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Determining the trends of using augmented reality in education between 2006-2016

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Abstract

This study aims to examine 58 articles, published in 8 educational technology journals under the Social Science Citation Index (SSCI) between 2006 and 2016, containing "augmented reality" in their title and, thereby, to determine the trends of using augmented reality (AR) in education by the content analysis technique. In this period of time, the total number of academic publications containing "augmented reality" in the Web of Science database, in all indices, was determined as 3540, and among these publications, 58 articles with SSCI index were analyzed within the scope of the research. It analyzes the change of articles related to AR by years; the usage of methods and data collection tools; education field, educational advantages, the type of applications used, technologies, assets used, physical environments in which researches were carried out, sensory types that applications address to, countries and continents in which the articles were published, and the keywords in these articles. Findings obtained were visualized with tables and graphics. According to the results obtained from the findings, there has been a sudden increase in the number of publications since 2013 and it reached the highest level in 2016, the most commonly used method is the mixed method and the data collection tool is questionnaire, most of the studies are carried out in Science, tablets and smartphones are most used, AR applications address to visual sense mostly and such articles are published mostly in the Asian continent. It has been determined that the most positive effect of AR on education is for academic success and learning motivation. It has been understood that the AR is closely related to disciplines such as human-computer interaction, robotics and remote laboratory systems. In addition, some suggestions have been made to researchers and developers based on these research findings.

Keywords Education · Augmented reality · Trends · Content analysis

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1 Introduction

Great technological developments that have changed and transformed the structure of people and society were experienced in the twenty-first century and such advancements continue today. These technological developments are no longer limited to certain areas but they effect and strengthen each other. In this new era, where a development in the field of engineering can be integrated into medicine and all disciplines feed each other, new technologies and applications have also emerged in the field of education. Augmented reality (AR) is one of these innovative technologies.

AR, rather than a completely virtual and artificial environment, is a technology that makes it possible to offer interactive experiences by enriching the real world with virtual items (Höllerer and Feiner 2004). AR, far from being a complete substitution of reality, supports reality by expanding it and bridging the gap between the real and virtual world (Chang et al. 2010). Milgram and Kishino (1994) defined four kinds of reality media in their "virtuality continuum" diagram, and sorted them as real environment (RE), augmented reality (AR), augmented virtuality (AV) and virtual environment (VE) from left to right and placed the "mixed reality (MR)" on top, covering all. While AR refers to making virtual and digital enhancements to physical reality, AV is implemented by adding elements from the real world to virtual environments. The intensity of virtual elements in AV environments is greater compared to AR. Virtual reality (VR), on the other hand, is realized entirely in digital, artificial and virtual environments, unlike AR. VR is defined as a concept that simulates physical presence and allows realistic sensory experiences to be lived in computer-generated environments (Johnson et al. 2016). In view of the historical development of the AR and in addition to the development and strengthening of mobile devices with various hardware and sensors such as the internet, GPS, camera, compass, accelerometer, gyroscope (Pence 2010), it can be seen that the AR technology has begun to evolve much differently due to the digital convergence with spread of such popular communication technology as the internet in society, easy programming of mobile applications and gaining of different functions by wearable technologies such as smart glasses and smart watches. Further development of AR applications leads to an increase in the numbers of users, making AR more popularity and widespread day by day (Broll et al. 2008). Although AR has been discussed and practiced for more than 50 years, it has become available to everyone in the result of the proliferation and commercialization of mobile technology in recent years and the AR has become an easily accessible technology for everyone (Sommerauer and Müller 2014).

Cheng and Tsai (2013) divides AR into two as "image based" and "location based". According to this, image-based AR consists of artificial labels and natural graphics, while location-based AR is realized with GPS and wireless network. After the process of recognition, both features of AR technology will add augmented assets (e.g., text, audio, video, 3D model) to the physical elements on the users' display. The use of these two categories might enhance understanding of the features of AR applications, regardless of what hardware and software is used. Johnson et al. (2010), on the other hand, divides the types of AR into two as marker-based and markerless applications. While marker-based AR is realized using two-dimensional special visual symbols, images or data matrices, applications based on tools such as GPS, digital compass or accelerometer are identified as markerless AR. Maqableh and Sidhu (2010) identified

smart glasses, smart displays, computer webcams and computer screens as AR technologies. Different innovative technologies such as AR-related mobile devices, wearable computers, holograms and three-dimensional technologies are also used (Wei et al. 2015).

AR has a widespread use, from medicine (Andersen et al. 2016; Rodriguez-Pardo et al. 2015) to architecture (Abdullah et al. 2017; Arino et al. 2014; Fonseca et al. 2014), engineering (Coovert et al. 2014; Gavish et al. 2015) to museology (Capuano et al. 2016; Chang et al. 2014; Choi 2014).

According to Martín-Gutiérrez et al. (2015), information and communication technologies are intertwined in diverse ways with the daily lives of societies and play an active role in learning processes. Learners tend to prefer learning environments that are more interactive, more original, more authentic and appealing to more sensory stimuli. Today's and future learners who live with technology want their educational environments to be integrated with innovative approaches such as AR-based games and simulations (Klopfer and Yoon 2004).

AR, which is applied to many different areas, is also available in educational environments. AR can be used in various educational forms in sub-branches of science studies such as physics (Cai et al. 2016; Ibáñez et al. 2014), chemistry (Boletsis and McCallum 2013; Cai et al. 2014), biology (Bressler and Bodzin 2013; Chang et al. 2016; Hwang et al. 2016) as well as in Mathematics and Geometry (Estapa and Nadolny 2015; Lin et al. 2015) and Foreign Language Teaching (Liu and Tsai 2013).

The use of AR in educational settings has the potential to provide content in a three-dimensional perspective, to create simultaneous and collaborative learning opportunities, to make the invisible to visible, and to bridge formal/informal learning (Wu et al. 2013). Yuen et al. (2011), on the other hand, express that this technology attracts the learners interest, increases their motivation, enables them to pass on the experiences that can not be realized in the real world, enhances the cooperation and interaction between the learners-learners and the learners-educators, enriches the imagination and creativity of the learners, ensures that students decide on their method of learning and complete learning process at their own learning speed and makes it possible to prepare unique educational environments suitable for different types of learning. AR also provides opportunities for some problems to be solved in the learning processes. For example, some learners have difficulty in picturing the micro and macro worlds in their minds (Cai et al. 2014). AR can be used to simulate very large macro systems such as planets and galaxies, as well as to teach very small micro-structures such as atoms and molecules (Núñez et al. 2008).

The study by Billinghurst and Dunser (2012) examining the level of efficiency in using the AR in educational environments showed that high level of interaction provided by the AR improves the kinesthetic, visual / spatial skills of the learners and enriches collaborative problem-solving skills by increasing their motivation levels. Sayed et al. (2011) concluded that augmented learning environments improve the learners' visualization skills in the learning processes and provide the environment with edutainment.

