efficient. Multiple studies emphasize benefits that are common with other studies. Table 7 lists the benefits provided by using augmented reality in education and Table 8 lists the limitations. In the light of this information, it is observed that the use of game and AR technologies or environments in education often provides benefits in functions such as motivation, attitude, learning performance, success motivation, and interest in the lesson.

Table 7. Benefits of AR and Game Usage in Education Mentioned in Reviewed Studies

Benefits	Number of usages (f)
Improving learning performance	13
Increasing motivation	15
Triggering the sense of success	1
Increasing the interest in a lesson	8
Improvement in attitudes towards learning	4
Spatial ability (embodying abstract concepts)	2
Increasing practice skills	2
Increasing thinking skills	5
Development of self-learning	7
Assist in understanding the topic	2
Increasing the willingness to learn	6
Assist in constructing knowledge	6
Development of collaborative work	8
Increasing communication among students	4
Interactive participation	6
Fast feedback	5

Table 8. Limitations of AR and Game Usage in Education Mentioned in Reviewed Studies

Limitations	Number of usages (f)
Need for Technical knowledge to develop game-based and AR course content	9
Lack of technical equipment	9
Prejudiced attitudes towards the use of augmented reality and game applications	5
Cost to be allocated for the provision and maintenance of the necessary hardware and infrastructure	7

Discussion

In this research, it is aimed to discuss the findings of the use of game-based learning and AR in education by systematically examining the studies on game-based learning and AR use. 53 academic studies, which were scanned in line with the purpose of the research and the specific criteria determined, were analyzed following the systematic literature review. The factors considered in order to analyze the findings for all studies determined as a result of the screening are as follows; "Educational field", "educational status of participants", "data collection tools", "research methods", "type of AR used", "AR application development software" "Benefits for the use of AR in a game-based learning environment" "AR's limitations regarding its use in a game-based learning environment."

As a result of the analysis made because of the findings of the study, it is seen that most of the examined scientific studies are concentrated in the fields of Science and Foreign Language education. This is followed by the fields of History-Geography-Astronomy, Health-Medicine, and Engineering-Architecture. Like these results, in a study investigating the use of AR in game-based learning, it was observed that the studies in the field of Science were intense (Pellas, Fotaris, Kazanidis, & Wells, 2018). The intensive use of abstract concepts that are difficult to understand by students in these disciplines and the fact that these abstract concepts can be concretized by augmented reality technologies and game-based learning environments and provide spatial ability may be among the reasons for this intensity. Another reason may be that AG provides a safer environment for dangerous and objectionable experiments and studies to be carried out in laboratory environments in real-life conditions. Also, when AR, appropriately use educational technologies in laboratories, students are not completely separate from the real laboratory environment and equipment, and their learning is optimized (Akçayır, Akçayır, Pektaş, & Ocak, 2016). During the literature review, it is seen that the least number of studies are in Mathematics, Native Language, Information Technologies - Computer Sciences, Educational Sciences - Instructional Design, and Special Education. Besides, it is not specified in which education/training field many studies were conducted. In this context, game-based learning and augmented reality-based research can be conducted with these areas whose deficiencies are detected. Considering the potential of game-based learning and AR to increase interest and skill together with its effect on motivation and performance, studies in these areas will play an important role in increasing educational effectiveness and efficiency.

Studies made in education levels of the participants are mostly concentrated in the primary and undergraduate levels. On the other hand, the number of studies conducted at pre-school, graduate, and high school levels are relatively low. Studies conducted on the use of augmented reality technologies in education, K-12 students were selected as the sample in almost half of the articles examined in parallel with these results. University students are also the second most preferred student type (Akçayır & Akçayır, 2017). At this point, although the beneficial effects of game-based learning and AR technologies in preschools are known, it is seen that they are not widely used. For example, in a study conducted with preschool students, it was observed that AR contents had a very positive effect on students, who were stated to be a real source of motivation and an encouraging catalyst for children (Cascales, Laguna, Pérez-López, Perona, & Contero, 2013). In the same way, AR technologies provide a realistic experience for high school and graduate-level participants where dangerous or expensive experiments and studies are performed, making laboratory environments safer and cheaper, and at the same time using them more flexibly in terms of working hours and materials (Andujar, Mejías, and Márquez, 2010). Considering these features of AR technologies, it can be said that there is a need for studies to investigate the use of game-based learning in education with participants at the pre-school, high school, and associate degree education levels.

The questionnaire, observation form, video recording, interview form, and achievement test were used as data collection tools in different studies. Besides, most of the articles investigated are dominant in quantitative research design. Qualitative and mixed research methods also follow the quantitative research method, respectively.

