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Effectiveness of Augmented Reality-Based Applications on Liquid Measurement Theme in Mathematics Course: An Experimental Study

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Abstract

This research examines augmented reality-based applications prepared for primary school third grade students concerning academic achievement and anxiety in a mathematics course. A quasi-experimental design, one of the experimental research designs, with a pretest-posttest control group was preferred in this study. The research group of the research consisted of 26 students attending grade 3 in a school in Siirt during the 2020-2021 academic year. Participants were determined as two different groups, 13 of which were experimental and 13 of which were control groups. In the research, AR-based applications were designed for various gains aimed at the "Liquid measurement" theme in the mathematics course, and these applications were presented to the students through the tablet. These applications were conducted during five weeks, including pre and post-test. Research data were collected through data sets obtained from achievement test and anxiety scale that were carried out before and after the application. Findings of the research indicate that there is a significant difference between the experimental and control groups in favor of the experimental group. It was found that augmented reality-based applications increased the academic achievement of the experimental group students and reduced their anxiety levels concerning the mathematics lesson.

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INTRODUCTION

Mathematics is one of the important branches of science that contributes to the development of science and technology. Mathematics is not just dealing with daily life problems but also helps individuals develop their creativity and imagination; in addition, strengthening their intuition, making them think logically while generating new ideas, and gaining the ability to solve challenging problems are some of the benefits that mathematics provides to individuals (Kusmaryono, 2014; Khan, 2015). Starting from primary school age, students need to master some basic subjects in mathematics, which have a significant role in the development and transformation of civilizations. Understanding these essential topics will help individuals understand higher-level mathematical concepts that they will encounter in the future. For this reason, mathematics education is underlined in the curriculum and education agenda, as it helps further learning and is essential in daily life (Milton, et al., 2007; Kelanang & Zakaria, 2012; Kusmaryono, 2014).

Students are terrified of mathematics, which has such an important place in daily and academic life, and this fear drags them to mistakes. One of the biggest reasons for this fear is that they believe in some stereotypes from the past. Some of these stereotypes are such as that mathematics is very difficult by its nature and that it is not possible to have information about all of it even if desired, that success in mathematics can be achieved with hereditary abilities rather than effort, that mathematics is a field specific to men and that it is not possible for women to be successful even if they wanted to be (Ernest, 2005). These stereotypes acquired through hidden educational programs negatively affect students' attitudes towards mathematics, reduce their academic achievement, and cause them to feel anxious about mathematics (Yenilmez, et al., 2004; Ernest, 2005).

Mathematics anxiety is generally defined as a feeling of tension, worry, and fear related to math performance (Lyons & Beilock, 2012). The mathematics performance of individuals with math anxiety is poor due to their anxiety and fear. (Mutlu & Söylemez, 2018). Maloney & Beilock (2012) state that a certain amount of anxiety and stress in primary education can increase performance, and an increase in this amount will negatively affect performance. It is also stated that this anxiety, which starts in primary school years, increases parallel with the following educational levels (Jackson & Leffingwell, 1999; Cited in Istikomah & Wahyuni, 2018). Studies in the literature indicate that many elementary school students are suffering from mathematics anxiety (Taşdemir, 2015; Tatlı, et al., 2016; Mutlu et al., 2017), and this situation indirectly affects academic achievement negatively (İlhan & Sünkür, 2013; Zhang, Zhao, & Kong, 2019).

Considering the contributions it provides to individuals, in order to raise students who are successful in mathematics, who have a positive attitude towards the course and are free from anxiety, it is necessary to take measures to eliminate the existing judgments about this subject area and to teach the courses using more entertaining methods that will keep students away from anxiety. In order to reduce students' math anxiety, it is necessary to eliminate these problems of teachers who have math anxiety. It is stated that teachers with mathematics anxiety only teach the courses by adhering to the course materials, and therefore they cause students to acquire only basic skills and keep discussion activities at a very superficial level. In addition, it was stated that these teachers had fewer skills in applying different strategies in mathematics education (Chopin, 2011; Swars, et al., 2007). It should be noted that meaningful learning experiences can be achieved in fun environments where creativity allows students to participate actively (Mulwa, 2015).

