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Augmented Reality Trends in Education between 2016 and 2017 Years

Rabia M. Yilmaz

Abstract

The aim of this chapter is to review literature regarding using augmented reality (AR) in education articles published in between 2016 and 2017 years. The literature source was Web of Science and SSCI, SCI-EXPANDED, A&HCI, CPCI-S, CPCI-SSH, and ESCI indexes. Fifty-two articles were reviewed; however, 14 of them were not been included in the study. As a result, 38 articles were examined. Level of education, field of education, and material types of AR used in education and reported educational advantages of AR have been investigated. All articles are categorized according to target groups, which are early childhood education, primary education, secondary education, high school education, graduate education, and others. AR technology has been mostly carried out in primary and graduate education. "Science education" is the most explored field of education. Mobile applications and marker-based materials on paper have been mostly preferred. The major advantages indicated in the articles are "Learning/Academic Achievement," "Motivation," and "Attitude".

Keywords: augmented reality, education, review, web of science, educational target group

1. Introduction

Augmented reality (AR) is a new technology that acts as a bridge between real world and virtual environment by providing synchronous interaction. Virtual objects can be added on real world through this technology. In other words, during recording of the real world with the camera, AR uses pre-determined target points in real world by connecting virtual objects and interpreting the results through certain programs [1]. AR can distinguish itself

from other technologies by combining virtual and real objects, by providing real-time inter-action, and by involving 3D objects [1, 2]. AR is an increasingly popular technology that can be used on different platforms such as desktop, laptop computers, portable devices, and smartphones [3]. Applications developed with AR technology allow use of 3D objects, texts, images, videos, and animations, and this technology provides the use of them together at the same time [4]. Therefore, users can naturally interact with events, information, and objects [5, 6].

With the development of software and hardware used in AR, this technology has begun to be used in many areas such as entertainment, marketing, military, medicine, engineering, psychology, and advertising [1, 3, 7]. Thanks to AR's advanced technology, related appli-cations have been transformed from a blank area into a rich learning experience [8]. This situation leads AR technology to be used in education area. It is known that technological tools used in education provide new opportunities to increase interaction of learners and to learn by enjoying, making the learning process more active, effective, meaningful, and motivating [9–11]. AR technology has also attracted attention in education field with its ability to allow interaction with virtual and real objects, to learn by doing, and to increase attention and motivation [12]. AR offers many advantages when used in education and pro-vides educational gains. While enabling rich interaction [13], AR provides a natural expe-rience, enhancing attention and motivation [14, 15]. In addition, it enhances interpreting, problem solving [16], and creative thinking skills [17] and provides flexibility for students [16]. Although AR technology provides significant contributions, there are still many prob-lems that need to be addressed. The first of these problems is the difficulty of developing and implementing content for AR applications. It is known that many teachers and learners are biased to use AR, especially because of technical knowledge requirement in 3D object development [18]. In addition, external factors such as light, output, and image quality negatively affect the applications. Students who use AR may have to use more than one device. It requires them to have spatial orientation, collaborative skills, problem-solving skills, and ability to intervene in this technology [19]. Besides the technical and pedagogical problems that AR brought with, the potential of having educational applications has led researchers to this field.

When literature is examined, it is observed that many studies have been carried out for the use of AR applications in education. Yilmaz [20] categorized advantages of AR, gains achieved, and learning approaches it supports and they are presented in **Table 1** in detail.

The aim of this chapter is to review literature regarding using AR in education. The litera-ture source for this review was Web of Science and SSCI, SCI-EXPANDED, A&HCI, CPCI-S, CPCI-SSH, and ESCI indexes. The time span was limited from 2016 to 2017 and the docu-ment type was determined as "journal articles" in order to review studies regarding using AR in education of more consistent quality. The keyword was "Augmented reality" in title section and results were refined by "Education Educational Research" categories, one of the Web of Science categories. For this chapter, 52 articles regarding using AR in education were reviewed (*Reached date: October, 2017*). However, 14 of them were excluded in the study since 7 of them were review articles, 4 of them were technical articles, and 3 articles were not reached. Finally, 38 articles were examined for this study.

