

Does Teaching Geometry with Augmented Reality Affect the Technology Acceptance of Elementary School Mathematics Teacher Candidates?

Nezih Önal* Emin İbili[2] Erkan Çalışkan[3]

1. Department of CEIT, Nigde Omer Halisdemir University, 51240, Nigde, Turkey
2. Department of CEIT, Aksaray University, 68100, Aksaray, Turkey
3. Department of CEIT, Nigde Omer Halisdemir University, 51240, Nigde, Turkey

* E-mail of the corresponding author: nezihonal@gmail.com.tr

Abstract

The purpose of this research is to determine the impact of augmented reality technology and geometry teaching on elementary school mathematics teacher candidates’ technology acceptance and to examine participants' views on augmented reality. The sample of the research was composed of 40 elementary school mathematics teacher candidates who were freshman students in the faculty of education of a university which located in the central Anatolian region of Turkey during the fall semester of 2016-2017 academic year. Participants in the study were given a training seminar on teaching geometry via augmented reality (AR). They were provided with the opportunity to develop teaching materials for AR. At the end of this process, their opinions on the use of these materials were taken. Both qualitative and quantitative research methods were used in the research. The quantitative data of this study were collected by the Technology Acceptance and Use Scale for Information and Communication Technologies and the qualitative data were collected through semi-structured interviews. The themes and codes related to the usefulness of geometry teaching supported by augmented reality teaching emerged by means of qualitative content analysis. The t-Test, one of the parametric tests, was used to analyze the quantitative data. The data obtained from the semi-structured interview forms were classified under 9 categories and 35 themes. As a result of data analyses, it was found that the teacher candidates' attitudes towards the effectiveness geometry instruction supported by the augmented reality technology were positive but as regards’ teacher candidates’ intentions to use augmented reality technology, it was observed that some of them had reservations because of technological limitations, such as recognition of signs and freezing of the augmented reality environments.

Keywords: augmented reality (AR), geometry teaching, mathematics teacher candidate, technology acceptance and use

1. Introduction

Teaching techniques for memorization of geometric properties by transferring shapes onto two-dimensional planes do not enable students to adequately structure geometric concepts in their minds (Fujita & Jones, 2007). Virtual teaching materials are useful in developing visual perceptions and logical thinking skills, such as enabling students to visualize abstract concepts and visualize them from different angles (Alqahtani & Powell, 2012; Batti□ta, 2001; Pi□kin Tunc, Durmu□& Akkaya, 2012). Therefore, following new direction□in educational technologies and using them in teaching activities are necessary in terms of effective teaching processes. One of these new technologies is Augmented Reality (AR) technology. Thanks to AR technology, geometry materials can be displayed in three dimensions. It can interact with users and materials to create a sense of touch and movement, and allows users to make corrections, such as editing and making changes on these materials (Ibili & Sahin, 2015; Le & Kim, 2016).

In AR technology, digital objects such as pictures, videos and texts superimpose the real objects in the environment that are scanned by a camera by the user by adding layers upon them. That are scanned by a camera by the user. According to Azuma (1997), AR is a kind of virtual environment. Virtual reality technologies put the user in a completely artificial environment. In this artificial environment, the user cannot see the real world around him/her. In contrast, AR allows the user to see the real world that is super imposed by or combined with virtual objects. For this reason, the reality can be said to be complete rather than completely replaced by the reality of AR. However, the concept of AR and virtual reality can be confused with each other (Somyurek, 2014). The goal of virtual reality is to create three-dimensional and interactive virtual environments modeled by the real world. AR aims to enrich the real world with real-time and interactive virtual utilities developed in the computer environment. In other words, while the aim of virtual reality is to move to the virtual world as it is a reality, AR focuses on enriching it with virtual information. Today, this technology has started to be used in a wide range of fields: engineering, trade, entertainment, art, architecture, tourism, games, and education (Elford, 2013; Fritz, Susperregui & Linaza, 2005; Somyurek, 2014; Squire & Jan, 2007).

AR is technologically handled in two main categories. The first is optics-based technologies and the second is video-based technologies. The main difference between these two technologies is the place where the realization of the virtual world is seen. In optical systems, the integrated scene is seen in the real world through spectacles, whereas in video-based systems the integrated scene is seen on the computer /tablet/mobile device (Somyurek, 2014).

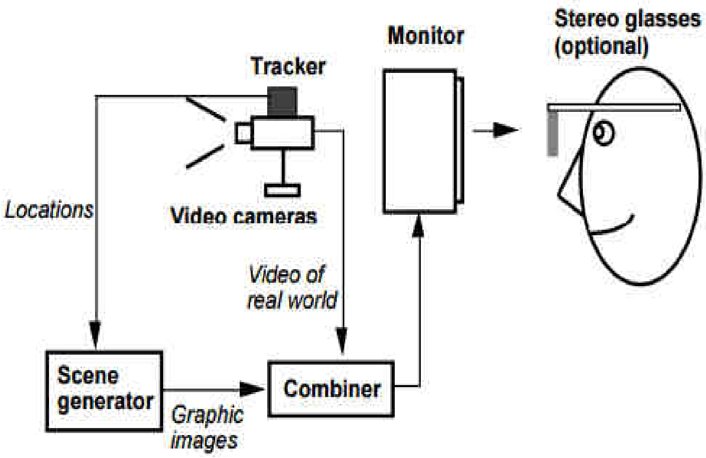

Figure 1. Conceptual diagram of a video-based AR system (Azuma, 1997)