AR is able to find effective solutions at the points where learners have difficulty in learning through the possibilities it provides. For example, each learner does not have equal three-dimensional spatial perception skills. Some learners may have difficulty visualizing a drawn two-dimensional object in three dimensions (Núñez et al. 2008). At

this point, AR affects not only spatial skills, but also temporal and contextual relationships between virtual and real objects in a positive way, and it also receives positive feedback in education, in terms of providing kinesthetic and exploratory stimuli (Woods et al. 2004). Ibáñez et al. (2014) stated that AR increased the levels of motivation, commitment and satisfaction of learners, whereas Wojciechowski and Cellary (2013) pointed out that the most important advantages of AR applications in the field of education were the active involvement of learners, low cost and safety. Chang et al. (2010) emphasize that AR is a technology that has a positive impact on cognitive development in terms of being attractive, stimulating, exciting and affordable. According to Lee (2012), AR also allows learners to discover unique learning paths that are unique to them, rather than just an environment that gives them the opportunity to learn interactively. Through the use of AR in education, interaction, simplicity, contextual knowledge, efficiency and effectiveness can be achieved. According to Wasko (2013), key features of AR-enriched learning environments are critical thinking, problem-solving and collaborative work.

Although the use of AR in education has many advantages, its limited aspects make its widespread use difficult. Portability problems in outdoor use, tracking and calibration problems, exposure to excessive loading of the interface, difficulty in its social acceptance are some of these limitations (Van Krevelen and Poelman 2010). The most common limitation encountered in education surveys regarding AR is the cognitive load. The second limitation, from the perspective of designers and teachers, is shown as the inability to integrate and manage all AR experiences. In addition, technical problems that occur during the implementation are also seen as a significant limitation (Dunleavy and Dede 2014). Besides the technical limitations of AR, there are also some issues related to privacy, ethics and user aspect (Berryman 2012). In particular, discussions on the use of wearable technologies such as smart glasses and AR-supported bionic contact lenses in learning environments continue in the context of safety, privacy and ethics.

As examples from the literature are given, with the use of AR in education, high-level interactions can be created, communication can be diversified and learning motivation is enhanced. In addition, AR can create positive attitude and behavioral changes and enrich the user experience. AR, which plays an active role in the realization of collaborative work with more entertaining learning environments, can also be used in education in order to acquire a variety of skills, especially spatial ability and conceptual understanding.

There have also been some literature reviews, content analysis and meta-analysis studies related to the AR applications which found such an intensive use area in the field of education in the recent years. These studies are particularly important in terms of identifying trends of using AR applications in the field of education and they play a leading role in this research.

The following table presents the title of these studies, their authors and a brief summary of the research conducted (Table 1):

Although there are some common points in terms of analyzed items in the literature review, many different items were included in the scope of this research as well. The results of this research are important as it covers a relatively long period from 2006 to 2016 and with respect to the determination of the current situation in current studies. Furthermore, unlike other studies in the literature, it is important to analyze some of the

Table 1 Previous researches and details

Years Analyzed	Title	Author(s)	Summary of the Research
2003–2013	Augmented Reality Trends in Education: A Systematic Review of Research and Applications	Bacca et al. (2014)	This article contains an analysis of 32 studies published between 2003 and 2013 in 6 journals covered by the SCI and SSCI indices. In this study, such components as the use of the AR in the education field, the target audience studied on, the purposes of using the AR in education, its advantages in education, its limitations and effectiveness, types of AR, research sample, research method, time dimension, data collection method were analyzed and the trends and a vision for the future is also presented.
2007–2016	Using Augmented Reality in Education: A Content Analysis of the Studies in 2007–2016 Period	Korucu et al. (2016)	This research covers the studies in Turkey only. This study analyzes 33 academic studies published between 2007 and 2016, which contain the concept of "augmented reality" in their key words. These studies are analyzed in terms of the journal or book in which the research was published, publication year, the general purpose of the study, the sector to which the study was related, the sample of the study, the research method used, and the data collection tool used in the study.
2005–2014	A Systematic Review of Usability Studies in Augmented Reality between 2005 and 2014	Dey et al. (2016)	Within the scope of this study, 291 studies published between 2005 and 2014 were examined and classified according to their application areas. The study presents the changes in the method used (experiment type), display type and application type according to the publication year.
2012–2016	The Use of Augmented Reality in Formal Education: A Scoping Review	Saltan and Arslan (2017)	This study includes researches published between 2012 and 2016 on the use of AR applications in the context of formal education. 23 studies were analyzed in the ERIC database using the "augmented reality" key word.

components such as the detection of technological devices and assets used in the AR studies, in which physical learning environments the researches are conducted, to which type of sense the AR, and which keywords are intensely used. In particular, the physical environment in which the research was conducted and the types of sensations addressed were not examined before in any study. Also, unlike other studies,

the findings and results obtained from this study are important to show in which countries and continents the AR researches are published intensely.

1.1 Purpose of research and research questions

This study aims to determine the trends of using AR in education by examining 58 articles containing "augmented reality" in their title and published in 8 educational technology journals under the Social Science Citation Index (SSCI) between 2006 and 2016. To reach this aim, we have searched for answers to the following research questions:

Educational technology journals within the scope of SSCI between the years of 2006–2016

1. What are the changes in the number of articles published by years?
2. What methods are used in the articles on the AR?
3. What are the data collection tools used in articles on AR?
4. In which sub-branch of education are the AR studies concentrated?
5. What are the types of AR applications?
6. What are the technologies used for AR applications?
7. What are the assets used in AR applications?
8. What are the physical environments in which AR researches are carried out?
9. Which senses do the AR applications appeal to?
10. What are the countries where AR researches are carried out?
11. What are the continents where the AR researches are carried out?
12. What are the most used key words in the AR articles?

2 Method

2.1 Research design

The model used in this research is general survey model. The researches conducted with the general survey model are intended to describe the situation related to the subject "as it is" (Şimşek et al. 2009). General survey models are screening arrangements that are established over the whole universe or a sample group that is taken from a part of the universe in order to arrive at a general judgment about the universe composed of many components (Karasar 2006). This study aims to examine 58 articles containing "augmented reality" in their title and published in 8 educational technology journals under the SSCI between 2006 and 2016 and, thereby, to determine the trends of using AR in education. The study employs general survey model as it aims to describe the current situation.

2.2 Sample

The sample consists of 58 articles with "augmented reality" in the title published in 8 journals within the scope of SSCI between 2006 and 2016.

The indexes of the journals were checked before the selection of journals the articles to be analyzed. The journals in the field of education and within the scope of SSCI are listed and sorted according to their impact factors. Later, articles were selected using the "advanced search" option of the journals with the year range of the articles (2006–2016) and only the articles containing "augmented reality" in their title. In this process, some journals (Journal of Research on Educational Effectiveness - Learning, Media and Technology - Social Science Computer Review - Journal of the Learning Sciences) were eliminated because they do not have any articles with "augmented reality" in the title, although they provide the necessary indexing conditions. The 8 journals that make up the sample of the study are shown in Table 2 below in terms of impact factors and the number of articles with "augmented reality" in the title.