Advantages of AR in education	Providing a sense of reality	[21]
	Presenting a natural experience	[11, 14]
	Visualize complex relationships	[19, 22]
	Offer experiences that cannot be done in real life	[6, 19]
	Concrete abstract concepts	[6]
	Having fun learning	[23]
	Presenting safe learning environment	[6, 24, 25]
	Saving time and space	[24, 25]
	Increasing student participation	[6]
	Providing flexibility	[16]
Supported learning approaches	Authentic learning environments	[18]
	Situational learning environments	[6, 26]
	Constructivist learning environments	[3]
	Learning by doing environments	[6]
	Inquiry-based learning environments	[6, 27]
	Research-based learning environments	[18]
Gains of using augmented reality in education	Increasing attention	[11, 14, 25]
	Making learning attractive and effective	[6, 28–31]
	Providing motivation	[11, 14, 25, 32]
	Providing interaction	[6, 13, 17, 19, 33–35]
	Facilitating understanding	[17, 36, 37]
	Connecting with real world experiences and problems	[38]
	Creating contextual awareness	[17]
	Increasing engagement	[17, 34]
	Ensuring permanent learning	[17]
	Improving communication	[17]
	Increasing collaboration	[18, 39]
	Triggering creativity	[18, 31, 40]
	Developed imagination	[18, 40]
	Controlling self-learning	[18, 34]
	Increasing spatial ability	[6, 27, 34]
	Enhancing problem-solving skills	[16]
	Improving interpretation skills	[16]

Table 1. Advantages of AR, gains achieved, and learning approaches it supports.

In total, 38 articles were analyzed from many different journals, including EURASIA Journal of Mathematics Science and Technology Education (5), Interactive Learning Environments (5), Computers & Education (4), British Journal Of Educational Technology (4), Journal of Computer Assisted Learning (2), Education and Science (2), Education Tech Research Dev (2), Asia-Pacific Edu Res, IEEE Transactions on Learning Technologies, Australasian Journal of Educational Technology, BMC Medical Education, Croatian Journal of Education, Digital Education Review, Early Child Development and Care, Innovations in Education and Teaching International, International Journal of Science Education Part B Communication and Public Engagement, International Journal of Serious Games, International Journal of Emerging Technologies in Learning, Journal of Geography in Higher Education, Revista Iberoamericana de Educación a Distancia, and Journal of Research on Technology in Education.

Firstly, level of education used in these reviewed studies has been investigated. Results show that AR technology has been mostly carried out in *primary* and *graduate education*. On the other hand, early childhood education and secondary school education need further research regarding using AR in education. All results are summarized in **Figure 1**.

When analyzed using AR by field of education, "*science education* (f = 16)" is the most explored field of education. Reviewed studies have generally focused on "mathematic education," "storytelling," "foreign language education," "culture education," and "health education." **Figure 2** shows all results regarding using AR by field of education.

Material types of AR used in education have been examined in reviewed articles. Mobile applications (f = 16) and marker-based materials on paper (f = 12) have been mostly preferred in them. Besides, some of the studies have used AR picture books and AR game systems. Related results are stated in **Figure 3**.