Educational samples of AR technology in Turkey are often encountered in studies in the fields of physics, geography, biology, and archeology (Koyuncu & Bostanci, 2007). However, when the related literature is examined, it can be noticed that mathematics courses are among the most difficult courses for students, and that students fear mathematics and have mathematics anxiety (Basar, Unal & Yalcin, 2002; Dede & Argun, 2004; Onal, 2013; Onal, 2016). The low mathematical averages in PISA exams, conducted at various levels of education in Turkey as well as in the OECD member countries, are important indicators of Turkish students' low success rates in mathematics. This is why it is believed that various measures must be taken for more effective teaching and learning of mathematics, which can be considered as the basis of many sciences. The use of information and communication technologies enables students to see different representation forms of the concepts and relationships indicated in the secondary school mathematics curriculum, and enables students to discover mathematical relationships. "With the help of these technologies, it is necessary to prepare the environments for the students to develop their skills such as problem solving, communication, reasoning by modeling" (MNE, 2013, p.1). Generally speaking, program designers and teachers, especially mathematics teachers, have an important role in the preparation of such environments. In the updated mathematics curriculum, five basic learning areas have been identified: (1) Numbers and Operations, (2) Algebra, (3) Geometry and Measurement, (4) Data Processing and (5) Possibility (MNE, 2013). The extent of these learning areas by class level is shown in Table 1:

Table 1. Mathematics Curriculum Learning Areas

LEARNING AREAS	CLASS LEVELS			
	5	6	7	8
NUMBERS AND TRANSACTIONS	x	x	x	x
ALGEBRA	-	x	x	x
GEOMETRY AND MEASUREMENT	x	x	x	x
DATA PROCESSING	x	x	x	x
POSSIBILITY	-	-	-	x

As seen in Table 1, one of the learning areas that exists across all levels of the mathematics curriculum is Geometry and Measurement. It can be said that particularly students who have problems visualizing three-dimensional objects, which is one of the subjects of geometry in mathematics, spend a long time and experience difficulty in trying to figure out how geometric shapes look from different angles while turning around the shapes in their mind. The use of a variety of concrete materials can be considered to overcome this problem because the development of individuals' minds proceeds from concrete to abstract, so what they see and perceive concretely can be learned more easily. It is a well-known fact it is for this reason that teaching is based on concrete constructs as much as possible. Nowadays, various solutions are sought in this situation especially through the information technologies, which has developed rapidly in recent years because it is known that some objects prepared by means of information technology have a more flexible structure than their real counterparts. Students can change the shape and size of the object while working with objects on the computer. After organizing these objects in different sizes, they can be stored on the computer and students can repeat the movements made on these objects when necessary. This can help students to create dynamic forms. Many things that cannot be done with concrete models can be done using computer software. Students can automatically draw symmetrical shapes on the computer or create new movements on these shapes (Yolcu & Kurtulus, 2010). The geometry subjects taught in the secondary school mathematics course in Turkey are predominantly about plane geometry teaching. In general, it is possible to say that the teaching of three-dimensional space geometry is taught on two-dimensional plane geometry. It is quite difficult to picture the space planes. This work, which forms the basis of geometry, also plays an important role in the teaching of three-dimensional geometry. However, either the two-dimensional drawings made on paper of three-dimensional shapes are not precise and thus lead to visual misperceptions or, even if they are drawn precisely, it is not possible to see the shapes from different angles due to the static nature of the environment. It has been revealed by several studies that students the space geometry course based on plane geometry experience difficulty in understanding the relations among geometric objects and that they arrive at misinterpretations caused by varying perceptions (Baki, Kose & Karakus, 2008). For this reason, these problems can be solved by using AR technology in the field of education.

The materials created by modeling geometric concepts using AR technology help students understand concepts more easily by visualizing abstract expressions. Thus, students' participation in and motivation towards the lessons increase, and their ability to comment on concepts and to solve problems develops (Ibili & Sahin, 2015). Most of the research done in this area is carried out by researchers who are well informed about the technologies used; they primarily focus on the cognitive and affective effects of virtual and physical materials (Lee & Chen, 2014). However, there is insufficient research on how teachers can use these materials effectively, what they should consider when choosing materials, what their attitudes are and how they can use these materials. For this reason, software or teaching materials developed in this area without sufficient academic preliminary work can prevent effective and qualified teaching software from emerging. In addition, these materials need to be integrated into mathematics curricula with specific teacher activities (Ibili & Sahin, 2015).

Teachers' use of a new technology can be described in the framework of the Technology Acceptance Model. Davis (1989) and Davis, Bogazzi and Warshaw (1989) utilized the Technology Acceptance Model (TAM) to determine what influenced users' adoption of Information and Communication Technologies (ICT). TAM is actually an application of the Critical Behavior Theory, developed by Fishbein and Ajzen (1975), to explain an individual's willingness and positive behavior in the face of a particular situation. TAM, which is used in many studies on acceptance of different technologies, has been regarded as a powerful model in explaining user behavior and ICT usage (Davis, 1989; Legris, Ingham & Collerette, 2003, King & He, 2006; Ursavas, Sahin & McIlroy, 2014). This research has been dealt with within the framework of TAM.

In the present research, researchers gave a seminar on geometry teaching with AR technology, and the impact of this seminar on participants' acceptance and use of information and communication technologies was revealed. In the related research, the importance of examining the effect of geometry teaching seminar conducted via AR on the acceptance and use of ICT or attitude towards geometry, is emphasized. This is because it is believed that teacher candidates who are in their pre-service training period will be influenced by the adoption and use of new technologies such as AR, which will, in turn, affect their teaching practices in their future classrooms. For this reason, the purpose of this research in general is to determine the effect of augmented reality technology and geometry teaching on secondary school mathematics teacher candidates' acceptance of technology and to examine the participants' views on augmented reality. To this end, the following questions have been answered:

1. Is there a meaningful difference between the pre-test and post-test scores reflecting the technology acceptance opinions of participants before and after the seminar on geometry teaching via AR technology?