It is thought that one of the ways to make students stay away from this stress and anxiety and become more willing to the mathematics course is to benefit from technological resources. Some studies in the literature confirm these assumptions (Sun & Pyzdrowski, 2009; Barry, 2017; Chen, 2019). However, when the methods adopted by teachers in teaching mathematics are examined, it is evident that technology is not much involved in this process. Aktepe, et al., (2015) stated in their research that the methods mostly used by teachers in mathematics teaching are direct instruction technique,

question-answer, and problem-solving methods, while the least used methods are drama, group teaching, and project making. Topçu, et al., (2014) stated in their study with pre-service teachers that the use of technology-based educational games would be beneficial in teaching mathematics, but added that they did not feel adequately equipped for the application.

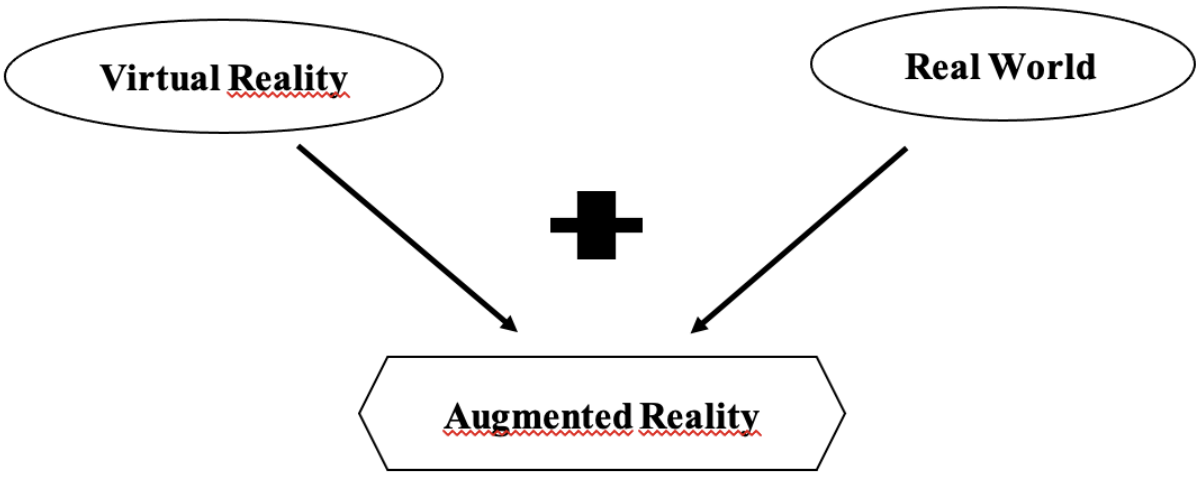
The use of technology-based activities that can excite students more in the abstract and difficult to understand mathematics subjects increases academic success and facilitates mathematics teaching (Cheung & Slavin, 2013). Significantly, the fact that unique contents for each student can be design by using technology and that the program prepared afterward is determined by considering the student data obtained in this process helps students learn mathematics at their own pace. In order to realize these advantages and increase students' mathematics achievement, many schools have started to allocate a large amount of their spending to educational technologies (Kitchen & Beck, 2016). Due to the fact that inclusion of technology into learning environments brings many positive results, this study examines the effect of AR-based applications on the anxiety and achievements of third grade students regarding mathematics courses.

LITERATURE REVIEW

AUGMENTED REALITY

Augmented reality (AR) is defined as transferring virtual objects enriched with visuals created in computer environments to the real-world environment (Chen et al., 2019). Intelligent imaging technology, 3D recording technology and intelligent interaction technology are defined as the core technologies that form the source of AR (Chen et al., 2019). In order for an application to be AR-based, it must provide three essential features. These are; bringing together natural and virtual objects in real environments, being interactive and real-time applications, and harmonizing virtual and real objects (Azuma et al, 2001). Although AR and virtual reality (VR) seem like similar concepts, they have different structures. While the difference between actual and simulated universes can be explained to individuals in AR environments, such a thing is impossible in VR environments (Shoaib & Jaffry, 2015). VR applications are about entering an artificial environment created in a computer environment rather than in the natural universe, which helps individuals gain some psychological and sensory experiences (Bohil, et al., 2009). The nature of the relationship between AR and VR is presented below with a simple illustration.

Figure 1. *The simple relationship between AR and VR*



(Adapted from Shoaib & Jaffry, 2015).

In Figure 1, it is evident that the virtual and real universe come together to form the AR environment.