"Reported Educational Advantages of AR" has been explored as another category in this review. **Table 2** shows the results regarding them in the articles analyzed. As one study can
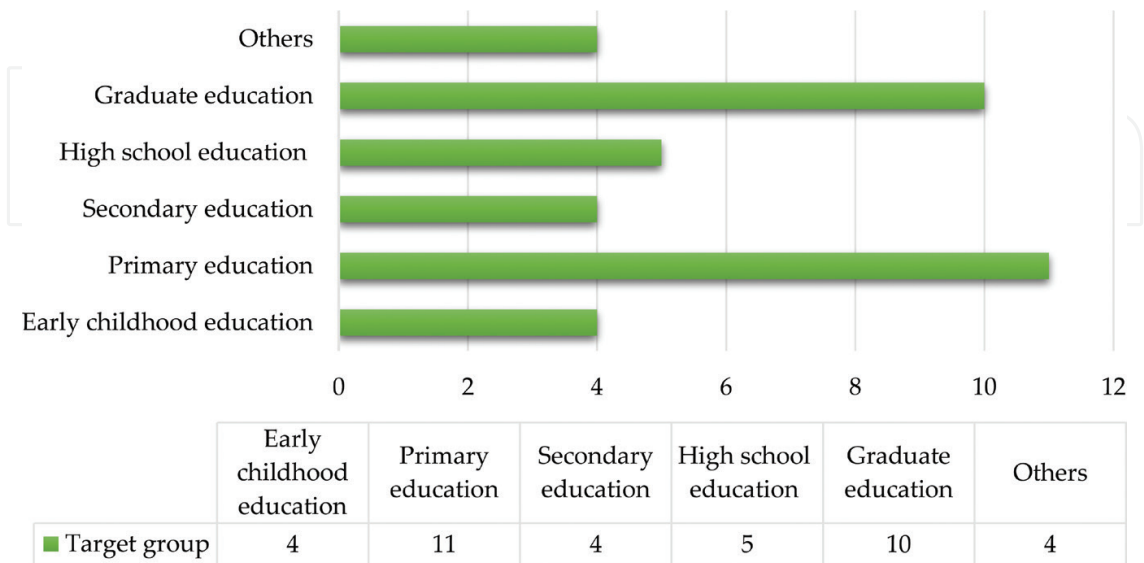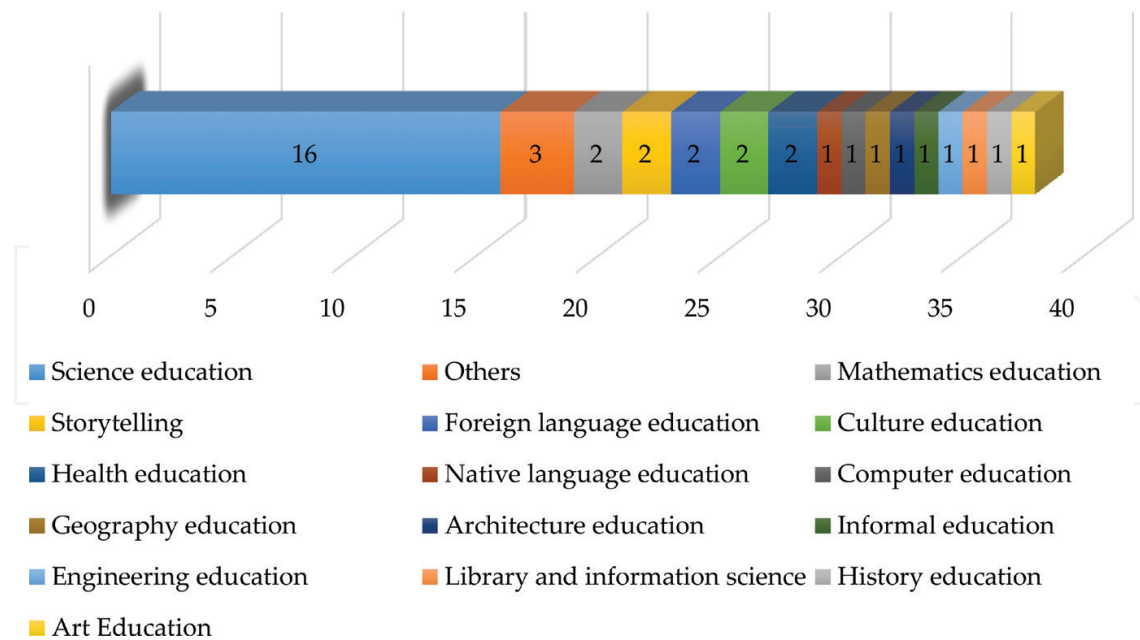

	Early childhood education	Primary education	Secondary education	High school education	Graduate education	Others
■ Target group	4	11	4	5	10	4

Figure 1. Target group of reviewed articles.

Figure 2. Using AR by field of education in reviewed articles.

