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The Educational Potential of Augmented Reality Technology: Experiences of Instructional Designers and Practitioners*

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Abstract

In this study, the educational potential of the augmented reality (AR) technology was investigated in the context of the instructional designers and practitioners' experiences. Within this scope, intrinsic case study design was used in this study. 42 instructional designers and 10 practitioners participated in the research. The data were collected using open-ended questionnaire from instructional designers. Interviews were held with the practitioners through the semi-structured interview form created from the open-ended questionnaire. The qualitative data were analyzed with the content analysis method, using Nvivo 8.0 software. The participants suggested that AR would be more influential in the educational fields of science education, social studies, and health education. Among the most important instructional materials to be developed with AR technology are 3D materials, videos, and animations. The participants suggested that AR could be useful in the development of special applications for other fields of education. For example, AR could be used to create magic books, 3D demonstrations related to different subjects, and experimental simulations in the field of science education. Moreover, the participants suggested that AR could provide system design enhancements to better attract users' attention, to improve retention, to increase user motivation, and to "concretize" virtually presented information by creating a fuller sense of reality in terms of educational. Lastly, in order to develop an AR application, several points must be considered in the stages of analysis, design, development, and implementation. We present these points for consideration in detail. The results obtained in this study can be used to guide future research studies on AR technology.

Keywords: Media in education; augmented reality; educational potential.

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Arttırılmış Gerçekliğin Eğitsel Potansiyeli: Öğretim Tasarımcılarının ve Uygulayıcıların Deneyimleri*

Makale Türü	Başvuru Tarihi	Kabul Tarihi
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Öz

Bu çalışmada öğretim tasarımcılarının ve uygulayıcıların deneyimleri bağlamında arttırılmış gerçeklik teknolojisinin eğitsel potansiyeli incelenmiştir. Bu kapsamda içsel durum çalışması deseni tercih edilmiştir. Araştırmaya 42 öğretim tasarımcısı ve 10 uygulayıcı katılmıştır. Veriler öğretim tasarımcılarından açık uçlu anket soruları aracılığıyla toplanmıştır. Açık uçlu anket sorularından oluşturulan yarı yapılandırılmış görüşme formu aracılığıyla da uygulayıcılar ile görüşme gerçekleştirilmiştir. Toplanan nitel veriler Nvivo 8.0 yazılımı kullanılarak içerik analizi yöntemiyle analiz edilmiştir. Katılımcılar ile yapılan görüşme neticesinde AG'nin fen eğitimi, sosyal bilgiler ve sağlık eğitimi alanında daha etkili olacağı önerilmiştir. AG teknolojisiyle geliştirilen en önemli öğretimsel materyallerin 3 boyutlu materyaller, videolar ve animasyonlar olduğu belirtilmiştir. Katılımcılar, AG teknolojisinin eğitimin diğer alanları için geliştirilecek özel uygulamalarla da kullanışlı olabileceğini belirtmişlerdir. Örneğin AG teknolojisi; sihirli kitaplar, farklı içeriklere yönelik 3 boyutlu gösterimler ve fen eğitimi alanındaki deneysel simülasyonlar oluşturmak için kullanılabilir. Ayrıca katılımcılar, AG teknolojisinin kullanıcıların daha fazla dikkatini çekmek, akılda kalıcılığını arttırmak, motivasyonlarını yükseltmek ve eğitsel açıdan daha kapsamlı bir gerçeklik oluşturarak sunulan bilgiyi somutlaştırmak için de sistem tasarlanabileceğini belirtmişlerdir. Son olarak AG uygulaması geliştirmek için analiz, tasarım, geliştirme ve uygulama aşamalarında bazı noktalara dikkat edilmesi gerektiği ifade edilmiştir ve bu noktalar ayrıntılı olarak sunulmuştur. Bu çalışmada elde edilen sonuçlar, AG teknolojisiyle ilgili gelecekte yapılacak olan çalışmalara yönelik bir rehber niteliğindedir.

Anahtar Sözcükler: Eğitimde medya kullanımı; arttırılmış gerçeklik; eğitsel potansiyel.

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Introduction

Due to rapid developments in information technologies, people can now access a wide range of information in nearly where and when they want. The existence of this "ubiquitous" information has both greatly influenced and has become a focus within the field of education. The development of information technologies makes possible that to reach information in everywhere at any time, and get many innovations in teaching and learning methods. So this situation pushes education researchers to develop new methods to permit interactions between the real environment and the virtual environment. Augmented Reality (AR), which provides such an interactive learning environment, was consequently developed as a technology that allows interaction between people and information, and impact learning performance (Huang, Chen, & Chou, 2016; Kye & Kim, 2008). AR can be defined as a system that fulfills three basic functions: it combines the real world with virtual worlds, provides real time interaction, and features accurate three dimensional (3D) representations of virtual and real objects (Azuma, 1997).