USE OF AUGMENTED REALITY IN EDUCATION

Today, technological tools and applications have begun to be used in medicine and engineering, from scientific research to art activities. Augmented reality-based applications have also taken their place in this process, which is constantly in rapid change, and has begun to be used in many areas (Yılmaz & Göktaş, 2018; Chen, 2019; Kapur, 2019). One of the areas where augmented reality technologies are used is the field of education. Yuen, Yaoyuneyong, and Johnson (2011) stated that five of the most critical augmented reality-based technologies used in educational applications are AR-based books, AR games, discovery-based learning, object modeling, and skills training. Among these technologies, it is stated that AR-based books and games have a structure that excites students and educators and offers students interactive experiences (Kraut & Jeknic, 2015; Sural, 2018). It is stated that the discovery-based learning process will help students to see historical places as if they are reasoned, thus strengthen their knowledge of history (Efstathiou, et al. , 2017). In terms of skill exercises, AR technologies allow individuals to easily do experiments that are unlikely to be done in real life or lead to high costs, even if they can be done without much cost. Students argue that it is difficult to understand because there are too many abstract concepts, especially in courses such as science, and that visualization should be increased to achieve a deeper understanding. On the other hand, the cost of applications and experiments will be reduced (Saidin, et al., 2015). In object modeling, it is thought that individuals can transfer any object that they are curious about to the AR environment, it enables them to have detailed information about the object's physical properties and interact with the object. This convenience provided by AR technologies can allow individuals to understand the concepts they encounter more efficiently, especially in courses where abstract concepts such as science and mathematics are abundant. Research shows that AR-based applications are effective methods for concretizing abstract concepts (Sayed, et al., 2011; Özdemir, 2017; Tulgar, 2019). When the studies in geometry are examined, it is observed that the students who interact with the objects created in the virtual environment through AR-based applications are more encouraged about the course (Liarokapis, et al., 2002).

MATHEMATICS ANXIETY

Almost all people give different emotional reactions to everyday situations, such as fear or anxiety, in the normal course of life. However, in some people, these reactions can reach dimensions that are more severe, do not decrease over time, and negatively affect daily life. This situation is expressed as anxiety (Bamber & Schneider, 2016; The National Institute of Mental Health, 2016). The concept of anxiety is generally defined as the reaction of people to any threat or danger. When people feel anxiety or perceive any danger, they have thoughts about harm and this causes individuals to be physiologically or psychologically alarmed (Moss, 2002). Anxiety disorder is expressed as the most common or frequently occurring mental disorder (Adwas et al., 2019). Individuals can experience anxiety about many things. Especially in the early stages of school age, individuals may experience a general anxiety about lessons that are difficult to understand. Mathematics can be defined one of these courses (Tooke & Leonard, 1998).

Mathematics anxiety is a problem that can negatively affect children's academic achievement and their prospects for employment in the future (Ramirez et al., 2016). Individuals whose anxiety levels increase when they encounter mathematical stimuli are in a more disadvantageous situation compared to other individuals in the exams they take, and this negatively affects their performance in the exam (Lebens et al., 2011). The most dominant feature of individuals with math anxiety is to avoid math. Individuals exhibiting avoidance behavior in situations related to mathematics may have fewer opportunities to improve their mathematics skills. This attitude of individuals causes them to enter a vicious circle at the point of experiencing difficulties in mathematics. In order to eliminate this vicious circle, it is necessary to take measures to prevent the occurrence of math anxiety in individuals at an early age (Ashcraft & Moore, 2009; Dowker et al., 2016).

MATHEMATICS ANXIETY AND TECHNOLOGY

Mathematics anxiety is defined as panic, feeling helpless, paralyzed and not feeling mentally ready when individuals need to solve any mathematical problem (Tobias & Weissbrod, 1980; Cited in Mitchell, 2018). The basic characteristics of individuals' math anxiety; avoidance, lack of perseverance, rigidity and resistance to change (Kulkin, 2016).

Mathematics anxiety, which is defined as an emotional factor in the related literature, is stated as one of the biggest obstacles to students' liking mathematics (Shen, 2009). This makes it necessary to see math anxiety as a problem to be overcome. Overcoming this anxiety is seen as an important recipe for students to be successful in mathematics and to pave the way for their development (Bolaer, 2008). When some of the studies conducted to eliminate mathematics anxiety are examined, it is seen that many researchers suggest different methods (Burton, 1984; Stuart, 2000; Geist, 2010; Hellum-Alexander, 2010; Alkan, 2013). Technology-based education is also one of the methods that helps to eliminate math anxiety (Sun & Pyzdrowski, 2009; Istikomah & Sakinah, 2013; Soewardini et al., 2019; Wangid et al., 2020).