It is stated that the number of articles including location-based augmented reality technology type among the AR types used in the reviewed studies is much higher than the others. Similarly, in a study examining AR technologies in education, it was stated that most of the AR games used were location-based (Koutromanos, Sofos, & Avraamidou, 2015). Besides, a wide variety of software is used to develop AR-based applications. Some of this software is Software such as Unity 3D, Vuforia SDK, Aurasma Studio, Aris-ArKit, Wikitude, Metaio Creator, Quiver. Unity 3D is the most preferred software in the scientific studies discussed, followed by Vuforia SDK and Aurasma Studio software.

The use of game-based learning and augmented reality together is beneficial for the learner and teacher, as well as for learning environments. According to the data obtained from the studies considered, the use of AR, along with game-based learning, increases students' motivation, learning performance, interest in the lesson improves collaborative work and self-learning, increases willingness to learn, helps to structure knowledge, provides interactive participation, thinking. It has been observed that it increases their skills, gives quick feedback, improves attitudes towards learning and communication between students, increases spatial ability (concretizing abstract concepts) and application skills, helps to understand the subject, and triggers the motivation for success. Like these results, in a study conducted by Di Serio Ibanez and Kloos (2013), it was concluded that the positive effect of AR on motivation led students to participate in higher-level learning activities with less cognitive effort. Also, it can help the realization of active learning by making the learning environments and laboratory environments safe by allowing them to make experiments as if they are in their real environment, and thus permanence in learning can be achieved.

The use of game-based learning and augmented reality together is beneficial for learners and teachers, as well as limitations. According to the data obtained from the studies considered, it was seen that technical knowledge was needed in the use of AR with game-based learning and there were deficiencies in terms of technical equipment. Besides, biased attitudes towards the use of augmented reality and game applications can cause the use of cost-increased reality and game technologies for purposes other than educational purposes, which should be allocated for the provision and maintenance of the necessary hardware and infrastructure. In addition to all these, individual differences among students, excessive cognitive load caused by unnecessary multimedia use, and students' desire to use devices for non-educational purposes also lead to a decrease in the educational efficiency of these environments. In this sense, in most of the articles examined in a study synthesizing AR application in education, it was seen that users evaluated the use of AR systems as more difficult than physical or desktop-based alternatives (Radu, 2014).

Conclusion

To conclude, research in the field of education shows that AR technology has great potential to provide effective learning support both in-school and out-of-school activities (Hwang, Wu, Chen, & Tu, 2016). For example, AR can be used in biology teaching to improve students' cognitive and affective domains (Kozcu Cakir, Guven & Celik, 2021), in mathematics teaching to improve students' self-efficacy and deep learning strategies (Cai , Liu , Yang & Liang, 2019) or in special needs education to help students' learning (Köse &Güner-Yıldız, 2020). Similarly, game-based learning is also beneficial for students who learn English as a foreign language (Syafii, Kusnawan & Syukroni, 2020), who want to improve computational thinking skill (Israel-Fishelson & Hershkovitz, 2020) or who study science (Hussein, Ow, Cheong, Thong, & Ebrahim, 2019). This multipurpose use of AR and game-based learning is seen as educationally beneficial when combined together. Used in conjunction with game-based learning, AR-enabled students to increase their cognitive acceleration, increase self-management, and increase their participation in practice-based activities (Fotaris, Pellas, Kazanidis, & Smith, 2017). Unlike other information technologies, AR interfaces offer an infinite interaction between real and virtual worlds, a concrete interface metaphor, and a means of transition between real and virtual worlds (Mackay, 1998). The combination of AR technology with game-based learning method makes the concepts three-dimensional, enabling students to understand abstract subjects better, to be able to be in environments where it is difficult or impossible for them to be in real life and to have first-hand experience (Leitão, Rodrigues, & Marcos, 2014). In this context, educators should work with researchers and designers in the field to discover the most effective and efficient applicability of augmented reality in educational environments with the game-based learning method.

The number of scientific studies conducted in our country on the use of AR in education processes is very low compared to internationally published studies. Although there are few published books on AR technologies and environments in our country, there are also ongoing academic and private-sector studies. In most of the academic studies obtained because of the literature review, the lack of technical knowledge of the practitioners about AR and the lack of equipment in the environment stand out. At this point, necessary in-service training and hardware support should be provided to practitioners related to AR and game-based learning. The quality,

success, and achievement of the game-based teaching performed with the AR application depend on the quality of all the content designed for the AR application. For this reason, visual design principles and instructional design theories and models should not be ignored in the development of content designed to be used in the AR application.

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