indicate more than one advantage, total frequency of them is high. The results show that major advantages indicated in the articles are: "Learning/Academic Achievement" (f = 23), "Motivation" (f = 9), and "Attitude" (f = 6). Also, many variables, such as academic procrastination; writing skills; cognitive aspect; the number of errors they made; ability to remember the content; page design; teachers' acceptance and views; potential uses of augmented reality in education; social, emotional, and cognitive improvement; story comprehension performance; time spent; acquired learnings; metacognitive perception; experiential activity; and prospects of the use of AR for study, have been focused in reviewed articles by researchers.
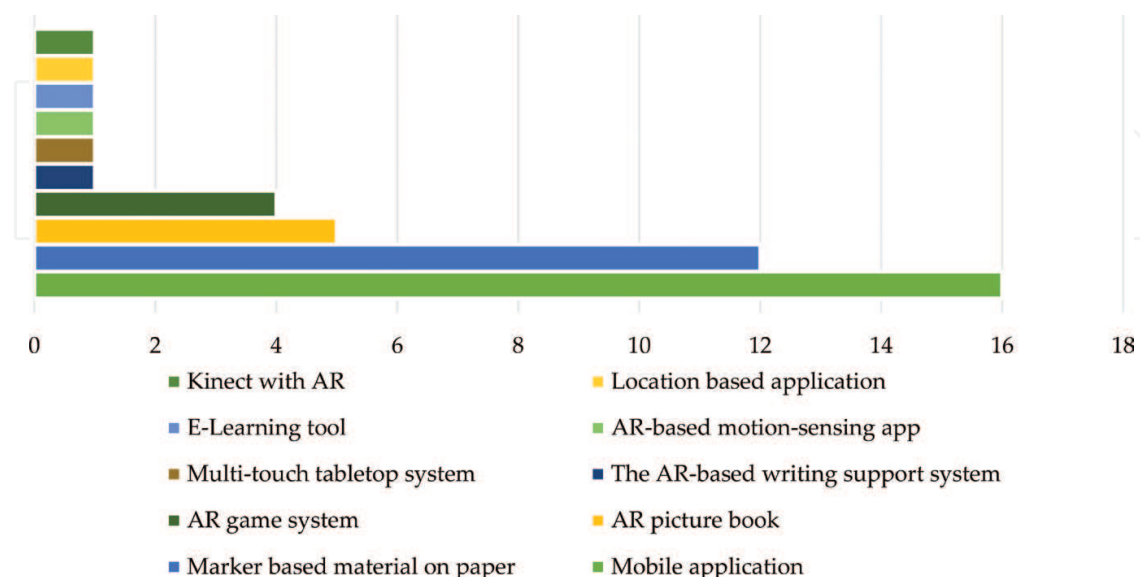
Figure 3. Material types of AR used in education.

Advantages	Number of studies	Percentage (%)
Learning/academic achievement	23	34.33
Motivation	9	13.43
Attitude	6	8.96
Satisfaction	4	5.97
Usability	4	5.97
Interaction	3	4.48
Spatial ability	3	4.48
Emotions	2	2.99
Cognitive load	2	2.99
Learning anxiety	2	2.99
Perception	2	2.99
Retention	2	2.99
Behaviors	2	2.99
Enjoyment	1	1.49
Flow experience	1	1.49
Communication	1	1.49

Table 2. Reported educational advantages of AR.

In this chapter, reviewed articles are categorized according to target groups, which are early childhood education, primary education, secondary education, high school education, graduate education, and others. Related studies with each title are stated below in detail.

1.1. Using augmented reality in early childhood education

When analyzed the articles related to using AR in early childhood education, four studies were found. Firstly, Yilmaz et al. [41] examined preschool children's attitudes, enjoyment, and story comprehension performance. They used AR picture books for storytelling activities. This study showed that most of the children felt "very happy" during this activity, found them interesting, and enjoyed them. Their story comprehension performance was good. Besides, AR picture books were attractive for children and they perceived them as magical and enjoyable. Secondly, Safar et al. [42] investigated effectiveness of using AR for teaching English alphabet lesson with flash cards to kindergarten children. A mobile application was developed for using flash cards. The results revealed that there were significant differences between control (traditional activities) and experimental group (AR activities) in terms of interaction and academic achievement in favor of experimental group. In addition, there has been a strong positive correlation between their interaction and academic achievement in experimental AR group.

Thirdly, Huang et al. [43] explored the effectiveness of coloring activities with AR technology in early art education. ColAR mobile application was used for coloring activities. This study showed that children could control, interact, and design with AR application, and this technology was seen as pedagogical innovation. All children enjoyed playing with them and loved it so much. In addition, teachers believed that AR promoted children's development. Lastly, Cheng et al. [44] focused on how the children and their parents behaved when using AR picture books. They consisted of four groups such as "parent as dominator," "children as dominator," "communicative child-parent pair," and "low communicative child-parent pair." In parent as dominator group, parents tent to narrate story to children. In children as dominator group, children had a tendency to operate AR book and engage them. Communicative child-parent group's parents guided their children to find virtual information in the book. In low communicative child-parent pair, parents did not continually interact with AR books.

1.2. Using augmented reality in primary education

When analyzed the articles related to using AR in primary education, 11 studies were found. Joo-Nagata et al. [45] aimed to design a navigation mobile application in Geography field and evaluate effectiveness of the software. Their results revealed that experimental group using the mobile application had better learning score than control group. Besides, AR technology enhanced the effectiveness of learning process, contributed to student-content interaction, and increased students' performance. Gun et al. [46] examined the effect of AR technology on elementary students' spatial ability and academic achievement and views of students and their teachers. They studied on mathematics education and used marker-based material on paper. This study showed that there was a significant increase on spatial ability of experimental and control groups. However, there was no significant difference between mean scores of spatial ability and academic achievement in both groups. Academic achievement scores had an increase in experimental group. Hung et al. [47] focused on determining advantages of AR in biology teaching. In addition, they examined which material enabled students' learning the most. They compared AR graphic book, a picture book, or physical interactions with each other. Their results showed that AR graphic book provided a practical way to examine the lesson. In addition, students enjoyed the book and preferred it.