THE SIGNIFICANCE AND PURPOSE OF THIS STUDY

With the constant advancement of technology, some changes occur in learning environments. The primary purpose of learning environments in our age is to enable individuals to access information and to adapt to technological developments that will enable them to use this information (Seferoğlu, 2009). It is stated that augmented reality-based environments offer enriched learning environments that will facilitate access to information for students (Dunleavy & Dede, 2014). From this point of view, it is assumed that using AR-based technologies in educational environments will provide positive results in gaining many skills. Various studies in the literature indicate that AR-based applications increase the academic success and motivation of individuals (Diegmann, et al., 2015; Cheng & Tsai, 2016; Tobar-Munoz, et al., 2017; Sırakaya & Çakmak, 2018; Wahyu, et al., 2020; Danaei, et al., 2020) and provide more interactive learning environments (Cheng, 2017; Arvanitaki & Zaranis, 2020).

It is stated that especially in subject areas such as mathematics, which contain a lot of abstract concepts and where visualization is thought to be more than other subject areas, it increases students' interest and understanding levels provides more successful results compared to traditional methods (Demitriadou, et al., 2019; Arvanitaki & Zaranis, 2020) and increases spatial thinking skills and mathematics achievement (Amir, et al., 2020). The thought that mathematics anxiety would not be high at primary school level has led to limited research in this area (Mutlu & Söylemez, 2018). However, it is thought that identifying and eliminating the problems that students have with mathematics at the primary school level will contribute to the training of successful students with positive attitude towards mathematics in the future.

In the light of the above information, it is seen that AR supports concretizing the abstract concepts in the mathematics course and gaining a positive attitude towards mathematics. However, it has been observed that the number of researches on AR at primary school 3rd grade level is low in Turkey. With this study, it is aimed to fill this gap in the literature.

Since it is known that many students have mathematics anxiety and therefore experience various problems (Harari, et al., 2013), this study aims to determine what kind of effects augmented reality-based applications have on primary school third grade students' math anxiety and academic achievement. For this purpose, answers to the following questions were sought:

1. Do AR applications affect the math course success of third grade students?
2. Do AR applications affect third grade students' math anxiety level?

METHOD

RESEARCH DESIGN

An experimental research design was conducted in this study to examine the effects of augmented reality-based applications on math anxiety and academic achievement levels of third grade students. In experimental designs, experimental and control groups are determined, intervention is applied to the experimental group, the lesson is routinely taught with the control group and the outputs are compared (Creswell, 2012; Karasar, 2007; Ocak, 2019). The purpose of these procedures is to identify the effect of the intervention program on the process (Punch, 2013). Experimental research is one of the most widespread methods in educational research in terms of presenting new information to the literature (Cook et al., 2008). In this study, a quasi-experimental design, one of the experimental research designs, with a pretest-posttest control group was preferred. In educational researches where new designs are applied, school administrators often do not allow the determination of random groups (Büyüköztürk et al., 2011).

Table 1. *Experimental design steps*

Group	*Pre-test*	*Intervention*	*Post-test*
Experiment	Math Achievement Test Math Anxiety Scale	Math syllabus of augmented reality-based activities	Math Achievement Test Math Anxiety Scale
Control	Math Achievement Test Math Anxiety Scale	Routine syllabus	Math Achievement Test Math Anxiety Scale

SAMPLE

The research participant group consists of 26 students attending the third grade of a primary school in the Southeastern Anatolia Region. Participants were determined as two different groups, 13 of which were experimental and 13 of which were control groups. The distribution of the participants by gender in the context of groups is presented on Table 2.