2. What are the opinions of prospective teachers regarding geometry teaching via AR technology?

2. Method

1.1 Research Design

This research was conducted using a mixed research method. According to Creswell and Clark (2011), mixed methods are defined as a research method developed for collecting, analyzing and correlating both quantitative and qualitative data in a single study or multiple study sequences to understand the research problem. It is possible to say that the results obtained from mixed methods research are richer, more comprehensive and more reliable than the results obtained solely from quantitative or qualitative research, and it is a good option to carry out mixed methodological research as it has the power of bringing different perspectives to the research as it utilizes both methods, quantitative and qualitative (Creswell, 2012). The research method of the present study is based on the Explanatory Sequential Design. In explanatory hybrid method studies, initially quantitative data and subsequently qualitative data are collected to explain the quantitative data.

In the quantitative part of the present study, a single group pretest-posttest model was used to reveal the changes in the views of secondary school mathematics teacher candidates regarding the use of ICT and ICT Acceptance. The main purpose of this model was to make measurements via the Technology Acceptance and Use Scale for ICT before and after the seminars on AR and geometry instruction by enabling the use of the AR technology, which was an independent variable for the target group of the research.

In the qualitative part of the research, the "phenomenology" research method was employed in order to reveal in more detail the participants' views regarding the use of AR technology in the teaching of geometry. Phenomenology focuses on phenomena, the patterns of which we are aware of but do not have in-depth and detailed understanding of. In the world we live in, phenomena can emerge in various forms such as events, experiences, perceptions, orientations, concepts, and situations (Yildirim & Simsek, 2013). After the scale and the semi-structured interviews were administered, the interpretations of the findings obtained by using various quantitative and qualitative data analysis techniques were made. In the interpretation of qualitative and quantitative data, attention has been paid to emphasize and prioritize the relationships between the results that supported each other.

1.2 Participants

The research was carried out in the fall semester of the 2016-2017 academic year in the Department of Mathematics and Science Education of the Faculty of Education at a state university in the central Anatolian region with Freshman students in the primary mathematics teacher education program. A total of 40 teacher candidates, of whom 29 were females (72.5%) and 11 were males (27.5%), participated in the study.

1.3 The Implementation Process

1.1.1 Implementation of pre-tests and providing basic information about AR

At this stage, the Technology Acceptance and Use Scale for ICT, developed by Ursavas et al. (2014), was applied. Later, various videos about how AR applications were watched, in which sectors they are used and how they can be used in education, in the training process. An environment in which the content of the videos being watched could be debated was created, and the candidates were asked how they could use the AR technology in their own fields. A written record was made of the ideas that appeared to be unique. Subsequently, the participants were asked to do a literature survey on teaching geometry via AR technology, which they were expected to complete in one week, and the first training seminar was finalized, thus increasing students' awareness in the subject their motivation towards learning about this technology was prepared.

1.1.2 Teaching the learning outcomes related to geometry and measurement using AR technology

The literature surveys done by the participants on teaching geometry via AR technology paved the way for further discussion in the second training seminar. Subsequently, a four-hour (2 hours theoretical and 2 hours application) training seminar on AR technology aided geometry teaching was given by a specialist from the department of Computer and Instructional Technologies Education. (Figure 2).

Figure 2. Information about ARGE3D software

After this training, students were separated into two groups and they were asked to prepare AR-supported geometry teaching materials based on the teaching objectives of the MNE secondary school mathematics curriculum. AR-enhanced geometry teaching materials were prepared for the use of AR technology in geometry teaching. To develop materials, the demo version of BuildAR PRO 2.0 software, developed by The Human Interface Technology Laboratory New Zealand (HIT Lab NZ), was used. This software can create marker-based and image-based marker AR environment without the need for advanced software or hardware knowledge. Instructor lecturer step-by-step describes what students should do with the help of the image they got from the computer monitor.

The teacher candidates reflected the 3D images on the computer screens they used (Figure 3) by using the data matrix data they prepared as described by the instructor.

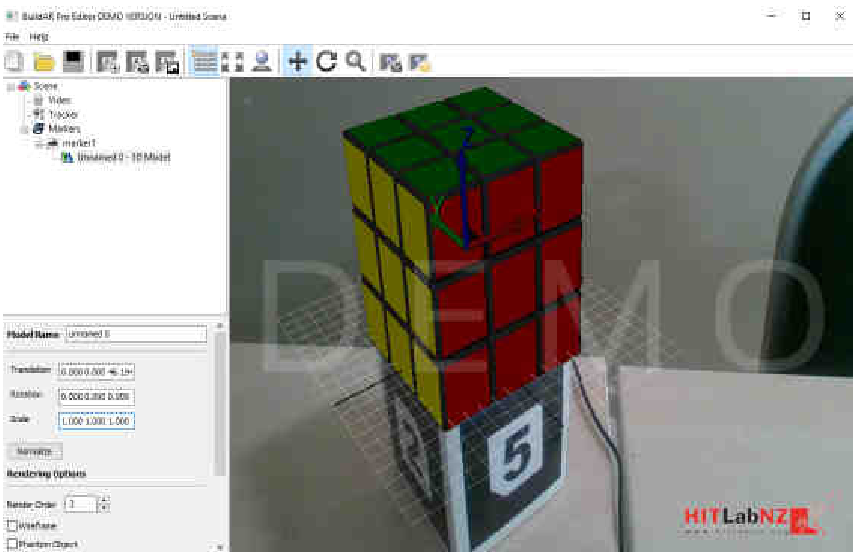

Figure 3. Development of a sample application with BUILDAR PRO 2.0

1.1.3 Implementation of target group measurement tools at the end of laboratory training

At this stage, the Technology Acceptance and Use Scale for ICT, developed by Ursavas et al. (2014), was reapplied as a post-test 4 weeks after the pre-test. Immediately after this process, the participants' opinions were obtained with the help of semi-structured interview forms on the use of AR technology in geometry teaching, prepared by the researchers. After the teacher candidates' views were collected quantitatively via the scale and their opinions regarding AR technology were elicited qualitatively so that they could be interpreted together, the next stage of organizing, analyzing and reporting all the gathered data was passed on to.