Nadolny [48] studied on over 13,000 data points in two different interactive print activities in order to reveal trends and patterns in user engagement. Marker-based material on paper was used in mathematics and informal learning field. This study revealed that user interaction was impressed by instructional design, pedagogical strategies, and digital interactions. Besides, page design, feedback, and cognitive tasks were important elements to engage users. Hsu [49] developed two different AR educational game systems (self-directed and task-based) for teaching English vocabulary. He evaluated students' flow experience, English learning anxiety, cognitive load, and learning effectiveness. Students using both game had similar learning performance; however, self-directed system provided higher flow experience for them. In addition, he stated that a little learning anxiety and mental effort were helpful and important factors for learning process.

Cascales-Martínez et al. [50] used a multi-touch tabletop system for mathematics learning with special needs. They focused on feasibility of it and found that this tabletop was feasible, attractive, and motivating. In addition, it contributed to improve the knowledge acquired and motivation of students. Hwang et al. [51] used an AR mobile game application for biology learning to improve students' academic achievement and attitude. The results showed that students' academic achievement and attitude enhanced with AR game. Chen et al. [52] investigated students' motivation, attitude, and learning outcomes when using concept map with AR picture book. Students using concept mapped AR technology were better than other students using only AR technology. Besides, they stated that using concept map provided them to organize their learning process.

Laine et al. [53] aimed to develop an AR game system called as Leometry in science field. They produced a prototype and evaluated its effectiveness. The results revealed that it was feasible and had a valuable potential for science learning. In addition, they stated that using AR technology in game was important motivator for students. Solak et al. [54] examined current applications in literature about AR in education and tested effectiveness of AR application for English teaching. They used marker-based material on paper and their results revealed that students using AR application had better learning scores than those in control group. They stated that using AR technology in English teaching was affective way for improving learning performance. Chang et al. [55] tested the effectiveness of ARFlora system, which is marker-based material on paper about biology filed. They compared this system with digital video in terms of students' learning. Results revealed that both materials had same effect on students' learning. However, AR system was more effective and useful in terms of retaining knowledge and motivating students.

1.3. Using augmented reality in secondary education

When analyzed the articles related to using AR in secondary education, four studies were found. Cai et al. [56] examined the effectiveness of AR-based natural interaction in terms of learning performance, attitudes, and deep understanding. They compared it with traditional learning tools for physics learning. They used AR-based motion-sensing software and results showed that it could increase their learning and attitude. Salmi et al. [57] investigated motivational and cognitive aspects of informal learning while using AR technology in learning process and made a SEM path analysis. They focused on science education and found that AR was effective especially in lowest achieving group and for girls. They stated that AR was a promising method for teaching abstract phenomena.

Huang et al. [58] used AR-based learning system for biology field. They consisted of three groups: (1) self-directed AR group, (2) AR system with commenter guidance, and (3) traditional group. They compared them in terms of learning outcomes, emotions, and experiential learning activity. The results showed that AR system with commenter guidance had better learning performance than the traditional group. In addition, self-directed AR group has more positive emotion than the others do. Hsiao et al. [59] compared to AR technology with multimedia tools in inquiry-based learning environment for science education. They developed a manipulative AR system and used it in experimental group and control group used multimedia tools for learning activities. This study revealed that integrating AR technology in learning activities had positive effect on students' academic achievement and motivation in experimental group.

1.4. Using augmented reality in high school education

When analyzed the articles related to using AR in high school education, five studies were found. Wang [60] investigated the effectiveness of AR-based writing support system for Chinese writing education. The results indicated that this system helped students to improve their writing performance. Besides, it provided students to start writing quickly their first paragraph and to enrich their ideas. Wang [61] compared effectiveness of AR-based material and YouTube videos in software editing course. AR-based content provided positive contribution to support blended learning. Besides, it helped to increase students' interest and made them more active in the case that designers take proper content design, information displayed on screen, and learning environment into consideration.