Table 2. *Research participant group*

Group	*Female*	*Male*	*Total*
Experiment	7	6	13
Control	6	7	13
Total	13	13	26

The fact that schools were usually closed during the pandemic made the data collection process very difficult. Such difficulties hinder the efficient progress of research. For this reason, the convenience sampling method was used to obtain qualified data within the scope of the research. The convenience sampling method is a preferred method for obtaining economic, practical, and fast data (Yıldırım & Şimşek, 2011). The research was carried out with primary school third grade students because AR-based applications were made using tablets. During the application, the tablets were left under the control of the students. In this process, it was thought that holding the tablet throughout the application process might cause fatigue in lower class levels. Such a decision was taken because it was thought that the tablet camera had to see the data matrix in the whole process. Otherwise, the application would disappear from the screen, cause distraction on the students, and indirectly affect the learning process. Another reason for studying with the 3rd grade in the research is that the attention span of the students is important in such applications. (John and Flavell, 1985; Cited in Cicekci and Sadik, 2019). 3rd grade students were preferred as it was thought that attention would be easily distracted at lower grade levels (Ozdamli & Karagozlu, 2018; Karagozlu, 2021).

DATA COLLECTION

Mathematic course success of the participants and their anxiety concerning the mathematics course was examined in this study. In order to identify the mathematics course success of the participants, an achievement test was developed under the guidance of the course teacher, mathematics field specialist, classroom teaching field specialist, measurement and evaluation field specialist, and the table of specifications for the course. The mathematics achievement test consisted of 10 items obtained from the acquisitions determined within the scope of the "Liquid Measurement" theme. While the highest score that can be obtained from this test was "10", the lowest score is "0". All of the items related to the mathematics achievement test consisted of three options, one of which was correct answer and two distractors. In Figure 2, there is a sample question about the mathematics achievement test. The KR-20 value for the achievement test was determined as ,852.

Figure 2. *An example question of the achievement test*

How many liters of milk are there in total?

a) 4L b) 6L c) 8L

"Mathematics Anxiety Scale," developed by Mutlu and Söylemez (2018), was used to identify the anxiety level of the participants concerning the mathematics course. The mathematics anxiety scale shows a structure with three factors in total. These factors are "Avoidance-Worrying", "Positive Emotion Towards Mathematics", and "Attitude Towards Mathematics". The scale consists of 13 items in total. In addition, the scale is in a 3-point Likert type consisting of "disagree", "undecided" and "agree" antecedents. The item load values of the scale are between .513 and .765. The general Cronbach's Alpha reliability value of the scale is .747. Confirmatory factor analysis indices for the scale, $X^2/sd=3.74$; RMSEA=.08; RMR=.04; GFI=.92; CFI=.93; NFI=.90; NNFI=.91 and AGFI=.89.

RESEARCH EXPERIMENTAL PROCESS

The experimental process of the research consists of four steps. These four steps are; preparation, development of program, application, and evaluation.

PREPARATION

At this stage of the research, a needs analysis was conducted so as to determine the general expectations of the teachers and students from the mathematics course and to identify what should be done to meet these expectations. The needs analysis process was carried out in an environment where teachers and students were together. At the stage of determining the needs of the students, teachers stated that the mathematics courses are very abstract, and the connection with daily life is generally not established. Teachers also stated that such situations estrange students from mathematics, and this causes them to experience anxiety in mathematics courses. They stated that this situation had reached further dimensions during the pandemic process. It would be beneficial to give abstract courses, such as mathematics, that are connected with daily life by supporting students in eliminating this negativity.

DEVELOPMENT OF THE PROGRAM

As a result of the students' suggestions and the needs analysis, it was determined that it would be appropriate to design technology-supported AR-based mathematics courses to eliminate the anxiety experienced by the students in mathematics courses and the low success that results from this anxiety. In this process, AR-based activities were prepared for the achievements in the theme of "Liquid Measurement" using the Unity program. These prepared activities were transferred to the tablet via the Xcode program, and the activities were made to become three-dimensional by using data matrix papers. Considering the course acquisitions, a five-week math syllabus was designed for the determined learning outcomes of the "Liquid measurement" theme in the mathematics course. During the design process of the courses, information was constantly exchanged with a program development specialist, a classroom teaching specialist, a mathematics education specialist, and an expert with research experience in AR.

IMPLEMENTATION

Before applying the developed five-week mathematics program to the experimental group, an orientation course covering information about the introduction, course content, application pre-tests, and augmented reality was given. After the orientation week, a four-week program including students' views on the practices was implemented. A tablet was used for students in the applications process. Meanwhile, the teaching of the courses with the control group continued student-centered but without benefiting from technological educational material. No augmented reality application was used for the control group students. Information on the details of the five-week program for the experimental group is presented in Table 3.