1.4 Data Analysis

First of all, the pre- and post-test data obtained from the teacher candidates were entered into the SPSS package program and the necessary analysis regarding teacher candidates' opinions was made. In the analysis of the quantitative data, the dependent groups t-Tests were carried out by checking the assumptions to find out whether there was a meaningful difference between the pre-test and post-test ICT mean scores of the Technology Acceptance and Use Scale. The dependent groups are two assumptions of the t-Test, where the point difference distributions are normal and the data are at least equally spaced data types (Field, 2009). In this study, the differences between the pre and post-test scores in each dimension of the scale were calculated. The normal distribution in the analyses was investigated by means of the Kolmogorov-Smirnov test. It was seen that the normality assumption was satisfied in all the analyses ($p > .05$).

In the analysis of the qualitative data, the content analysis was used. In the process of content analysis, the four stages, defined by Yildirim and Simsek (2013), were applied. These are coding the data, identifying themes, arranging the codes and themes, and identifying and interpreting findings. In order to increase the reliability of the qualitative data analysis, two researchers first worked independently to determine codes and themes, and then came together and discussed the codes and the proposed codes. The codes and the themes were given their final shape by arriving at a common consensus.

3. Findings

A comparison of the participants' pre-test and post-test scores on the Technology Acceptance and Use Scale for ICT is presented in Table 2:

Table 2. The t-Test results of the participants' pre-test and post-test total scores

Mean Scores	***N***	***X***	***ss***	***sd***	***t***	***p***
Pre-test	40	121.45	14.58	39	5.759	.000**
Post-test		139.85	15.77			

***:0.01*

When the teacher candidates' total scores on the Technology Acceptance and Use Scale for ICT were compared between the pre-test (X = 121.45, ss = 14.58) and post-test scores (X = 139.85, ss = 15.77) $T_{(39)} = 5.759$, $p < .01$), a significance difference in favor of post-test was found (Table 2). Based on this outcome, it can be concluded that the geometry training seminar realized via AR has a positive impact on the teacher candidates' acceptance and use of technology for ICT. The findings obtained by analyzing the data collected from the interviews conducted with the participants in order to investigate this situation were tabulated as the questions directed to them and the responses taken from them.

At the end of the training given to the teacher candidates, the initial aim was to determine whether AR technology was found easy to use by the teacher candidates, so the following questions were posed to them: "How did you find teaching AR with geometry? Can you use the AR software? Please indicate what difficulties you have experienced during the learning process." The categories, themes, and codes formed from the responses of the candidates are presented in Table 3:

Table 3. Categories, themes, and codes related to geometry teaching with the given AR

Categories	Themes	Teacher Candidates	Codes
Difficulties in Usage	It takes time to learn.	T14, T33	2
	Camera image is difficult.	T7, T11, T14, T22, T26, T33, T35,	7
	Its usage a little complicated.	T1, T2, T3, T5, T6, T8, T10, T14, T15, T16, T19, T30, T31, T32, T38	15
	I had difficulty learning.	T3, T5, T6, T10, T14, T16, T17, T19, T20, T21, T23, T24, T25, T27, T28, T30, T31, T32, T33, T34, T36, T37, T38	23
Practicality	The three-dimensional modeling is easily done.	T1, T5, T9, T12, T13, T19	6
	Concrete activities are easily done.	T1, T5, T9, T11, T12, T13, T24, T25, T39, T40	10
	It is easy to use.	T2, T4, T7, T11, T12, T13, T17, T18, T23, T26, T29, T34, T37, T40	14
	It was easy to learn.	T1, T2, T3, T6, T8, T9, T10, T25, T31, T32, T33, T35, T36, T39, T40	15
Attitude towards its Usage	I am thinking about using it in the future.	T15, T16, T19, T26, T28, T29, T30	7
	It is a good practice.	T1, T3, T4, T9, T11, T14, T15, T19	8
	It is a fun practice.	T4, T8, T16, T17, T19, T25, T37	7
	It offers instructional convenience.	T1, T3, T4, T8, T12, T15, T19, T28, T29, T39	10
	The training provided was useful.	T1, T2, T3, T4, T5, T6, T7, T8, T11, T12, T15, T16, T17, T18, T20, T21,	16
3 Categories	**13 Themes**		**146**

According to the coding of the responses obtained from the question about how they found the AR geometry training given to the participants, 13 different themes were reached under three categories. The categories of the themes were named by the researchers as Difficulties in Usage, Practicality, and Attitude towards its Usage. Approximately half of the teacher candidates (23/40) stated that they experienced difficulty in learning the augmented reality technology. However, 8 of these 23 teacher candidates (T3, T6, T10, T25, T31, T32, T33, T36) indicated that the process was easy once it was learnt. This was valid for the other three pre-service teachers (T1, T2, T8) who had found it complicated to use at first. In general, it can be deduced that 11 of the teacher candidates participating in the process could easily use the system and 15 of them could do so after learning how to use it. The fact that more than half of the teacher candidates expressed that augmented reality technology can be used by teachers in geometry teaching. While some teacher candidates reported to be experiencing problems in taking pictures with the camera during the process, only two teacher candidates stated that it took a long time to learn this application. Approximately half of the teacher candidates (n = 19, T1, T3, T4, T8, T9, T11, T12, T14, T15, T16, T17, T19, T25, T26, T28, T29, T30, T37, T39) were found to have the intention to use augmented reality technology in geometry teaching. 9 teacher candidates (T1, T2, T4, T8, T11, T12, T15, T16, T17) were among the group (n=16) who thought this training seminar was helpful. This fact indicates that teachers and teacher candidates should be given the opportunity to integrate these and similar technologies into instructional environments.