Augmented Reality Technologies

AR is a software technology that creates 2D or 3D virtual images. It overlaids these images onto the physical, real-world environment, in which the component elements are augmented (or supplemented) by computer-generated sensory inputs, such as graphic, sound, video, or Global Position System [GPS] data. In order to achieve this, imaging devices, portable devices, computers, and input and output devices are used as basic instruments. One type of device that is used to display virtual objects in real environments is known as "Head Mounted Displays". These devices are placed on the head and allow objects to be displayed with the help of optic viewers located over the eyes. In most cases, this can also be achieved with specially adapted eye-glasses. "Handheld Displays" can be viewed with small, hand-held devices. "Spatial Displays" use video projectors, optic elements, and holograms. "Projection Displays" use physical objects that display computer-generated information. Lastly, with the help of special gloves called "Pinch Gloves," virtual objects can be controlled (Kesim & Ozarslan, 2012). Apart from all these imaging devices, a variety of software is now available to develop AR applications. There is software for computers and for portable devices. The complexity varies to suit the users' knowledge of programming and ability to use authoring tools. Among these software programs are Ar-media, ARToolkit, FLARtoolkit, MRToolkit, Studierstube, osgART, DART, ComposAR, BuildAR, FlashLite, Junaio, Metaio, Aurasma, and Layar (DePriest, 2012; Schmalstieg, Langlotz, & Billinghurst, 2011; Wang, Kim, Love, & Kang, 2013). Some of these programs are also available as add-ons in such three-dimensional drawing programs as SketchUP, Autocad, and 3Ds Max (Redondo, Navarro, Sánchez, & Fonseca, 2012). Although AR systems can integrate several software and hardware devices, this integration can be complicated by issues involving interfacing between multiple devices (Klopfer & Squire, 2008; Wu, Lee, Chang, & Liang, 2013). Another challenge encountered by designers is how to allow different interactions to occur easily and inexpensively using free options (Fonseca, Martí, Redondo, Navarro, & Sánchez, 2014). AR systems require programming skills, special software, and hardware, which are typically expensive.

Augmented Reality in Education

The most distinctive characteristic of AR technology compared to the Virtual Reality technology is that it increases the sense of reality in a virtual setting by including virtual information within a real environment. AR technology combines virtual objects or events into the real environments (Kye & Kim, 2008; Tarng, Ou, Yu, Liou, & Liou, 2015). These characteristics make AR potentially useful for education. Because of that, educators use AR technology in every level of schooling (Akçayır, Akçayır, Pektaş, & Ocak, 2016). In educational AR applications, text, symbols and indicators, 2D images/videos, 3D wireframes, 3D data, 3D models, and animations are among the most frequently used materials (Wang et al., 2013). Of all these materials, the 3D learning content in particular facilitates more effective and permanent learning (Arvanitis et al., 2007; Chen, Chi, Hung, & Kang, 2011; Wu et al., 2013). AR applications encourage students to interact actively with models, games, simulations, and virtual objects. They support ubiquitous, collaborative, and situated learning in learning environments. Because of that, AR gives opportunity students promote learning performance, improve authentic exploration skills and establish constructivist learning environments. AR applications also make it possible for abstract, invisible concepts, and dangerous events these don't observe to be displayed with the help of physical objects, animations, and virtual environments (Akçayır et al., 2016; Arvanitis et al., 2007; Azuma, 1997; Broll et al., 2008; Dunleavy, Dede, & Mitchell, 2009; Huang et al., 2016; Kye & Kim, 2008; Tarng et al., 2015; Wu et al., 2013). AR technology improves learners' motivation, reduces cognitive load, and it can reduce educational costs (Wei, Weng, Liu, & Wang, 2015). In spite of these advantages, educators need to take into consideration some pedagogical challenges when AR systems are implemented. Firstly, implementations of educational innovations in the past might be hindered by constraints imposed by different reasons, so AR is almost a new technology and it could be difficult to integrate in education. Instructional design has a vital role in designing AR learning environments, and the AR integrated learning activities are rather different from traditional learning environments. For example; in some AR systems, fixed flow of instruction is one of the pedagogical challenges associated with this technology. Ideally, teachers could arrange the the flow of instruction according to students' needs and course's instructional objectives (Kerawalla, Luckin, Seljeflot, & Woolard, 2006). There are also both challenges and advantages related to the students and their learning processes. The students encounter a large amount of information, which could lead to cognitive overload in an AR learning environment. Also, they must use multiple technological devices. As a pre-requisite, students should possess proficiency in certain skills, such as spatial navigation, mathematical estimation, problem-solving, usage of technology, and collaboration, (Dunleavy et al., 2009; Wu et al., 2013).

Literature Review

A number of studies have focused on the integration of AR technology into education. AR has been applied at different education levels. AR technology is also frequently used in such fields as geography, mathematics/geometry, chemistry, and biology, as well as in literacy-traing pre-schools, elementary schools, secondary schools, and universities. It is additionally sometimes used in such fields as medicine, engineering, and education for the handicapped. AR applications are used in these fields for such purposes as obtaining information, interacting with virtual objects, displaying invisible events, developing cognitive skills, and increasing motivation. Studies on these uses of AR applications are summarized in Table 1. The specific fields of education, the education levels of the research samples, and the purposes for the use of AR applications are included in this table.

As can be seen in Table 1, AR technologies have positive effects on the learning process across many applications. These effects are especially positive with respect to increasing motivation and activity, making lessons more interesting, facilitating learning, and developing thinking skills (Ifenthaler & Eseryel, 2013).