Of these 8 journals, the journal "Computers & Education" has the highest impact factor as well as 17 articles with "augmented reality" in its title between 2006 and 2016.

2.3 Data collection tools and process

In this study, the advanced search module on the web pages of Computers & Education, Computers in Human Behavior, British Journal of Educational Technology, Interactive Learning Environments, Journal of Educational Technology & Society, Journal of Computer Assisted Learning, Journal of Science Education and Technology, Educational Technology Research and Development journals were used as data collection tools In the scientific articles of these eight journals within the scope of the SSCI, 58 articles have been identified to have "augmented reality" in their titles. Since the criteria were set at the beginning of the study, no screening was made. All articles were downloaded to the computer and classified under the folders. A Microsoft Excel spreadsheet was created for the articles that have been accessed containing 11 columns for "Methods used", "Data collection tools used" "Education sub-branch", "Types of applications", "Technologies used", "Assets", "Physical Environments", "Sensory Types" "Countries", "Continents," and" Keywords", and the titles of 58 articles

Table 2 Journals used in research, impact factors and number of articles examined

The indexes	Journals	Impact Factor (July 2017)	f
Social Sciences Citation Index (SSCI)	Computers & Education	3.819	17
	Computers in Human Behavior	3.435	12
	British Journal of Educational Technology	2.410	5
	Interactive Learning Environments	1.674	8
	Journal of Educational Technology & Society	1.376	3
	Journal of Computer Assisted Learning	1.253	1
	Journal of Science Education and Technology	1.080	8
	Educational Technology Research and Development	0.725	4
	Total		58

regarding which journal they belonged to. The content analysis studies, meta-analysis and bibliometric analysis studies determining the trends were guiding in the creation of this table (Bacca et al. 2014; Bozkurt et al. 2015; Göktaş et al. 2012; Kilinç et al. 2017; Koutromanos et al. 2015; Lopes et al. 2017). In addition, small changes were made to the table as the articles were examined.

2.4 Data analysis

In this study, the analysis of data was performed by content analysis technique. It describes a family of analytic approaches ranging from impressionistic, intuitive, interpretive analyses to systematic, strict textual analyses (Rosengren 1981). Content analysis is also a method of analyzing written, verbal or visual communication messages (Cole 1988). Content analysis, which can be used together with qualitative and quantitative methods, is also known as a method of analyzing documents (Elo and Kyngäs 2008). With content analysis, it is possible to separate words related to content into fewer categories (themes). When entered in the same categories, it is assumed that similar words, phrases, and the like share the same meaning (Cavanagh 1997).

In this study, during the analysis of the data, similar contents are combined in the same category and the data to be eliminated were removed from the relevant category in accordance with the nature of the content analysis. Descriptive statistics (percentage and frequency) were used when the content analysis was performed. Analyzes are visualized with tables or graphics.

In the analysis and classification of the articles according to the determined criteria, 58 articles were first analyzed and evaluated according to the 11 criteria. The same articles were then re-evaluated and checked by two specialists who teach scientific research methods in order to ensure the reliability of the analyses on the method. After the corrections were made on this aspect, the data under certain columns ("Education Sub-Branch", "Type of Application", "Technologies Used", "Components (Assets) Used", "Physical Environments", "Sense Types") were also checked by an educational technology faculty member who works on AR studies. Experts have conducted data validation on a voluntary basis.

2.5 Findings

Within the scope of this research, 58 articles containing "augmented reality" in their title and published in 8 educational journals within the scope of SSCI were examined. The findings of the content analysis are presented in 12 sub-headings within the frame of the purpose of the study and the research questions.

2.6 Changes in number of article published by years

In the analyses made, the distribution by years of 58 articles with "augmented reality" in their title in 8 SSCI-included journals (Computers & Education, Computers in Human Behavior, British Journal of Educational Technology, Interactive Learning Environments, Journal of Educational Technology & Society, Journal of Computer Assisted Learning, Journal of Science Education and Technology, Educational Technology Research and Development) is shown in Fig. 1. When the graphic is examined,
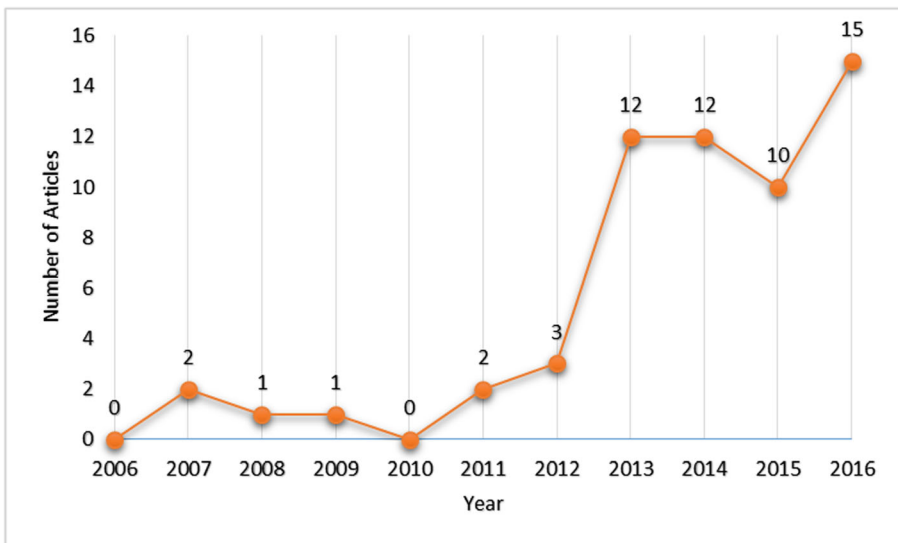
Fig. 1 Changes in number of article published by years

it appears that no articles that meet these criteria were published in 2006 and 2010. It is seen that the number of articles which did not increase very much linearly between 2006 and 2012 showed a sudden increase in 2013 ($n = 12$), this increase continued in 2014 (n = 12) and 2015 ($n = 10$). In 2016, it is seen to reach the highest point ($n = 15$).