Some of the participants' views regarding the category of Difficulties in the Usage of AR technology can be exemplified as follows:

T14: "The training process was not easy for me because I did not know the software. I had some difficulties in the learning process. I specifically had problems reading the data matrix that we printed out and opening more than one program."

T11: "The training provided was very efficient. The technique was different from the classical learning techniques. It will be very effective in making abstract geometry and mathematics knowledge more concrete. It's easy to use once one listens carefully to what is explained. As far as I can tell, the only difficulty that can be encountered is that the camera cannot recognize the markers."

T19: "It's a good practice and an application that makes it easier for children to learn. I experienced difficulty while doing the operations, but it was fun. I'd like to use this practice in the future during my lessons to the students if, hopefully, I will become a teacher. It was a really good practice from the aspect of both myself and children."

Some of the participants' views regarding the category of Practicality of AR technology can be exemplified as follows:

T12: "The elementary school students' ability to think in three dimensions with this system will develop.

Lessons will be more understandable and productive and a more successful generation of students will be created. Students will not have difficulty in classes. These will accelerate the development of students."

T36: "The training was conducted with understandable and simple language. We can easily do it ourselves too. That it has several phases make it a bit challenging, but it's repeated several times, it becomes easy to do."

T40: "Considering the present conditions, this education is a very successful system because today, interest in technology is growing at an incredible speed, especially among the new generation. I understood that it was easy to learn. I think it will be very effective in making difficult lessons more comprehensible. In the learning process, as long as the lecturer is good, it will be understood without experiencing a big problem. I learned easily."

In the category of Attitudes toward its Usage category, some of the participants' opinions can be exemplified as follows:

T3: "I liked the training that was given. I believe that it will facilitate my future life. I experienced some difficulty when using the software for the first time, but as I learned, I actually understood what I could do."

T15: "I did not have difficulty in the learning process. It was easy to use. I think it would be more efficient in lessons that involve shapes, such as mathematics and geometry, because it enables us to visualize the shapes in our minds more easily."

T17: "The training was good. I could use it easily after I got used to it. The difficulties were actually due to lack of knowledge. I think it was fun."

At the end of the training given to the prospective teachers, the second question that was posed to them was as follows: "What are your positive thoughts on geometry teaching supported by AR materials in secondary school mathematics courses? (In terms of teacher and student) ". The categories, themes, and codes generated from the responses obtained from candidates are presented in Table 4:

Table 4. Positive thoughts on geometry teaching supported by AR materials

Categories	**Themes**	**Teacher Candidates**	**Codes**
Learning	Enables active learning.	T23, T25	2
	Provides the advantage of visual learning.	T15, T25, T27	3
	Enables quick learning.	T10, T12, T13, T16, T25, T33	6
	Provides lasting learning outcomes.	T17, T22, T25, T27, T32, T37	6
	Makes learning fun.	T13, T16, T17, T23, T24, T25, T26, T32, T35, T40	10
	Enables geometry to be convenient for students.	T1, T3, T4, T5, T6, T7, T9, T10, T15, T20, T25, T26, T28, T31, T35, T36, T39	17
Teaching	Saves time.	T13, T29	2
	Makes abstract concepts concrete.	T11, T12, T20, T21, T22, T23, T27, T36, T37	9
	Facilitates the teaching of geometry.	T1, T2, T5, T6, T9, T10, T14, T15, T20, T32, T35, T36	12
Contribution to Cognitive and Affective Activities	Enhances imagination.	T18, T25, T27, T30, T34, T38, T40	7
	Increases the interest of the learner.	T4, T5, T8, T11, T12, T13, T14, T16, T24	9
	Facilitates visualization in the mind of the learner.	T3, T5, T6, T7, T8, T13, T14, T18, T20, T24, T28, T32, T38	13
	Enables three-dimensional thinking.	T12, T15, T16, T17, T18, T19, T23, T24, T26, T28, T29, T30, T31, T32, T36, T37, T38	17
Usefulness	Can be used in other lessons.	T25, T32, T37	3
	Is useful as material.	T9, T14, T22, T32	4
4 Categories	**15 Themes**		**120**

As a result of the encodings of the responses obtained from the participants who have the positive opinions about geometry teaching supported with the given AR materials, 15 different themes were reached under four categories. The categories of the themes were named by the researchers as Learning, Teaching, Contribution to Cognitive and Affective Activities, and Usefulness. Teacher candidates expressed that the AR materials were especially helpful in the process of learning and teaching and that this process was fun. It was stated by prospective teachers that they would also help students in the development of spatial thinking skills, and that they could also be used in different courses.

Some of the participants' views regarding the learning category can be illustrated as follows:

T23: “I think this application is advantageous. Students can see the objects more easily by seeing them in 3D. It can make the lessons more fun and make the students more active.”