Table 3. *The details of the five-week program*

Weeks	*Theme*	*Acquisition*	*Activities*	*Product*
1.week	Pre-test, the introduction of augmented reality-based applications,			
2.week	Liquid Measurement	Makes measurements in liters or half-liter units by explaining the necessity of standard liquid measuring tools and units.	Displaying tools such as measuring glass in augmenter reality environment	Able to give various examples of liquid measurement tools used in daily life
3.week	Liquid Measurement	Estimates the amount of liquid in a container in liters and half-liter units and checks the accuracy of the estimation by measuring	AR-based activities related to liters and half-liters	Able to explain how many half liters a 5 liters bucket consist of
4.week	Liquid Measurement	Solves problems with liters	Liter-related problem-solving in AR-based environments	Developed visualization skills can help in problem-solving process
5.week	Post-test, evaluation of the applications by students,			

Below are some examples of AR-based applications designed to examine the effects on academic achievement and anxiety during the implementation process.

Figure 3. *AR example*

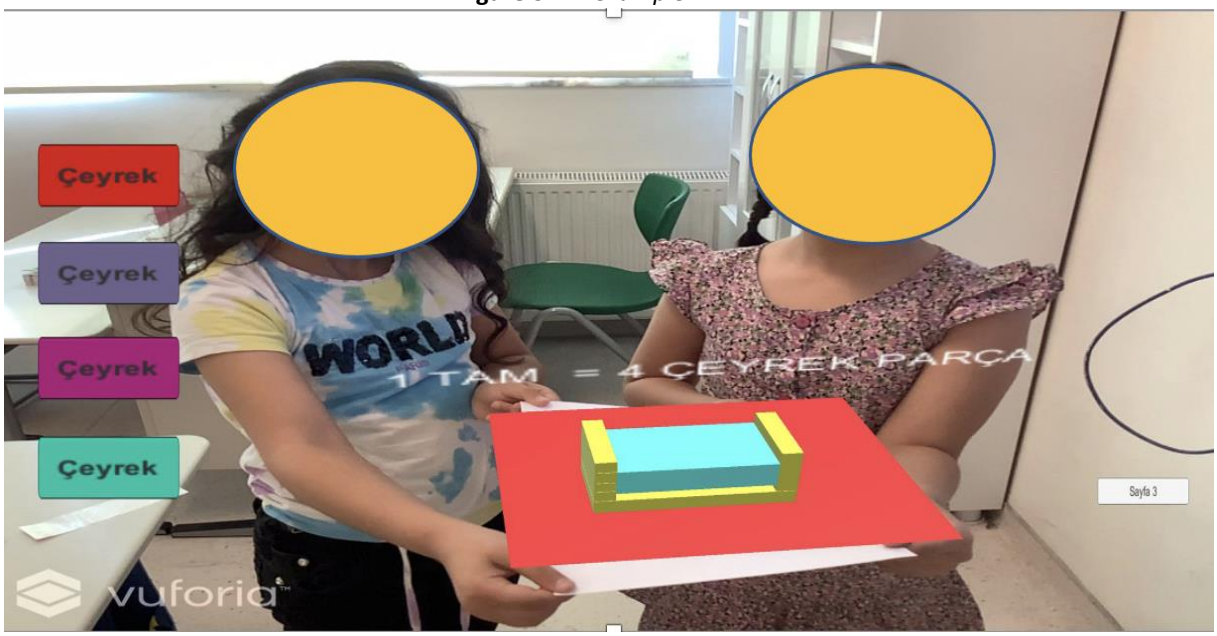


Figure 3 shows an augmented reality-based application example prepared to explain that the four quadrants form a whole.