Table 1

Fields of Education, Education Levels of the Research Samples, and Purposes for the Use of AR Applications

Author(s)	Date	Fields of education	Education Level	Purposes for the use of AR applications
Akçayır, Akçayır, Pektaş, & Ocak	2016	Physics	Undergraduate	Comparing tradational teaching and AR on laboratory skills and attitudes towards laboratories
Aziz, Aziz, Paul, Yusof, & Noor	2012	Special education	Primary	Investigating the learning capacity of individuals with hyperactivity and attention deficit disorder
Balog & Pribeanu	2010	Biology	Primary	Determining the influence of internal and external motivation on technology use
Billinghurst, Kato, & Poupyrev	2001	Literacy	-	Authoring a book that includes AR technology and written texts, pictures, and 3D objects
Carlson & Gagnon	2016	Medical	Undergraduate	AR technology integrated into Simulation

Chen & Wang	2015	Science Education	Secondary	Assesing the effectivenes of AR-embedded instruction
Cheng & Tsai	2016	Reading	Primary & Adults	Examining the interaction of children with parents shared reading with AR picture book
Chien, Chen, & Jeng	2010	Medical/anatomy	Undergraduate	Teaching bone structures, and comparing traditional teaching and AR applications
Dünser	2008	Literacy	Primary	Examining the influence of AR applications on students' reading skills
Dünser & Hornecker	2007	Literacy	Preschool	Evaluating the effectiveness of such a story-listening system
McKenzie & Darnell	2004			
Jan, Noll, Behrends, & Albrecht	2012	Medical/anatomy	Undergraduate	Comparing traditional teaching and AR applications
Kaufmann	2004	Math/Geometry	Secondary	Developing mobile AR application in geometry education
Kim & Lee	2016	Special Education	Primary	Develop AR contents and examining the posibility of applying to science education
Kye & Kim	2008	Biology	Primary	Determining the influence of factors related to AR technologies on learning, and revealing the relationships between these factors
Lee, Chan, & Kwon	2016	Programming	Undergraduate	Comparing the effectiveness of traditional teaching and AR in programming instruction
Liarokapis et al.	2004	Engineering	Undergraduate	Material teaching
Liarokapis, Petridis, Lister, & White	2002	Math/Geometry	-	Establishing interactions with various virtual objects
Lin, Chen, & Chang	2015	Geomety	High School	Comparing traditional teaching and AR assisted learning system in learning solid geometry
Lin, Wang, Duh, Tsai, & Liang	2012	Physics	Undergraduate	Structuring information by developing an elastic impact application
Núñez, Quiros, Núñez, Carda, & Camahort	2008	Chemistry	Undergraduate	Displaying crystal structures in 3D
Park, Beak, Seo, & Lee	2016	Special Education	Undergraduate	Investigating the preservice special education teachers' perceptions about applying AR in special education environment
Schmalstie et al.	2002	Math/Geometry	-	Displaying complex 3D structures
Shelton & Hedley	2002	Geography	Undergraduate	Examining the relationship between the Earth and the Sun
Singhal, Bagga, Goyal, & Saxena	2012	Chemistry	Undergraduate	Examining molecular structures

Sumadio & Rambli	2010	Physics	Secondary	Determining the practicality of AR applications in education
Tarng, Ou, Yu, Liou, & Lio	2015	Biology	Primary	Develop AR contents and examining the effectiveness on students' academic archivement
Thomas, John, & Delieu	2010	Medical/anatomy	Undergraduate	Determining the practicality of AR technologies in anatomy education
Wei, Weng, Liu, & Wang	2015	Creative Design	High School	Examining the effect of AR on students' creativity and motivation
Yeom	2011	Medical/anatomy	Undergraduate	Examining the effects of AR applications on students' learning, and comparing AR technologies with other Technologies
Yoon, Elinich, Wang, Steinmeier, & Tucker	2012	Physics	Primary	Developing a conceptual understanding of scientific phenomena and helping users to acquire cognitive skills
Zhou, Cheok, Pan, & Li	2004	Literacy	-	Designing a system for story-listening that can be opened and closed in cubes, and including hidden stories

The Importance of This Study and Its Rationale

Due to its numerous features, AR technology seems to have many potential uses in the field of education. Education researchers and teachers are interested, as this technology provides an effective learning environment that can be adapted for all education levels, and can especially enrich the contents of non-mathematical courses which normally involve low levels of interaction. AR technology is also believed to be helpful when developing learning environments for different learner profiles. The current availability of a variety of multimedia alternatives supported by AR technology is very helpful when designing for individual differences in learning. But despite all of these benefits, the limited number of comprehensive and explorative studies has been conducted on the educational potentials of AR technology in the literature. Because, AR is a newly developing technology, and so most of the studies are about on its development (Wu et al., 2013). For this reason, to share experiences of the instructional designers and reseachers who apply AR technology in the field of education is important. This study presents the experiences about integration process of AR technology into education. The purpose is to reveal the educational potential of AR technology, based on these experiences. The following questions guided this study:

1) In which education fields and levels can AR technology be used most effectively?
2) What kind of educational applications and materials can be developed via AR technology?
3) What are the opportunities and challenges associated with AR technoloy in education?
4) What are the recommendations of instructional designers and practitioners while developing an effective educational AR application?
    a) What are the recommendations in the stage of analysis?
    b) What are the recommendations in the stages of design and development?
    c) What are the recommendations in the stage of implementation?

Method

Intrinsic case study design was used in this study. Intrinsic case study is a type of case study, and it is an ideal methodology when needed in-depth investigation and better understanding. The intrinsic case study method was prefered in this study because it can be used to examine in-deep, and describe detailed opinions of the participants (Creswell, 2013; Stake, 1995).

Participants

Participants of the study are 42 instructional desginers (F: 20, M:22; age range: 20-25 years) who have education in instructional design field and 10 practititioners (F: 2, M: 8) who used AR applications in their courses or conducted at least one AR based educational research. The forty-two instructional designers were also pre-service teachers who were last level of undergraduate in the Department of Computer Education and Instructional Technology at Ataturk University. They had taken the course “Project Development and Management”. That course was taught by one instructor and two research assistants who are expert in AR based educational research. Students separated to seven groups, and each groupcompleted a final project on “AR in education”. Each group focused their projects on different topics and education levels (see Table 2). Also Figure 1 contains sample pictures of the AR implementations by these groups. On the other side, practitioners’ implementation field, level, topic and materials are presented in Table 3.