T33: “In terms of students, I think that geometry will be of great help in understanding three-dimensional shapes.”

T36: “It will be easier and more convenient for students to think in 3D. The geometry lesson will no longer be a nightmare.”

Some of the participants' views regarding the teaching category can be illustrated as follows:

T1: “I think it will provide a lot of conveniences in the field of geometry. When we show something to the students, we can easily show it with this application instead of going to the great efforts to make a shapes with boxes.”

T20: “Since I assume that I will have difficulty in explaining to the students three-dimensional objects when I am a teacher, I think that this program will make it easier for the teacher to ensure that students understand because it's really hard to explain these shapes by drawing them. When we first learned it, we also had difficulty in perceiving it. So it is a very good application.”

T29: “I think that using these materials in secondary school mathematics lessons will enable teachers to transfer knowledge and skills efficiently while developing students' three dimensional thinking skills. In addition, I think they can manage time more effectively.”

Some of the participants’ views as regards the category of contribution to cognitive and affective activities can be illustrated as follows:

T18: “The presence of geometry teaching supported by augmented reality materials enhances the imagination of students. It is difficult for students to visualize the shapes they see in 3D, but they can visualize 3D shapes more easily [with this application].”

T24: “It's a great application for students to visualize shapes. It makes learning both enjoyable and easy. ıt can attract children’s interest.”

T32: “First of all, since the students in the elementary school are very fond of games on the computer or the Internet, this activity will attract them. Then since seeing and studying these shapes in math lessons will make them feel like they are playing games, it will enable them to like and enjoy the lesson. Since seeing shapes in 3D will reinforce their presence in long-term memory, it will also increase their success in the course. Teachers will not have to worry about keeping and preserving course materials.”

T34: “It’s a nice software for students, especially for students with a low level of imagination.”

Some of the participants’ views on the usefulness category can be illustrated as follows:

T9: “It’s a technology that the teacher can use to teach a shape throughout the whole year to enable students to easily comprehend and clearly see all the sides and details.”

T26: “Such an application is specifically appropriate for elementary school students. I think many students will be pleased when they are introduced to this application. I would consider this type of learning fun. When applying the AR software, I felt like I was playing with a toy. I wish we had had it in my time period [elementary school years] too.”

T37: “Especially in geometry lessons it is very difficult for students to think in three dimensions. By using AR materials, we are making abstract concepts concrete in the minds of students. This makes it easier for students to understand and love the lessons. I think it can be used in different lessons too.”

At the end of the training given to the prospective teachers, the third question posed to them was "What are your negative thoughts about geometry teaching supported by AR materials in secondary school mathematics courses?

(In terms of teacher and student) ". The categories, themes, and codes formed from the responses obtained from the candidates are presented in Table 5.

Table 5. Negative opinions regarding geometry teaching supported by AR materials

Categories	Themes	Teacher Candidates	Codes
Difficulties in Implementation	It can adversely affect other courses.	T8, T21	2
	The teacher needs a lot of time.	T2, T6, T7	3
	It cannot be measured with an exam.	T2, T18, T23, T25	4
	It is difficult to use on slow computers.	T4, T26, T32, T39	4
	Students can deviate from the purpose of its usage.	T11, T12, T18, T21, T30, T35, T36, T39	8
	It is difficult to learn.	T17, T19, T20, T21, T29, T31, T37, T39	8
	The teacher's learning process is time-consuming.	T6, T7, T9, T10, T14, T16, T21, T22, T24, T25, T26, T27, T37	13
Health Problem	Eye health	T3, T9, T28, T32, T35	5
2 Categories	**7 Themes**		**47**

Seven different themes were reached under two categories as a result of the encodings of the participants' answers obtained from their negative opinions about geometry teaching supported by the AR materials given. The categories of the themes were named by the researchers as Difficulties in Implementation and Health Problems. Compared with the other categories and themes, it was seen that the teacher candidates did not report many negative opinions about the AR materials. The most important problem reported was its being time-consuming for the teacher to learn. At this point, the importance of the training to be given to prospective teachers at the graduate level emerges once again.

Teacher candidates' negative views of AR technology can be exemplified as follows.

T4: "I think the only negativity would derive from a slow computer."

T6: "The disadvantages of teaching geometry with AR materials are the loss of time loss in terms of teachers who do not know how to use this software. If they cannot use it correctly, they can suffer various troubles because it looks like it will take some time to get used to it."

T7: "It is actually a program that will make it easier for students to perceive [the shapes], but it can disrupt the flow and speed of the course."

T9: "For those who do not know how to use a computer, there may be some difficulty at first. It can be a problem for those with visual impairments. One hundred percent success may not be achieved by everybody."

T21: "It can be a little time-consuming and when teachers do not constantly lecture on the computer, the students can take this opportunity to disrupt the lesson."

4. Discussion, Conclusion, and Implications

This research led to the conclusion that applied AR technology-enhanced computer laboratory training were effective and efficient for the participants' acceptance and use of technology. Teacher candidates stated that they had difficulty learning AR applications, but they were easy to use once learnt. It is quite natural for them to experience difficulty at first because the technology is new to them and they have yet to complete the necessary training in information technologies. Moreover, the fact that the process is found to be easy after the training reveals how easy it is to learn and use AR technology. While teacher candidates also expressed that the AR applications were nice and fun applications that facilitate teachers' job, there were also teacher candidates who stressed that they intended to use the application in the future. This suggests that AR education and its applications have a very positive effect on teacher candidates. González (2015) states that AR-enhanced geometry instruction makes lessons fun and transforms the lesson into a pleasant learning environment by preventing boredom. It was derived from qualitative research data that a significant portion of the students find

AR-enhanced teaching fun. Lin et al. (2016) have stated that teachers' learning process and learning activities may be difficult due to lack of technological knowledge, but can overcome this difficulty by using programs such as Aurasma.