Figure 4. *AR example*

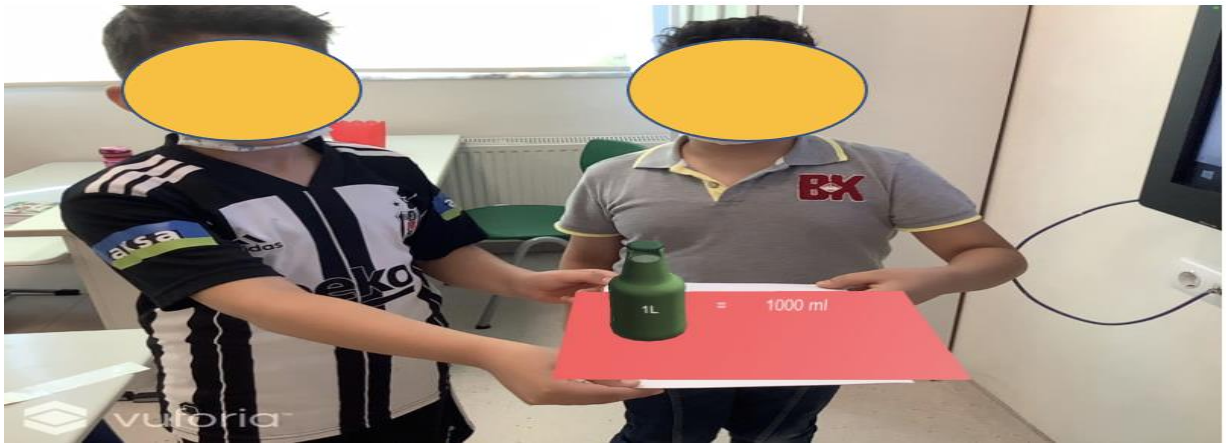


Figure 4 shows an augmented reality-based application designed to show that a liter and 1000 milliliters have the same measure.

Figure 5. *AR example*

Figure 5 shows the augmented reality-based application prepared to see the difference between the measurement tools used to measure liquids and other measurement tools.

Figure 6. *AR example*

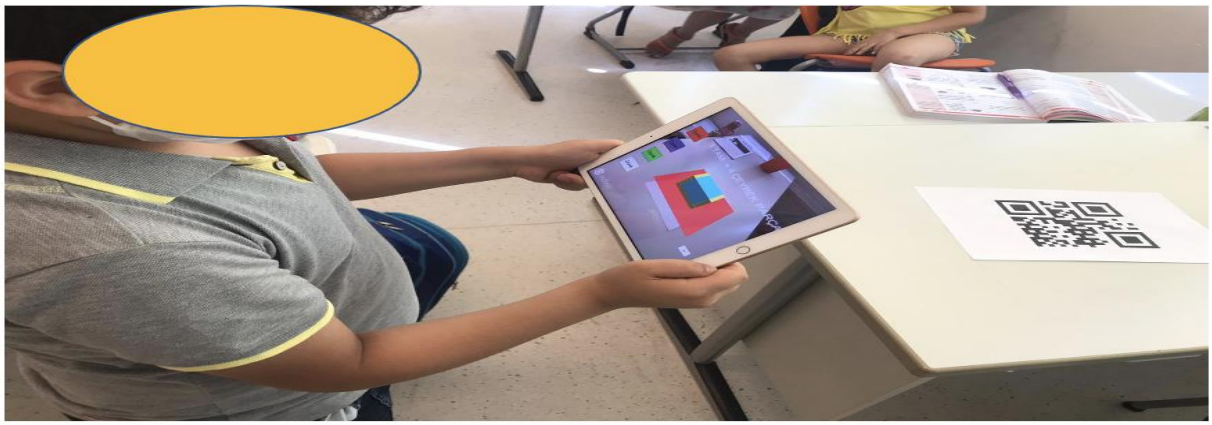


Figure 6 also shows augmented reality-based application examples prepared for the concepts of whole, half and quarter.

EVALUATION

At this stage, after the five-week program in which the application was carried out, the opinions of the students about the augmented reality-based mathematics courses were taken. In addition, within the scope of this course, post-test applications were included. Pre-test and post-tests were applied to the students in the control group, and the courses were delivered routinely within five weeks.

DATA ANALYSIS

SPSS 20 program was preferred for the analysis of the obtained data. Shapiro-Wilk normality test, one of the normality tests, was used to determine the data method. In data sets with less than 50 participants, the normal distribution is determined by the Shapiro-Wilk Test (Büyüköztürk, 2011). Since the number of participants was 26, the Shapiro-Wilk Test was applied. Normality values were found to be p<,05 on the basis of tests. According to these results, the data do not show normal distribution.