2.7 Methods used in articles on AR

When the methods used in 58 articles related to the AR are examined (Table 3), it is seen that most of the studies were conducted with mixed research ($n = 26$) method. Mixed researches constitute 44.82% of total studies. The most widely used method after mixed surveys is quantitative studies ($n = 23$). It is seen that mixed and quantitative studies constitute a large part of total studies (84.47%). In terms of the method used, other studies are listed as

Table 3 Methods used in articles on AR

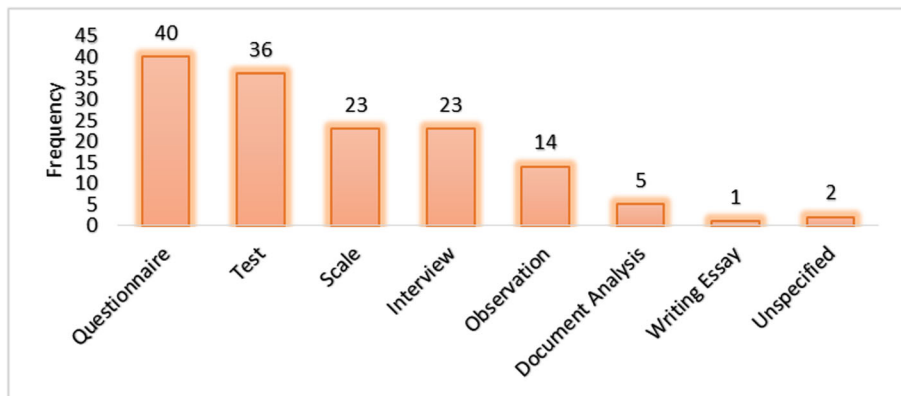| Method	f	Percent (%)
Mixed	26	44,82
Quantitative	23	39,65
Design Based	4	6,89
Review	3	5,17
Qualitative	1	1,72
Theoretical	1	1,72
Total	58	100

Fig. 2 Data collection tools used in articles on AR

"Design Based Researches" ($n = 4$), "Review" ($n = 3$), "Qualitative" ($n = 1$) and "Theoretical" (n = 1).

2.8 Data collection tools used in articles on AR

While data collection tools used in articles on AR were being examined, it was observed that more than one data collection tool was frequently used in one article. When we look at the data collection tools used in the articles on the AR, it is seen that the questionnaire ($n = 40$) is used the most. The most frequent use of tests ($n = 36$) after the questionnaire is remarkable. It was observed that these tests consist of such types of tests as pre-test, post-test, achievement test, evaluation test. Then comes the scale ($n = 23$) in the list. Qualitative data collection tools such as interview (n = 23), observation ($n = 14$), document analysis ($n = 5$) and essay writing (n = 1) were used after quantitative data collection tools showed frequency. In 2 of the studies, no data collection tool is specified (Fig. 2).

2.9 Education branch and sub-branches of AR

One of the findings is that, when a total of 58 articles using AR in education are classified according to determined themes, most of the studies are carried out in the field of Science ($n = 23$) (Table 4). It is seen that studies in the field of Biology ($n = 10$) including Plant Education and Ecology and Physics ($n = 8$) including Nuclear Science are intensively studied. Apart from that, Mathematics & Geometry ($n = 4$) and Engineering Education (n = 4) are among the main subjects of study. In 2 studies, general educational subjects other than a specific education area were studied while no education areas and sub-branches were found in 3 studies.

2.10 Educational advantages of AR applications

In line with the purpose of the use of AR applications, some findings have been obtained regarding the positive effects of AR applications in the field of education

Table 4 Education branch and sub-branches of AR

Education Field	Sub-Branches (If Any)	Number of Studies (Sub Branches)	Total
Science Education	Physics	8	23
	Chemistry	2	
	Biology	10	
	General	3	
Mathematics & Geometry			4
Engineering Education	Electrical Engineering Education	2	4
	Industrial Engineering Education	1	
	Other	1	
Astronomy and Space Science			2
Foreign Language Teaching			2
Communication			2
Behavior Training			2
Clinical Psychology			2
Art			2
Tourism			2
Library Teaching			1
Design			1
Adult Education			1
Pre-School Education			1
Architecture Education			1
History			1
Acting Education			1
Medical Education			1
General			2
Unspecified			3
Total			58

and their advantages. The theoretical foundations of this technology have been rewritten and supported by strong literature while determining the principles regarding the positive effects and potential advantages of AR in education. While examining the articles in the context of content analysis, the educational advantages and effects of the applications used in each article were determined using SCORM principles. It has been observed that AR does not only provide a single advantage, but it has multiple positive effects in the articles studied by creating common standards. According to this, AR applications used in the articles examined were mostly used in order to increase academic success / improve learning performance ($n = 16$). Apart from this, it was determined that AR applications were used for increasing learning motivation ($n = 13$), diversifying perceptions ($n = 12$), increasing satisfaction in learning processes (n = 13), enriching learning environments in terms of learner-interface, learner-content and learner-tools (n = 12) (Table 5).

Table 5 Advantages of using AR in educational environments

Educational Advantages	f
Achievement/Performance	16
Motivation	13
Perception	12
Satisfaction	12
Interaction	12
Retention	9
Cooperation/Collaboration	8
Attitude	8
Evaluation	7
Usability	6
Attention	6
Behavior change	5
Engagement	5
Communication	4
Enjoyment	4
Skill	3
Visualization	3
Improving user experience	2
Treatment	2

*Some articles involve multiple advantages

2.11 Types of AR applications

In this study examining 58 articles, it can be seen that AR applications may not have only one model and more than one model can be used at the same time. According to the findings obtained, a large part of the studies carried out were realized as three dimensional (3D) image-based ($n = 28$) (Fig. 3). Then, it was found that location-based ($n = 17$) and video-based ($n = 16$) AR applications are widespread. It is observed that applications such as AR based remote laboratory (n = 1), speech recognition (n = 1), hologram (n = 1) and authoring tools (n = 1) are not studied intensively yet. In the case of four studies, the type could not be determined because there was no application.

2.12 Technologies used in AR applications

In this research, when examining the articles, many articles do not use only one technology for AR applications but multiple technologies can be used together. According to the findings, there are tablets ($n = 19$) and smart phones ($n = 16$) in the first two rows of technological devices used to view AR applications (Fig. 4). This situation shows how effective mobile AR is. However, it can be seen that applications ($n = 14$) are still being viewed on webcams integrated to desktop computer. Laptop & web camera ($n = 6$), projection ($n = 5$) and PDA & pocket PC ($n = 4$) are also used as the viewer technological device. When the studies using PDA and pocket PC are
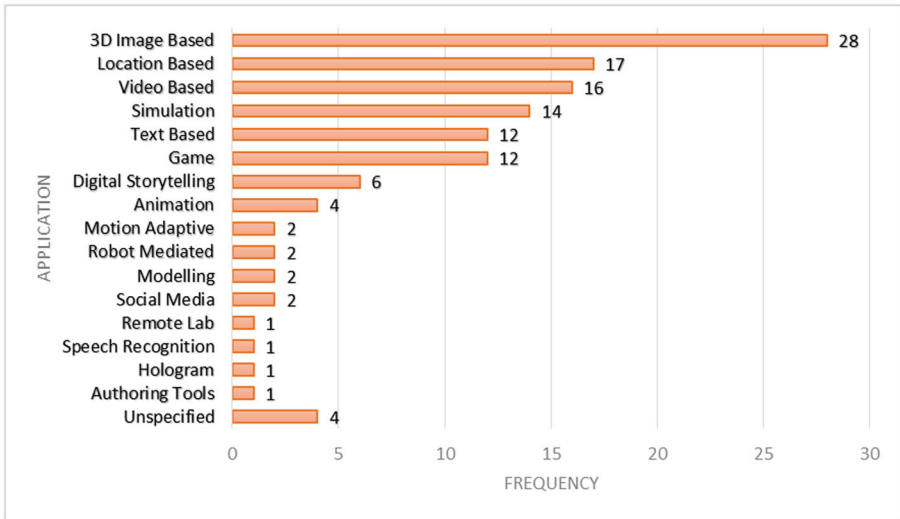
Fig. 3 Types of AR applications