Teacher candidates stated that AR application is very convenient in teaching geometry for both students and teachers and it helps to think in three dimensions. However, they stressed that it will take time for teachers to learn and adapt to this technology. Effective in-service training will be needed at this point for on-the-job teachers. On the other hand, teacher candidates in their pre-service training should undergo training on such applications in their undergraduate programs such as Computer, Special Teaching Methods and Teaching Technologies and Material Design. It is believed that such technology-enhanced training given during the teacher training process can directly affect the quality of the training of the candidate teachers who will be assigned to different regions in Turkey to carry out their teaching profession. For this reason, the impact of this type of research is widespread. In addition, it is possible to replicate this research, which is limited to the target undergraduate students of education department undergraduate program, with the students and faculty members of other faculties by focusing on different aspects of different topics. It is believed that the given AR technology training will lead to a sound implementation of the technology in academic units, courses and, if necessary, throughout the university. In this way, students and faculty members from different faculties can be encouraged to develop their techno-pedagogical qualifications.

As a result of the present research, it was found that the teacher candidates had higher post-test scores than the pre-test scores when the total scores of the Technology Acceptance and Use Scale for ICT were compared, and this difference was found to be statistically significant. Based on this finding, it can be concluded that an AR-enhanced geometry training seminar positively affects teacher candidates' acceptance and use of technology in terms of ICT. Interviews were also held with participants to gain in-depth information. The interview findings were classified under 9 categories and 35 themes in total. According to the results obtained, it was noteworthy that positive opinions were more prevalent than the negative opinions about the use of the AR technology in the teaching of geometry by the candidate teachers. Lin, Chen and Chang (2015) have found that individuals with low academic achievement in solid geometry have a higher level of positive attitudes towards the usefulness of the AR system than individuals with high academic success. For this reason, that it was not possible in the present study to examine the individuals' attitudes towards AR in terms of different variables can be considered as a limitation. Wu, Lee and Chang (2013) point out that AR offers new learning opportunities but also introduces new challenges for educators. Similarly in the current study, that some of the teacher candidates believed that AR would impose additional workload to the teachers emerged as a limitation of AR technology.

As Pajares (1992) emphasizes, teachers' identities and belief systems influence teaching. On the other hand, the vision of the Turkish education system of was expressed by the Ministry of Education (2013) as to integrate the education system with advanced technologies, to support with innovations, to continuously evaluate and evaluate them, to provide student-centered and project-based education using information technology. In this respect, the role of teacher and teacher candidates is of great importance, especially as they are practitioners of technology integration in classroom learning and teaching activities. The primary aim is to shift these applications to the university environments. Thus, it is believed that awareness of AR technology, which is one of the most up-to-date technologies, and using it in one's own field will shed light on the studies conducted specifically in other departments of our university and in all education faculties in the country. Quintero et al. (2015) pointed out that in terms of integrating class activities into the teaching process, AR should be used meaningfully.

References

Aktaş, C. (2014). *QR kodlar ve iletişim teknolojisinin hibritleşmesi*. İstanbul: Kalkedon Yayınları.

Alqahtani, M. M., & Powell, A. B. (2016). Instrumental appropriation of a collaborative, dynamic-geometry environment and geometrical understanding. *International Journal of Education in Mathematics, Science and Technology, 4*(2), 72-83.

Azuma, R. T. (1997). A survey of augmented reality. *Presence, 6*(4), 355-385.

Baki, A., Kösa, T. & Karakuş, F. (2008). *Uzay geometri öğretiminde 3D dinamik geometri yazılımı kullanımı: Öğretmen görüşleri*. VIII. Uluslararası Teknoloji Konferansı, Eskişehir.

Başar, M., Ünal, M. & Yalçın, M. (2002). *İlköğretim kademesiyle başlayan matematik korkusunun nedenleri*. V. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi'nde sunulmuş bildiri. Orta Doğu Teknik Üniversitesi, Ankara.

Battista, M. T. (2001). A research-based perspective on teaching school geometry, *in Jere Brophy (ed.) Subject-specific* *instructional methods and activities* (Advances in Research on Teaching, Volume 8) Emerald Group Publishing Limited, pp.145-185

Cheng, K.H., & Tsai, C.C. (2012). Affordances of augmented reality in science learning: Suggestions for future research. *Journal of Science Education and Technology, 14*(1), 449-462.

Creswell, J. W. (2012). *Collecting qualitative data. Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. Boston: Pearson.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research* (2nd ed.). United States of America: SAGE Publications, Inc.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), 319-340.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science, 35*(8), 982-1003.

Dede, Y. & Argün, Z. (2004). Öğrencilerin matematiğe yönelik içsel ve dışsal motivasyonlarının belirlenmesi. *Eğitim ve Bilim, 13*(4), 49-54.

Elford, M. D. (2013). *Using tele-coaching to increase behavior-spesific praise delivered by secondary teachers in augmented reality learning environment*. Unpublished doctoral dissertation, University of Kansas, The United States.

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention and behavior: An introduction to theory and research*. Reading, MA: Addison-Wesley.

Fritz, F., Susperregui, A., & Linaza, M. T. (2005). *Enhancing cultural tourism experiences with augmented reality technologies*. 6th International Symposium on Virtual Reality, Archaeology and Cultural Heritage (VAST).

Fujita, T., & Jones, K. (2007). Learners' understanding of the definitions and hierarchical classification of quadrilaterals: Towards a theoretical framing. *Research in Mathematics Education, 9*(1), 3-20.