Mumtaz et al. [62] focused on students' learning and motivation. They used AR mobile application for science field in blended and traditional classroom learning. Students using AR application had better performance and this application affected their learning positively. In addition, students' motivation was high during learning process. Chang et al. [63] compared AR technology and interactive simulations in terms of students' learning and attitude. They used a mobile application for AR in science field. They found that there was no significant difference between them in learning and attitude. However, there was a significant difference in terms of perception in favor of AR technology. Ibáñez et al. [64] used AR-based simulation system for science learning. They consisted experimental and control group randomly. While experimental group had an extra support, control group had no support for activities. They examined students' behavioral patterns and learning performance in both groups. The results showed that experimental group outperformed in learning performance compared with control group. Students in control group were more willing to search information.

1.5. Using augmented reality in graduate education

When analyzed the articles related to using AR in graduate education, 10 studies were found. Redondo Domínguez et al. [65] examined architecture students' experiences. They formed experimental and control groups. Students in experimental group used AR technology with a mobile application. Their results showed that using AR technology in course provided students to increase their academic performance, motivation, and satisfaction. Montoya et al. [66] developed an AR mobile application and they compared effect of static and dynamic content on students' science learning. Their results revealed that using dynamic content in AR applications helped students to enhance learning perception and performance. Bendicho et al. [67] focused on effect of AR technology on engineering students' academic procrastination. They used marker-based material on paper with mobile application. Results showed that using AR reduced students' academic procrastination.

Salinas et al. [68] developed an AR application in mathematics education. According to their results, students' anxiety towards mathematics could be reduced by understanding mathematical knowledge. In addition, using AR helped to develop students' spatial ability. Carbonell Carrera et al. [69] examined students' spatial orientation when using AR technology. They used marker-based material on paper in engineering field. Their results revealed that using AR enhanced students' spatial orientation skills. Cheng [70] focused on effects of

using AR books in culture education on students' cognitive load, motivation, and attitudes. He stated that they had low cognitive load, high motivation, and positive attitude when using AR book. Juan [71] used a mobile AR application for dental education. According to the results, AR application was affective tool to convey knowledge. Participants satisfied this application and perceived it as easy to use. In addition, they wanted to use it in future.

Ferrer-Torregrosa et al. [72] compared three tools, which were notes with images, videos, and AR (marker-based material on paper) in health education field. They focused on students' time spent, learnings, perception of metacognition, and the prospects of the use of AR. Their results showed that AR was the most effective tool among these tools in all aspects. Harley et al. [73] explored using AR in history education. They organized a historical tour with mobile AR location-based application and examined students' emotions and learning outcomes. They experienced it in and outside of the laboratory. The results revealed that they enjoyed from this experience. In addition, AR application was efficient in both environments. Martin-Gonzalez et al. [74] developed an AR system with Kinect technology for physics and mathematics education. They evaluated its usability and results showed that usability of it was acceptable. In addition, participants had positive attitude towards this system.

1.6. Using augmented reality in other target groups

When analyzed the articles related to using AR in other target groups, four studies were found. These target groups were primary school teacher, construction workers, special students with intellectual disabilities and autism, and adults. Alkhattabi [75] focused on primary school teachers' acceptance of AR technology. In addition, advantages and barriers of AR were investigated with e-learning tool. Results showed that teachers accepted this technology and would like to use in their lessons. Pejoska et al. [76] used a mobile application for construction workers and analyzed their experiences in informal learning. They suggested some design principles for AR app to support informal learning. McMahon et al. [77] studied on students with intellectual disabilities and autism. They used marker-based material on paper in science education field. The results revealed that these students succeeded in defining new science vocabulary terms with AR technology support. Boletsis et al. [78] tested usability of AR-based cubes gaming system for adults. This game was developed for cognitive field. According to the results, users satisfied to use this game system and gave positive responses.

2. Conclusion

The aim of this chapter is to review literature regarding the use of AR in education articles published in between 2016 and 2017 years. Fifty-two articles were reviewed; however, 14 of them were not included in the study. As a result, 38 articles were examined. The results showed that AR technology has been mostly carried out in primary and graduate education. "Science education" is the most explored field of education. Reviewed studies have generally focused on "mathematic education," "storytelling," "foreign language education,"

"culture education," and "health education." Mobile applications and marker-based materials on paper have been mostly preferred. Major advantages indicated in the articles are "Learning/Academic Achievement," "Motivation," and "Attitude." After all, it can be said that AR has been gaining importance and will be popular in educational fields by becoming widespread use of this technology in daily life.

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