examined, it is found that they were conducted before 2010. This can be attributed to the fact that these technologies are outdated and lose their popularity and leave their place to advanced mobile devices such as smartphones and tablets. In addition, it was concluded that there are not enough studies using wearable technologies addressing to tactile sense such as gloves ($n = 1$) and bracelets, older technologies such as mobile phones (n = 1), Kinect (n = 1) motion based AR applications, new wearable technologies addressing the visual sense such as smart glasses (n = 1) and holographic displays (n = 1) have not been sufficiently studied.
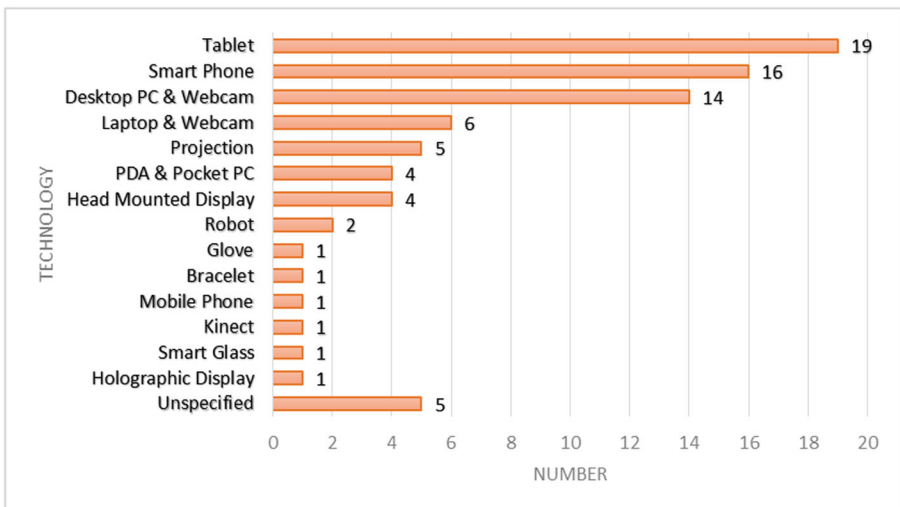

Fig. 4 Technologies used in AR applications

2.13 Assets used in AR applications

When the articles are examined, it can be seen that not a single asset is used but multiple assets can be used together when the applications are carried out. According to the findings, it is seen that researchers or AR developers enriched the AR applications using the special static images mostly ($n = 23$) (Fig. 5). Later, the marker-based AR applications ($n = 18$) and the GPS ($n = 14$) use of location based enhanced reality applications are listed. Apart from these, printed materials such as AR-based maps ($n = 10$), AR books and booklets ($n = 6$), cards ($n = 5$), QR code (n = 5), smart blackboard (n = 2), puzzle (n = 1), cube (n = 1), wooden block (n = 1), paper (n = 1) are among other assets used. In the case of four studies, no asset or object is used.

2.14 Physical environments in which AR researches are carried out

When the articles were examined, the physical environment in which the AR researches were performed most intensely was noted as classroom ($n = 19$) (Table 6). The classroom environment is followed by laboratories ($n = 6$). According to the findings, it can be seen that AR applications are applied in various physical environments from the hospital to the botanical garden, from museums to the libraries (Table 6).

2.15 The sensory types to which AR research address to

Some findings have been reached in the research about which senses AR applications appeal to more. It is seen that most of the applications were prepared for " sight sense
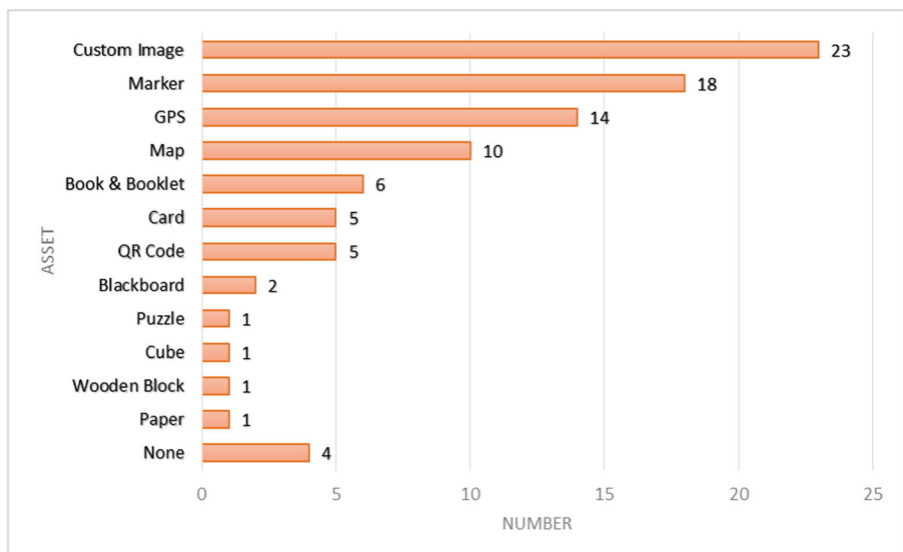

Fig. 5 Assets used in AR applications

Table 6 Physical environments in which AR researches are carried out

Physical Environment	f	Percent (%)
Classroom	19	32,75
Laboratory	6	10,34
Outdoor	4	6,89
Activity Room	4	6,89
Hospital	3	5,17
Home	2	3,44
Campus	2	3,44
Botanical Garden	2	3,44
Museum	2	3,44
Art Gallery	2	3,44
Library	2	3,44
Heritage Site	2	3,44
Lake & Pond	2	3,44
Workplace	1	1,72
Science Festival	1	1,72
Ecological Area	1	1,72
Unspecified	3	5,17
Total	58	100

only" ($n = 25$) and it is followed by applications for both visual and aural ($n = 24$) (Fig. 6). It is seen that haptic applications for tactile sense are still inadequate. No work has been found enriching the sense of taste and smell.
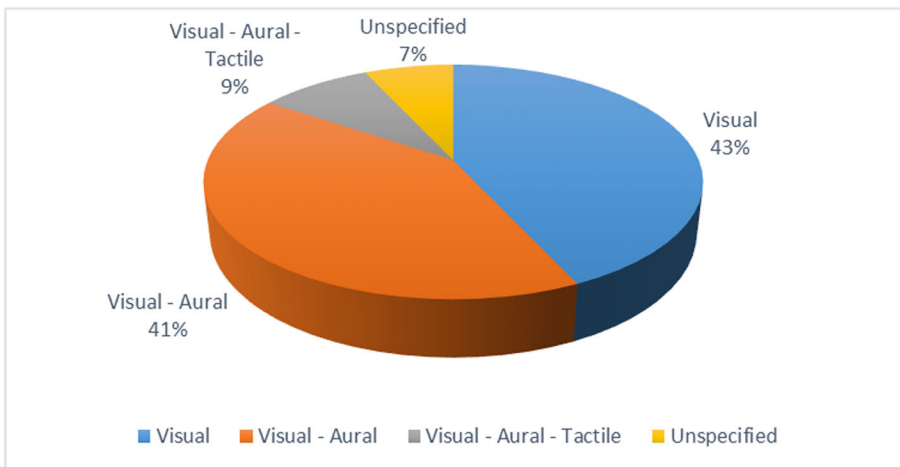