González, N. A. A. (2015). *How to include augmented reality in descriptive geometry teaching*. Procedia Computer Science, 75, 250-256.

İbili, E. & Şahin, S. (2015). Artırılmış gerçeklik ile interaktif 3d geometri kitabı yazılımın tasarımı ve geliştirilmesi: ARGE3D. *Afyon Kocatepe Üniversitesi Fen ve Mühendislik Bilimleri Dergisi, 13*(1), 1-8.

İbili, E. (2013). *Geometri dersi için artırılmış gerçeklik materyallerinin geliştirilmesi, uygulanması ve etkisinin değerlendirilmesi*. Yayımlanmamış Doktora Tezi, Gazi Üniversitesi, Eğitim Bilimleri Enstitüsü, Ankara.

Johnson, L., Smith, R., Willis, H., Levine, A., & Haywood, K. (2011). *The 2011 Horizon Report. Austin, TX: The New Media Consortium*. http://www.educause.edu/Resources/2011HorizonReport/223122 erişim tarihi 11.09.2016

Karasar, N. (2005). *Bilimsel araştırma yöntemi*. Ankara: Nobel Yayın Dağıtım.

Kazancı, A. & Dönmez, F.İ. (2013). *OKUL2.0 Eğitimde sosyal medya ve mobil uygulamalar*. Ankara: Anı Yayıncılık.

King, W. R., & He, J. (2006). A meta-analysis of the technology acceptance model. *Information & Management, 43*(6), 740-755.

Koyuncu, B. & Bostancı, E. (2007). *Virtual reconstruction of an ancient site: Ephesus*. XIth Symposium on Mediterranean Archeology, 233-236.

Küçük, S., Yılmaz, R., Baydaş, Ö. & Göktaş, Y. (2014). Ortaokullarda artırılmış gerçeklik uygulamaları tutum ölçeği: Geçerlik ve güvenirlik çalışması. *Eğitim ve Bilim, 39*(176), 383-392.

Le, H. Q., & Kim, J. I. (2016). An augmented reality application with hand gestures to support studying geometry. *Korea Computer Graphics Society*, 160-161.

Lee, C. Y., & Chen, M. J. (2014). The impacts of virtual manipulatives and prior knowledge on geometry learning performance in junior high school. *Journal of Educational Computing Research, 50*(2), 179-201.

Legris, P., Ingham, J., & Collerette, P. (2003). Why do people use information technology? A critical review of the technology acceptance model. *Information & Management, 40*(3), 191-204.

Lin, C. Y., Chai, H. C., Wang, J. Y., Chen, C. J., Liu, Y. H., Chen, C. W., Lin, C.W., & Huang, Y. M. (2016). Augmented reality in educational activities for children with disabilities. *Displays, 42*, 51-54.

Lin, H. C. K., Chen, M. C., & Chang, C. K. (2015). Assessing the effectiveness of learning solid geometry by using an augmented reality-assisted learning system. *Interactive Learning Environments, 23*(6), 799-810.

Milli Eğitim Bakanlığı (MEB) (2013). *Ortaokul matematik dersi (5, 6, 7 ve 8. sınıflar) Öğretim Programı*. Ankara: Devlet Kitapları Müdürlüğü.

Önal, N. (2013). Ortaokul öğrencilerinin matematik tutumlarına yönelik ölçek geliştirme çalışması. *İlköğretim Online, 12*(4), 938-948.

Önal, N. (2016). Development, validity and reliability of TPACK scale with pre-service mathematics teachers. *International Online Journal of Educational Sciences, 8*(2), 93-107

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research*, 62(3), 307-333.

Quintero, E., Salinas, P., González-Mendívil, E., & Ramírez, H. (2015). Augmented reality app for calculus: A proposal for the development of spatial visualization. *Procedia Computer Science, 75*, 301-305.

Saravani, S.A., & Clayton, J.F. (2009). *A conceptual model for the educational deployment of QR codes. In Same places, different spaces*. Proceedings ascilite Auckland 2009. http://www.ascilite.org.au/conferences/auckland09/procs/saravani.pdf.

Somyürek, S. (2014). Öğretim sürecinde Z kuşağının dikkatini çekme: Artırılmış gerçeklik. *Eğitim Teknolojisi Kuram ve Uygulama, 4*(1), 63-80.

Squire, K. D., & Jan, M. (2007). Mad City Mystery: Developing scientific argumentation skills with a place-based augmented reality game on handheld computers. *Journal of Science Education and Technology, 16*(1), 5-29.

Pişkin Tunç, M., Durmuş, S. & Akkaya, R. (2012). İlköğretim matematik öğretmen adaylarının matematik öğretiminde somut materyalleri ve sanal öğrenme nesnelerini kullanma yeterlikleri. *Matematik Eğitimi Dergisi, 1*(1), 13-20.

Ursavaş, Ö. F., Şahin, S., & McIlroy, D. (2014). Technology acceptance measure for teachers: T-TAM/Öğretmenler için teknoloji kabul ölçeği: Ö-TKÖ. *Eğitimde Kuram ve Uygulama, 10*(4), 885-917.

Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & Education, 62*, 41-49.

Yıldırım, A. & Şimşek, H. (2013). *Sosyal bilimlerde nitel araştırma yöntemleri* (9. Baskı). Ankara: Seçkin Yayıncılık.

Yolcu, B. & Kurtuluş, A. (2010). Altıncı sınıf öğrencilerinin uzamsal görselleştirme yeteneklerini geliştirme üzerine bir çalışma. *İlköğretim Online, 9*(1), 256-274.