Table 2

Education Levels, Topics, and Educational Applications/ Materials of the Group Projects

Group	Education Levels	Topics	Educational applications/ materials
G1	Elementary (5th grade)	Foreign Language Education	AR Flashcards
G2	Secondary (6th grade)	Science Education	Markers, Mobile Applications, Magic Book
G3	Undergraduate	Smoking Cessation	T-Shirt, Poster, Mobile Applications
G4	Elementary (5th grade)	Creating a Story	AR Flashcards
G5	Elementary (5th grade)	Listening to a Story	Magic Story Book
G6	Elementary (5th grade)	Foreign Language Education	Magic Book
G7	Undergraduate	Anatomy Education	Markers, Mobile Applications

Figure 1. *Examples of the Groups’ AR Implementations*

The project groups designed their AR technology metarials and instructional processes in cooperation with the teachers. They used the ADDIE instructional design model to form their projects. In every phase, they presented their studies in the faculty computer laboratory, and their peers and instructors provided feedback to them. In the analysis phase, the students determined a study group, the content, the requirements of this group, and the requirements for the AR application (hardware, software, etc.). In the design phase, Firstly, they designed materials and instructional activities using 2D marker-based AR technology. The 2D marker AR is PC and webcam-based. The marker is in black and white square image. This image is created virtually in front of a webcam to produce a 3D animation, a simulation, or a video. The other type 2D Marker AR is in a mobile device. This sort of phone involves a great deal of real time processing and a great capability (Rice, 2009). In the development phase, the students developed materials using BuildAR, Aurasma, ARMedia, or FlarToolkit software. In the implementation phase, at school, the students implemented the instructional process which they had designed. These educational AR implementations lasted approximately 4-hours. Finally, the students evaluated their students' learning and opinions, which were recorded by an academic achievement test, questionnaires, and interviews.

Table 3

Education Levels, Topics, and Educational Applications/Materials of the Practitioners' Implementations

Group	Education Levels	Topics	Educational applications/ materials
P1	Secondary (5th grade)	History Education	Magic Book
P2	Secondary (5th grade)	Science Education	Markers
P3	Undergraduate	Orientation Education	Markers
P4	High School (9th grade)	Physics	Markers
P5	Undergraduate	Foreign Language Education	Markers
P6	Secondary (7th grade)	Hardware, Science &Teknology Education	Magic Book
P7	Preschool	Foreign Language Education	Markers
P8	Secondary (6th grade)	Math	Markers
P9	High School (10th grade)	Hardware	Markers
P10	High School (9th grade)	Biology	Markers

The practitioners are designed AR implementations and used in the educational environments in the scope of their research. They conducted AR based educational implementations which include animation, video or 3D materials. They used 2D marker-based AR technology using mobile or PC devices. They preferred various AR softwares such as Aurasma, Voforia, MetaIOCreater, BuildAR, HITLAB-NZ. Some of the practitioners are developped 3D materials using Cinema4D, Unity, Ufuksar, 3DsMax or SketchUp programs as AR content. Their implementation process ranged between one class hour or 5-week class hour according to their research scope.

Data Collection

The data were collected using open-ended questionnaire from instructional designers. This questionnaire was developed by the researchers. And it was based on a literature review and on the study's research questions. After peer-review by two graduate students, two field experts examined the survey. Based upon their feedback, the instrument was revised. It was then checked by a Turkish Language expert for language clarity. Final version of the questionnaire consists 13 open-ended questions. The questionnaire was completed by each participant in class. With the same questions, the semi-structured interviews were conducted with practitioners by face to face or on the phone. All of the participants voluntarily answered the questions based on their learning experiences. To complete the questionnaire had been lasted about three hours each.

Data Analysis

The qualitative data were analyzed with the content analysis method, using Nvivo 8.0 software. Themes were created, which were based on the research questions, and the data was presented with descriptive statistical methods. The frequencies are presented in tables based on opinions of the instructional designers (ID) and practitioners (P).

Results

The data collected from the participants were analyzed with reference to the research questions. The results are presented below, under four headings.

Education Levels and Fields in which AR Technology can be Used Effectively

The instructional designers suggested that AR technology could be more effective in the fields of science, social studies, and health education. The practitioners also empshaised geography and history field. Moreover, they stated that it could be used in each education field when selected suitable content. The fields of sports education and mathematics teaching were among those least mentioned by the participants. The full findings are shown in Figure 2.