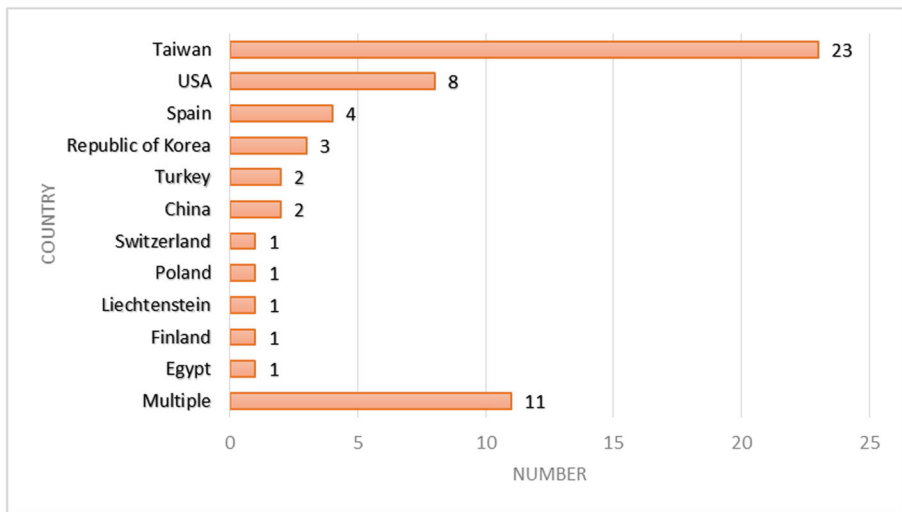**Fig. 6** The sensory types to which AR research address to

Fig. 7 Countries in which AR research were carried out

2.16 Countries in which AR research were carried out

According to the findings obtained, the AR is mostly investigated and applied in Taiwan ($n = 23$) (Fig. 7). The United States ($n = 8$) is in second place when the findings that Taiwan is clearly the first place are examined. It is followed by Spain ($n = 4$), South Korea ($n = 3$), Turkey ($n = 2$) and China (n = 2). Switzerland, Poland, Liechtenstein, Finland and Egypt ($n = 1$) are the other countries that have conducted studies on AR studies. In Fig. 7 the authors are categorized in the "multiple" category if they write a single article from different countries. There are 11 articles in total prepared by coming together from different countries.
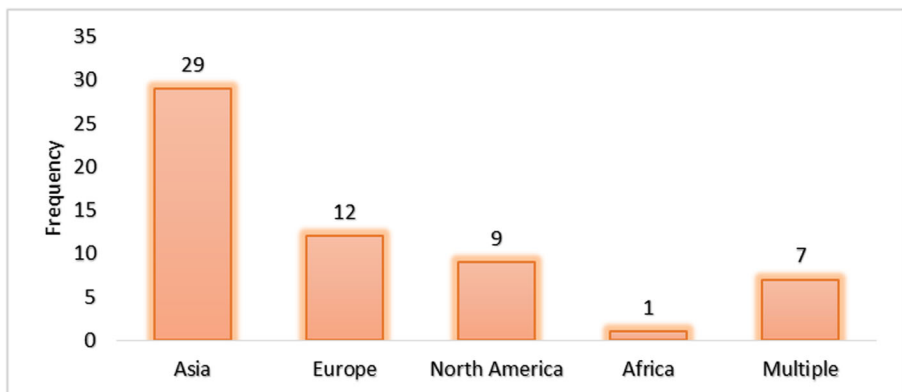

Fig. 8 Continents in which AR research were carried out

2.17 Continents in which AR research were carried out

In this study, it is seen that most of the articles examined were prepared by the authors of countries in Asia ($n = 29$) (Fig. 8). It is followed by studies carried out in Europe ($n = 12$), North America ($n = 9$) and Africa (n = 1). While authors in different countries of the same continent are classified in the same continent, authors of an article are included in the "multiple" ($n = 7$) category if its authors are from countries in different continents.

2.18 Keywords analysis in AR articles

When all the keywords in the AR articles are analyzed, the "AR" keyword is found in 39 articles (Fig. 9). This is followed by "interactive learning environments" (n = 12). Although "virtual reality" is a concept that is close to and related to AR, the "virtual reality" covering applications in purely virtual environments has been identified as a keyword in 8 articles.

3 Discussion, conclusion and implications

This study examines, with the content analysis technique, 58 articles containing "augmented reality" in their title and published in educational technology journals under the SSCI between 2006 and 2016 and, thereby, determines the trends of using AR in education. The findings are presented in 12 sub headings on the basis of the purpose of the study and the research questions.

When the findings are examined, the highest number of articles AR articles were published in Computers & Education journal, which has the highest impact factor among the selected 8 SSCI-included journals. This journal, publishing 17 articles, is followed by Computers in Human Behavior journal with 12 articles. It is striking that these journals which have the highest impact factor are the ones publishing the highest number of articles on AR. The fact that the study by Bacca et al. (2014) showed Computers &
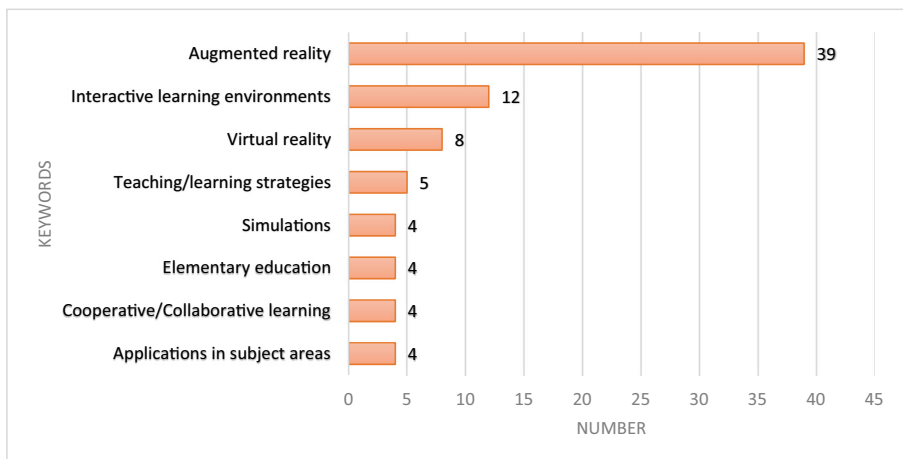
Fig. 9 Keywords analysis in AR articles

Education journal to publish the highest number of articles on AR between 2003 and 2013 proves that this journal frequently publishes works on the subject.