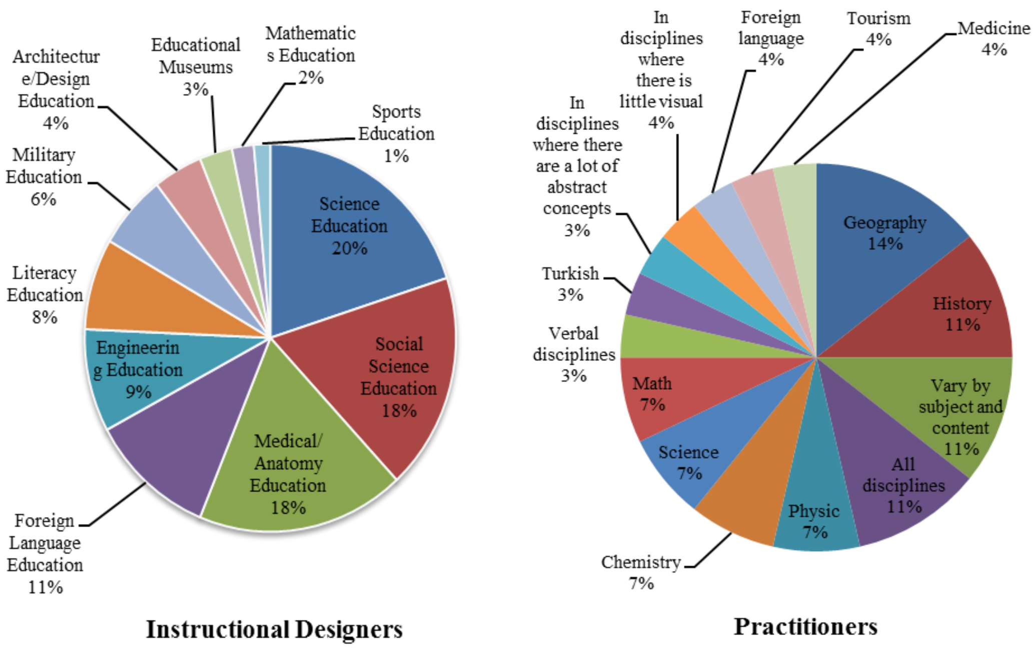

Figure 2. *The Participants' Opinion Education Fields in which AR Technology could be Used*

The instructional designers stated that educational AR applications could be used effectively in almost all education levels. While the the elementary school and university levels were mentioned more by the instructional designers, secondary school and university level were stated more by the practitioners. Moreover, they also mentioned educational AR applications could be effective in special education field and purpose of informal education. The related data regarding this result is shown in detail in Figure 3.

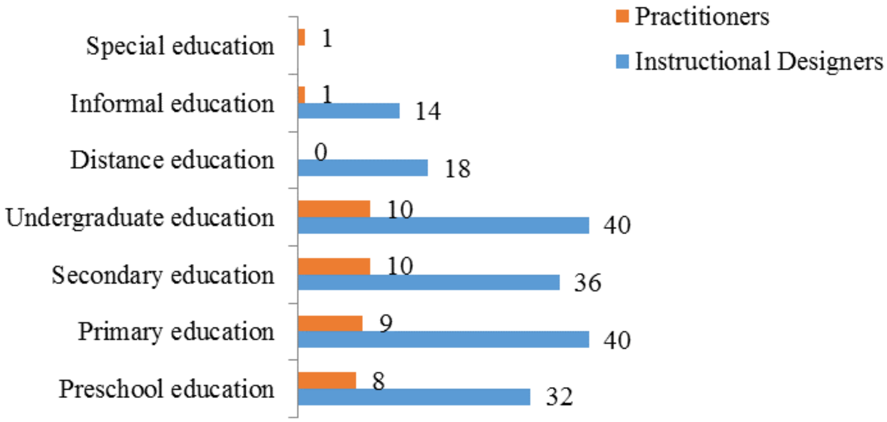

Figure 3. *Education Levels in which Educational AR Applications could be Effective*

Educational Applications and Materials to be Developed with AR Technology

The instructional designers stated that such educational applications and materials as magic books, 3D materials, simulations, games, videos, flash cards, animations, and story books could be developed with the help of AR technology. The practitioners emphasized video and 3D materials. The data are presented in Table 4.

Table 4

Educational Applications and Materials

Applications and Materials	ID	P
Magic book	23	1
3D materials	19	5
Simulations/Games	19	3
Videos	14	5
Flashcards	12	-
Animations	10	1
Story books	9	-
Poster/booklet	7	-
Audios	7	1
Drill and practice	5	-
Voice dictionary	4	1
T-shirt	4	-

In addition, the instructional designers and practitioners offered suggestions regarding AR technology applications for different fields of education. They suggested that magic books, 3D demonstrations on different subjects, and 3D experimental simulations for the field of science education could be prepared. They offered the opinion that in the field of medicine/health education, difficult and serious surgeries could be simulated; also first-aid applications; and such applications as 3D demonstrations of human anatomy could be produced. Table 5 presents their suggestions for AR applications in different fields of education.

Table 5

AR Applications to be Created for Different Fields of Education

Fields of Education	AR Applications
Science Education	3D demonstrations of chemical bonds and molecules 3D demonstrations of invisible cellular structures of plants and animals Demonstrations of procedural simulations for chemistry experiments Magic Book Similations
Medicine/ Health Education	Simulations of difficult and serious surgeries Simulations of first-aid applications 3D demonstrations of human anatomy Displays of cadaver models Teaching Latin words, and Consciousness raising activities regarding health
Social Sciences	3D models Animating historical events/wars/persons, and demonstrations of geographical formations The Earth's Crust, the Earth, the sun, the moon, and the planets; supporting maps with various multimedia elements Magic Book Videos*
Foreign Language	3D models Teaching vocabulary and pronunciation Magic Book
Engineering Education	3D demonstrations of the designs prepared 3D demonstrations of the present sample designs Introductions to materials, and simulating how a system/machine works

Literacy	Creating stories Story listening Animation/drama Teaching difficult and complex words Reading activities
Military Training	Demonstration and introduction of combat tools Teaching the features of weapons Simulation of shooting practice
Architecture/ Design Education	3D displays of drawings Preparing a 3D prototype
Educational Museums	Introductions to works presented in museums and videos Animations regarding historical events
Mathematics/ Geometry	Displays of complex 3D objects Magic Book
Sports Education	Location based implementations 3D animations of certain sports actions

Opportunities and Challenges for AR in Education

Opportunities for AR in education

The opportunities for AR in education are handled undes students' learning and attitudes, and educational environment themes. The instructional designers stated that AR technology provided such learning opportunities in education as concretizing information, drawing users' attention, improving retention and increasing motivation. The practitioners also emphasized increasing academic achievement especially for relatively lower successful students, maintaining active participation and learning through entertainment opportunities. Moreover, the participants stated that AR technology based educational environment provided conducting applications that are difficult to apply, facilitating class management especially for controlling hyperactive students, increasing interaction and communication. These findings are shown in detail in Table 6.