When the changes in the articles related to AR are analyzed according to the years, the number of articles which was 0–3 between 2006 and 2012 suddenly increased to 12 articles in 2013 and reached the highest point with 15 articles in 2016. This supports the prediction in the Horizon Report in 2011 (Johnson et al. 2011) that the AR will spread in 2–3 years and shows that the AR has gained rapid development acceleration and popularity in recent years and its application in education has also increased. The fact that "augmented and virtual reality" technologies are included in the 2016 Horizon Report (Johnson et al. 2016) proves this. The fact that systematic review research by Dey et al. (2016) in 2013 shows a significant increase in the number of publications on AR is can be said to support this finding. With the growth of computers, the emergence of communication technologies such as the internet, the spread of mobile devices and the diversification of wearable technologies, it can be seen that the AR has been shaped in different dimensions over the years (Altınpulluk and Kesim 2015). The AR, which is directly influenced by information technologies, can be said to have become the subject of scientific research in education more frequently, especially after the year 2010.

When the scientific research methods used in the AR researches are examined, it is observed that the mixed research method is mostly used and it is followed by the quantitative research method. Apart from these two research methods, design-based, review, qualitative and theoretical researches seem to be rarely used in AR research. In the analysis performed by Bacca et al. (2014) between 2003 and 2013, the mixed method seems to have the highest rate of 46.88% of the total work. It also shows the two studies confirm each other. It can be argued that the reason for such intensive use of the mixed method for AR studies is that it allows conducting studies with higher impact factors with more data collection tools using the power of both qualitative and quantitative research methods.

When data collection tools used in the articles related to the AR are examined, it is seen that data collection tools such as questionnaire, tests, and scale are used mostly. Qualitative data collection tools used most was the interview method. The fact that survey is the most commonly used data collection tool with 75% in the study by Bacca et al. (2014) also confirms the findings of this study. In the survey conducted by Korucu et al. (2016) for Turkey, it is noteworthy that the documents were used heavily and the questionnaires were used in the second place. This can be interpreted as the studies conducted in Turkey and the international studies differentiated.

When it is examined in which sub-branch of education is the AR is more intensively, it is seen that AR is most commonly used in science. It can be said to be used quite intensively especially in the field of Biology. When AR is considered to be an effective teaching tool to simulate both micro and macro systems, (Núñez et al. 2008), it can be thought that such finding is proved. In addition, according to the Next Generation Science Standard (NGSS) (NGSS Lead States 2013), AR-supported virtual science laboratories encourage more specific scientific experiments at the micro or macro level that cannot be done in real environments (Chiu et al. 2015). This suggests that further study in the field of Biology will continue to be carried out in the future as well. Researches in the field of biology have been concentrated on sub-branches such as ecology, introduction of plants, teaching of ecosystems, and the results of the studies have been achieved in the contexts of botanical gardens, laboratories of science, lakes & ponds and science festivals. In the field of physics, the intensive use of AR in the

teaching of atoms and nuclear physics draws attention specifically. Mathematics & Geometry, Engineering Education, Astronomy and Space Science, Foreign Language Teaching are also considered to be suitable fields for the use of the AR technology.

In the analysis of the educational benefits of AR applications, it was determined that these practices had the most positive effects on academic achievement. Parallel to the increase in learning performance, the academic achievement of students increased. In the study carried out by Bacca et al. (2014), more than half of the articles reviewed within the context of AR's effectiveness in educational environments being included in the "better learning performance" subcategory supports this finding. In addition, Yilmaz (2018), who examined the trends of AR in education between 2016 and 2017, also reached the conclusion that AR affects academic achievement the most in the articles she examined. Apart from that, the motivation for learning after academic achievement is understood to be the most effective educational advantage of the AR both in this study and in the analysis of Bacca et al. (2014). The fact that similar results were obtained In Yilmaz's (2018) analysis confirms the findings.

Various classifications have been made regarding the types of AR applications. For example, Martín-Gutiérrez et al. (2010) restrict the AR applications to four parts as monitor based, vision based, video based and projection based spatial system while Cheng and Tsai (2013) divide the AR into two as "image based AR" and "Location based AR ". Johnson et al. (2010) divide the types of AR into two as marker-based and markerless applications. In the meta-analysis study on AR by Radu (2014), the AR applications are divided into smartphone-based, webcam-based, Kinect and Wii-supported motion-based and head mounted display-based applications. In this research, a broader categorization of the type of application was made by approaching with a wider perspective. In the result of the findings obtained, we have come to the conclusion that the AR applications are mostly performed with 3D image basis. Location based, marker-based, video-based, simulation, text-based and game-based AR applications are the other most widely used applications. As some of the studies that have been analyzed bear characteristics different from the classifications in the literature, such an expansion was made in classification. The second most common type of applications used in this research, marker-based applications, draw attention as the most commonly used type of application in the research of Saltan and Arslan (2017). The results obtained in these two studies differ in this direction.

When findings related to which technological devices are most used in the implementation of AR technologies is examined, it is seen that mobile technologies such as tablets and smartphones are in the first two places. Mobile AR systems allow the user to take and use the AR wherever the user desires by removing the limitations of the user being in a specific location to use the AR (Höllerer and Feiner 2004). In this context, the fact that tablet and smartphones, which are the most used technological devices in recent times with mobile AR, have the first two places can be interpreted as the mobile AR will grow stronger. It can be argued that mobile phones, PDAs and pocket PCs, which are former representatives of mobile AR, were used in earlier periods before the popularity of smartphones and tablets. The fact that studies which show PDA and pocket PCs are used in AR are from the years 2007–2008 and 2009 proves this conclusion. One of the striking results under this title is that visual wearable devices such as smart glasses, holographic viewers; haptic technologies such as gloves,

bracelets; and AR systems integrated with motion-based systems such as Kinect have recently begun to be used in scientific studies but their number is still quite limited.

When we look at the assets and objects used in AR applications, it is remarkable that static special images are used in the articles mostly. The application of these special images through enrichment and interaction with special viewers is used most intensely. Then comes the applications developed through special patterns called markers. GPS and maps also represent location-based AR applications and are included in the articles. Augmented books and booklets through AR is also a frequently used approach. AR books, which aim to add value to printed books by supporting the lack of interactivity in printed books through virtual and three-dimensional items, are also frequently used physical objects. Cards, QR codes, smart boards, puzzles, papers, cubes, blocks, papers, and other objects are also used.

Given the results of physical environments in which AR researches are conducted, the most common place for applications is classrooms. After the classroom environment where the most applications are made, it is seen that these applications are also performed in the laboratories. Apart from these, applications were made in the outdoors, in the activity rooms and in the hospitals. It can be said that there is no research that examines the physical environments in which the researches of the AR are carried out and it is important that these deficiencies are eliminated.