Table 6

Opportunities for AR in Education

Students' Learning and Attitudes	ID	P
Concretizing information by developing a sense of reality	36	-
Drawing users' attention	34	6
Improving retention	31	1
Increasing motivation	27	8
Increasing academic achievement	-	5
Maintaining active participation	23	3
Progressing at one's own pace and learning everywhere	19	1
Facilitating learning	16	-
Learning through entertainment	15	4
Increasing creativity	11	-
Positive emotions	-	2
Technology awareness	-	2
Reducing cognitive load	-	1
Maintaining attention	-	1
Reducing anxiety and prejudice toward course	-	1
Eagerness for AR integration with different courses	-	1
Increasing spatial ability	4	-
High-level thinking	3	-
Educational Environment		
Conducting applications that are difficult to apply	21	-
Facilitating class management	-	3
Increasing interactions (content, student, teacher) and	-	3

Saving time	11	2
Addressing more than one sense organ	11	1
Low cost	9	-
Establishing relationships with real life	8	-
Minimizing individual differences	6	1
Increasing class participation	-	1
Reducing teachers' work load	-	1
Reusing when needed	-	1

Challenges for AR in education

According to the instructional designers, difficulties experienced in the educational AR application process occurred due to the facts that AR applications require a certain infrastructure of software and equipment, content development is difficult and time-consuming, and users are supposed to have competency with the technology. The practitioners also emphasized some challenges such as surpassing entertainment and game the instructional purpose, and focusing on the materials instead of content, and some students' boring. This data is presented in detail in Table 7.

Table 7

Challenges for AR in Education

Challenges	ID	P
AR applications require a certain infrastructure of software and equipment	41	-
Content development is difficult and time consuming	30	-
Requiring users and developers experience	27	-
Difficulty in organizing the physical conditions	22	-
Problems with content-software integration (defining markers, etc.)	22	2
Frequent technical problems (internet, charge, light, etc)	19	4
Failure of the software to support all file extensions	13	-
Difficulty in carrying out applications in crowded classrooms	12	-
Difficult to control the lessons	10	1
Surpassing entertainment and game the instructional purpose	8	1
Difficulty in adapting the environment for individual studies	6	-
The application process is time consuming	3	-
Problems about supporting programmes in some Tablets	-	**3**
Problems about supporting Turkish language in AR programmes	-	1
Lack of number of mobile devices used in implementations.	-	1
Causing distractibility due to technical problems	-	1
Being novice on using Tablet	-	1
Focusing on the materials instead of the content	-	1
Getting bored of some students	-	1
Problems regarding displaying virtual content such as text, images etc.	-	1
Having difficulty to rotate the displayed objects on the marker	-	1

Points to Consider While Developing an Educational AR Application

Points to pay attention to in the process of analysis

Especially, the instructional designers focused on software selection in the process of analysis to develop educational AR applications. Firstly, they reported that the applications should have an interface easy to use the program. Also, multimedia support of the program, the environment where the application will be implemented, and the related devices to be used should be primarily pay attention while selecting the software to develop an educational AR application. On the other side, the practitioners also emphasized the need assessment, selecting an appropriate multimedia theory and literature review. The collected data is presented in detail in Table 8.

Table 8

Points to Consider in the Process of Analysis

Points to consider	ID	P
Easy interfacing of the software (defining, creating the markers, etc.)	20	-
The environment where the application will be implemented, and the related devices to be used	14	1
Multimedia support of the program (pictures, audios, videos, 3D model support)	14	-
The target population addressed by the application	12	1
Recognizing and displaying the markers (duration, number, image quality)	12	-
Software, and equipment necessary to run the software	12	-
The subject related to the application	12	-
Technical difficulties due to the software	11	-
The variety of file extensions supported by the software	9	-
Cost of the software	8	-
Internet support required by the software	7	-
Selecting an appropriate multimedia theory and designing the educational materials to be appropriate for the design principles	4	1
Allowing interactive material development	4	-
Coding information required by the software	4	-
Need assessment	-	**4**
Considering literature review	-	1
Getting support from field experts	-	1
No changing of course flow	-	1
Regarding other course activities of students	-	1
Regarding students preknowledge level	-	1

Points to consider in the process of design and development

The instructional designers reported that during the entire process of designing and developing an educational AR application, it is important to control some points. As shown in Table 9, whether the application is appropriate to the target population, the content, and the aim; to provide the necessary technical infrastructure and the physical environment; to make it realistic and interesting; and to determine the environment and the materials to be used. The practitioners emphasized conducting pilot implementations, cooperation with field experts, and providing the necessary technical infrastructure and the physical environment. The data are presented in detail in Table 9.