Another result not addressed in any research is related to the types of sensations addressed by the AR surveys. Azuma et al. (2001) stated that it would be wrong to limit the AR only to the sense of sight and emphasizes that AR can be applied to other sensory types, such as tasting, smelling, touching and especially hearing. To sum up, unlike what is known, AR does not address the sense of sight only. In this context, when we look at publications on AR technology addressing five senses, it seems that the applications made are mostly for "visual only" stimuli. AR applications for both visual and auditory stimuli are also intense. Especially, it can be said that the wearable technologies-based AR applications, which have become widespread with the integration of wearable technologies such as gloves, textiles, bracelets, tend to spread even though they are still few. However, there have been no studies of AR addressing tasting and smelling sensations.

When we look at the countries of the authors of the AR researches, it is clear that Taiwan is at the top of the list. Such inclination of Taiwan to investigate AR applications can be interpreted as it is a very popular technology in the Far East. Taiwan has reached 159 universities in the last 10 years by increasing the number of universities by 120% with the progress it has made in higher education in recent years. 1/3 of these were established as national and 2/3 as private universities. Of 1.3 million university students, 33,751 are Ph.D. students, 183,401 are graduate students and 1 million are undergraduate students. In Taiwan, where the ratio of participation in higher education is 78.6%, the ratio of Ph.D. holder faculties is over 80%. According to 2015 data, in Taiwan, R & D expenditure was 16.5 billion USD, while the annual expenditure of higher education was 2.1% (Hou 2017). With the breakthrough in education and technology in recent years, Taiwan has begun to become a leading country in the field of AR, an educational technology product. The interest of Taiwanese scholars and researchers in this field is remarkable. As of 2015, there are 4583 higher education institutions in the USA which has the second place (Statista 2017). It is possible to associate the active status in this field with the number of higher education institutions in the country.

As seen in Table 7, with the World Bank Education Statistics (EdStats), current statistics of countries in the field of education can be displayed with various variables.

Table 7 Countries and education statistics (The World Bank 2018)

Country	Net Enrolment rate, upper secondary education (%) (2016)	Barro Lee: Percentage of population age 25+ with no education (%) (2010)	Population, ages (15–24), total (2015)	Enrolment in tertiary education (2015)	Adult Literacy Rate, 15 + Years (%) (2016)	PISA Test Scores (2015–2016)		
						Math	Reading	Science
Taiwan	–	–	–	–	–	–	–	–
USA	80.5	0.4	45.147.517	19.531.727	88,3	470	497	496
Spain	82.1	2.5	4.285.743	1.963.924	98	486	496	483
South Korea	94.8	4.1	6.456.561	3.268.099	97,1	524	517	516
Turkey	78.8	26.8	13.930.222	6.062.886	95,4	420	428	425
China	–	6.6	197.026.759	43.886.104	95.1	531	494	518
Switzerland	73.2	1.4	959.002	295.149	96,8	521	492	506
Poland	86.4	0.3	4.404.280	1.600.208	99	504	506	501
Liechtenstein	79.7	–	–	774	93,9	535	525	516
Finland	91.7	0.0	639.391	297.163	96,6	511	526	531
Egypt	66.8	37.4	15.377.746	2.789.278	75.1	–	–	–

Within the scope of this research also, a correlation can be established between the current status of education in the countries and the academic activities in the field of AR with the variables of net enrollment rate in upper secondary education, percentage of population age 25+ with no education, 15–24 ages population, enrolment in tertiary education, adult literacy rate and PISA test scores. Looking at the countries in the field, it is possible to see that it is composed of countries that have a good level of education in general.

When we look at the continent, we come to the conclusion that the AR studies are more widespread in Asia. Developments in the field of education on the Asian continent can be thought to be closely related to the number of universities. According to 2012 data, there are 1887 public and 836 private universities in China, while 61 public and 350 private universities in South Korea. It can be seen that Asian countries such as China, Hong Kong, India, Japan, South Korea, Malaysia and Taiwan have started to rank higher in the world rankings In research-based university performances as well (UNESCO 2014). These numbers reveal the difference in the field of education between Africa and the Asian continent and shed light on the results of this study. The fact that there are only 740 universities serving 1.2 billion people in the continent of Africa (Dahir 2017) shows Africa's place in education compared to the US with more than 4500 universities alone. Globally, 8 out of 10 countries with the lowest pre-school net enrollment rates are in Sub-Saharan Africa. The situation in higher education is not much different. Today, only 6% of young people in sub-Saharan Africa are enrolled in higher education institutions compared to the global average of 26%. In 2008, about 223,000 students from sub-Saharan Africa were enrolled in tertiary education outside of their home countries, representing 7.5% of the total global number of students who study outside of their home country. University enrollment rates in Sub-Saharan Africa are among the lowest in the world. While

governments are investing in their universities, efforts must focus on expanding access and improving the quality of education to meet the needs of today's workforce. The promising news is that universities in many African countries are experiencing a surge in their enrollment. Between 2000 and 2010, higher education enrollment more than doubled, increasing from 2.3 million to 5.2 million (AAI 2015). All of these results are important in terms of giving researchers an idea of the academic publication gap between continents.

When we examine the analysis of key words, naturally "AR" is in the first place apparently. It is followed by the "interactive learning environments". Increased inter-activity, which is the most important strength of AR, explains why this key word is in second place. The third most frequently encountered key word is the "virtual reality". While entirely computer-generated item replaces the real world and the user is surrounded by a virtual environment in virtual reality environments, AR is realized by blending the real and virtual in a real-world environment (Billinghurst et al. 2001). It is quite normal that these two terms, which are closely related but have different meanings, appear as keywords in the AR articles.

In this study, all articles with "augmented reality" in their titles published in educational technology journals within the scope of SSCI between 2006 and 2016 were subjected to content analysis and various conclusions were reached. In the result of this research, the changes in the AR trends from past to present, the current situation and its place in scientific publications have been determined. Based on the findings of this research, some suggestions can be made for use in different studies. This research focuses more on technological components rather than focusing on methods used in the articles. Methodological variables such as "research model", "sample size", "target group" can be examined in different studies. This study for the field of education can be realized based on the journals published in different disciplines such as engineering and medicine. By interpreting the data obtained from this study, Delphi studies aiming to make future predictions for the use of the AR in education can be realized. In addition, the lack of studies on sensations such as smell and taste in this research may be suggested to other researchers and developers in order to concentrate on researches, studies, and practices in this area. As there are not many studies related to fields of AR related to digital narration, animation, motion based, robot mediated, modelling based, social media based, virtual remote laboratory based, speech recognition based, authoring tools based and hologram based types, these fields can be suggested as research topics to be studied in this field. In addition, the fact that there are not many studies using the qualitative research method in the AR publications can be considered as a demonstration that the works carried out by this method are required.

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