Table 9

Points to Consider in the Process of Design and Development

Points to consider	ID	P
Appropriateness for the target population	32	1
Appropriateness for the aim and the content	21	-
Providing the necessary technical infrastructure and the physical environment	14	2
Making it realistic and interesting	13	
Designing the markers (size, color, number) in a way that they will be recognized by the software and by the camera	10	3
Determining the environment and the materials to be used	10	1
Making it easy to use, including providing the necessary guidance	7	-
Designing the materials appropriately for the subject and for the target population	6	1
Including a variety of multimedia elements	6	-
Conducting pilot implementations	5	**4**
Good-planning during the process	5	-
Good-quality audios and images	3	-
Cooperation between the field experts	2	3
Lack of distracting factors	2	-

Providing feedback and reinforcers	2	-
Conducting pilot implementations with similar target population	-	2
Avoiding to present long duration video materials	-	1
Designing interactive materials	-	1
Designing materials with a group	-	1
Designing the materials as 3D	-	1
Designing the materials as user friendly	-	1
Determining not easy content	-	1
Drawing attention of students	-	1
Meeting software and material properties with mobile devices	-	1
Providing Turkish language program interface	-	1
Regarding the teacher's opinions	-	1

Points to consider in the process of implementation

The instructional designers stated that in the implementation process of the educational AR application, it is important to arrange environment. Provide the necessary technical infrastructure and the physical environment, to inform the students (about the program, materials, purpose, gains), and to provide each students equal opportunities for usage. The practitioners emphasized conducting usability tests of the materials before the real implementation, providing enough devices for students, and preventing younger students from regarding the application as a game The data were presented in Table 10.

Table 10

Points to Consider in the Implementation Process

Points to consider	**ID**	**P**
Providing the necessary technical infrastructure and the physical environment (light, audio, class order, etc.)	42	1
Informing the students (about the program, materials, purpose, gains)	18	-
Providing students with equal opportunities for implementation	8	-
Offering education within the framework of the plan	7	-
Conducting usability tests of the materials before the real implementation	5	5
Helping students become active in the process	4	-
Achieving class management	3	1
Adjusting the camera well in webcam applications	3	-
Preventing younger students from regarding the application as a game	2	2
Allocating enough time to the students for the application	2	1
Providing enough devices for students	-	2
Allocating time for enjoyment	-	1
Guiding students for rotating object	-	1
Maintaining students' attention through implementation process	-	1
Meeting AR software capability with connected device number	-	1
Providing reusing opportunity after class	-	1

Discussion

The present study examined the educational potential of AR technology. For this purpose, the experiences of instructional designers and practitioners were analysed to elicit their opinions concerning the education levels and fields in which AR technology can be effectively used, also in which educational materials and applications are most effective, and points to be considered while developing an effective educational AR application.

The results suggest that AR technology would be more effective in the fields of science education, the social sciences, and health education. In the literature, the educational potential of AR technology has only recently been recognized in these fields (Núñez, Quiro, Núñez, Carda, & Camahort, 2008), though AR related studies are increasing in last four years (Akçayır & Akçayır, 2017), many published studies are not very comprehensive in their treatment of such applications (Wu et al., 2013). This situation could be due to the fact that AR technology is a newly-developing technology. But AR applications will likely be commonly used in these fields in future. Our findings indicate that AR applications can be used effectively in almost every education level, but most especially in the elementary school and university levels. Similarly, Akçayır ve Akçayır (2017) stated that AR based educational studies conduct commonly in K12 level. In addition, AR technology is favored in the elementary school level, because it is an attention-grabbing technology (Lamanauskas et al., 2007). In the university level, it can be used in any place at any time (Sandor & Klinker, 2005). AR technology provides such features as 3D graphics and animation, individual study, learning facilitation, and increased engagement (Chen et al., 2011; Lamanauskas et al., 2007; Wu et al., 2013), which makes it widely useful in different education levels.

Among the basic educational materials that should be developed with AR technology are 3D materials, videos, and animations. AR 3D materials are popular among students (Arvanitis et al., 2007; Wu et al., 2013), as this allows viewing of objects from multiple perspectives. The educational applications chiefly include magic books, simulations, and story books. In the literature, the first recorded application produced with AR technology was Magic Book (Billinghurst, Kato, & Poupyrev, 2001). Some studies have also been conducted to develop story books (Dünser & Hornecker, 2007; McKenzie & Darnell, 2004; Saso, Iguchi, & Inakage, 2003; Cheok, Li, Pan, & Zhou, 2004). However, the number of these studies is limited. AR technology could therefore be further utilized to support simulations and story book applications in the future. Although the present study suggests that the use of educational games should be limited, prior studies have shown that educational games can be used more effectively thanks to AR technologies (Wu et al., 2013).

We determined that AR technology can be used to develop special applications for different fields of education. In the field of science education, experimental simulations, 3D displays of different subjects, and magic books can be developed. In the literature, some studies have been conducted on 3D displays of chemical molecular structures (Singhal, Bagga, Goyal, & Saxena, 2012) as well as on displays of crystal structures (Núñez et al., 2008). In the field of Medicine/Health Education, our participants suggested that applications such as simulations of difficult and serious surgeries, simulations of first-aid applications, and 3D depictions of human anatomy could be created. In the literature, several studies have focused on AR applications for anatomy instruction (Chien, Chen, & Jeng, 2010; Jan, Noll, Behrends, & Albrecht, 2012; Nicholson, Chalk, Funnell, & Daniel, 2006). In the field of medicine, applications to facilitate difficult and serious surgical interventions have also been developed (Fischer, Neff, Freudenstein, & Bartz, 2004; Hamza-Lup, Rolland, & Hughes, 2004). In the field of the social sciences, various applications could be designed, such as to animate historical events, to teach vocabulary and pronunciation in foreign language education, to create 3D displays of designs in engineering education, to facilitate story building and listening in literacy education, to create war simulations in military training, to generate 3D displays of drawings in architecture, to portray historical artifacts in educational museums, to depict complex 3D objects in mathematics teaching, and to create educational games that are based on cooperation.

Our participants further suggested that AR technology could be useful for concretizing information, drawing users' attention, improving retention, and increasing motivation by creating a sense of reality in the virtual environment. Though other technologies can also be used for these purposes, it is the most distinguishing characteristic of AR technology which visualizes virtual object to real world, thus it supports interactions between the real and virtual environments by including virtual information within a real environment (Huang et al., 2016; Kye & Kim, 2008). Moreover, parallel with the literature, the practitioners reported that AR technology based learning environments increase motivation and academic success (Akçayır & Akçayır, 2017). Encouraging interactions and generating a sense of reality depends on the use of 3D materials and animations. However, several difficulties are likely to be experienced in the process of educational AR application. Among these difficulties are the factors that AR applications require a certain infrastructure of software and equipment, content development is difficult and time-consuming, and AR technology users must possess technological competency. The difficulty of maintaining the necessary infrastructure is likely due to the fact that it is a newly-developing technology. Although the opportunities and difficulties associated with AR technology have been mentioned in the literature, this study provides a larger framework and more data to examine this subject.

The stages of analysis, design, development, and implementation were investigated to develop an effective educational AR application. In the analysis of stage, designers should pay attention when selecting software. This software should have easy interfacing, multimedia support. And related devices in physical environment should be prepared for the application. About the selection software, the most advantageous technologies should be choosen to develop an effective educational application by designers (Kozma, 1994). Whereas Clark suggested that designers should consider pedagogy as a primary factor rather than technology (Clark, 1983),

AR technology is a relatively newly-developing, so it is inevitable that there will be certain limitations caused by current software. There have been recently developed softwares. Therefore, software selection is important. Studies have been conducted to compare these softwares (Schmalstieg et al., 2011; Wang et al., 2013). Other important points when designing and developing the materials that designers should pay attention to be appropriate for the students' levels, for the subject content, and for the purpose; providing the necessary technical infrastructure and physical environment; and attracting students' interest; and making the environment realistic. Designers should consider all of these points to make an effective learning environment. Besides designers should prepare and chooseappropriate environment and materials to be used with the AR technology. Because it is also important that the software and the camera should recognize the makers (size, position, color, and number). As is reported in literature, students will feel discomfort if the learning environment is not -designed as stated. This situation could cause low engagement and detrimentally affect learning (Kerawalla et al., 2006). Developers should consider that providing the necessary technical infrastructure and physical environment in the implementation process. To implement educational AR metarials in an effective way, special physical conditions, equipment, and software are required. In addition, before application, informing the studens about the application (gains, materials, purpose, and software) is also important. After then, it is important to provide students equal usage opportunities. Moreover, conducting usability tests of the materials before the real implementation and allocating enough time are extremely important in terms of preventing technical problems (Akçayır & Akçayır, 2017). Designers of educational AR environments need to provide support to help teachers and students (Wu et al., 2013). Moreover, students must be able to use multiple technological devices in AR learning environments. Because of this, they should possess some essential skills, such as spatial navigation, collaboration, problem-solving, technology manipulation, and mathematical estimation (Dunleavy et al., 2009; Wu et al., 2013). As with all new technologies, the use of AR technology draws students' attention. Students therefore may be willing to use educational AR applications. Thus, it is important to provide students equal usage opportunities. In the literature, most of the implemented AR systems are single user-based. More attention should be paid to collaborative systems (Wang et al., 2013).

Conclusion and Recommendations

To conclude, this study provides a wide range of in-depth information on the educational potentials of AR technology. The results can provide guidance for the design, development, and implementation of future studies in the field. However, the limitations of this study are that it included only marker-based AR applications, and our findings are based upon the opinions of 42 instructional designers and 10 practitioners. The following suggestions are offered, based upon our results:

- In different fields of education, researchers should integrate this technology into their own fields, and conduct applications and studies with different research sample groups.

- Educational magic books, simulations, and story books to be developed with AR technology could be enriched with 3D models, videos, animations, and audios.

- Location based AR technology should be integrated with appropriate contents.
- Using the findings from the study, specific applications could be carried out in different fields of education (See Table 3).
- In cases where a sense of reality is hard to create, AR technology can be effectively used in education.
- AR applications can also be used effectively in applications based on individual study.
- In order to draw users' attention, to increase motivation, and to improve retention and active participation, AR technologies can be used especially in non-mathematical courses that include the presentation of complex information.
- With the help of AR technologies, activities could be designed to increase students' creativity and to develop their high-level thinking skills, as well as their spatial ability.
- AR based educational materials should be designed based on an appropriate multimedia theory.
- Educational activities should be designed with AR technologies only after first considering the difficulties likely to be experienced when using these technologies.
- While designing educational applications with AR technologies, it is important to select appropriate software and to establish the necessary technical infrastructure.
- Interdisciplinary studies conducted by field experts could help to overcome the difficulties experienced in the processes of content development, material design, and application.
- In order to avoid any problems, especially while designing and displaying the markers, it is important to provide appropriate physical conditions and to use technical tools with efficient equipment.
- For the purpose of providing students with equal application opportunities, educational applications could be conducted in uncrowded classrooms.
- To deal with the spread of this technology in the field of education, schools should be provided with the necessary technical infrastructure support, and in-service training should be organized for teachers.
- The introduction of effective educational materials and applications developed with AR technology to teachers as well as to students will accelerate the spread of this technology.

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