According to analyze the pre-test mathematics achievement scores and pre-test anxiety scores do not show a normal distribution. The Mann Whitney-U test, one of the non-parametric tests, was conducted for data analysis. Lower scores correspond to lower rank in Mann Whitney-U tests. On the other hand, higher scores correspond to higher ranks (Siegel, 1956; Van Der Berg, 2021). Firstly, pre-test mathematics achievement and anxiety scores were compared in the data analysis process based on control and experimental groups. The main reason for making this comparison is to determine whether there is a difference between the pre-test scores of the experimental and control groups or not. The Mann-Whitney U-test results regarding the comparison between the experimental and control groups' achievement and anxiety pre-test scores based on groups are given in Table 4. Test Analyze Programs (TAP) was used to calculate the achievement test Kr-20 score

Table 4. *The differentiation status of math achievement and anxiety pre-test scores based on experimental and control groups*

Test	*Group*	*n*	*Mean Rank*	*U*	*p*
Achievement	Experiment	13	10,92	118,00	,091
	Control	13	16,08		
Anxiety	Experiment	13	10,69	121,00	,064
	Control	13	16,31		

According to Table 4, no significant difference was found between the experimental and control groups in mathematics achievement pre-test scores, U=118,00, p>,05. In addition, there was no significant difference between the experimental and control groups concerning math anxiety pre-test scores, U=121,00, p>,05. In other words, mathematics achievement and anxiety pre-test scores did not differ based on groups. Since there was no difference between the pre-test scores, the difference between the post-test achievement and anxiety scores of the participants and the pre-test scores will be compared, and this difference will give a meaningful result. In this context, the statistical results of the difference between the pre-test and post-test scores for the experimental and control groups were determined by the Mann-Whitney U-test.

FINDINGS

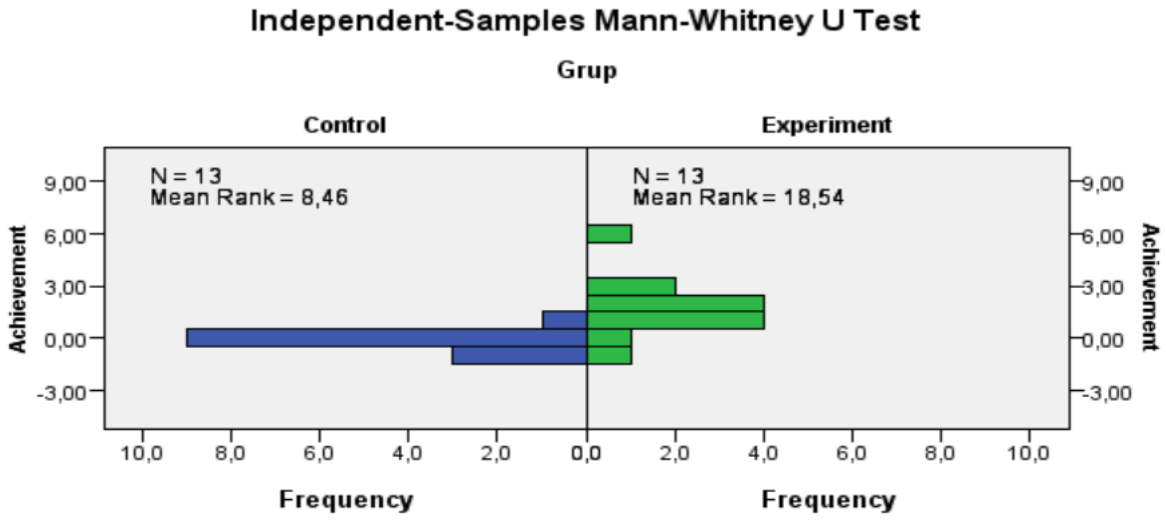
Do AR applications affect the math course success of third grade students?

The Mann Whitney U-test, which was conducted to identify augmented reality-based mathematics course on students' mathematics academic achievement is given in Table 5 and Figure 7. Table 5 and Figure 7 show the mean rank, U score, and p significance value of the experimental and control groups of participants. In addition, the arithmetic mean($\bar{x}$) and standard deviations(Sd) of the scores between the post-test achievement scores and the pre-test success scores of the experimental and control groups are given in the table.

Table 5. *Differentiation of mathematics achievement scores based on experimental and control groups*

Group	*n*	$\bar{x}$	*Sd*	*Mean Rank*	*U*	*p*
Experiment	13	1,77	1,69	18,54	19,00	,00
Control	13	,15	,55	8,46		

Figure 7. *Differentiation of mathematics achievement scores*



When Table 5 and Figure 7 is examined, the mean rank of experimental group's mathematics achievement was 18.54, while the mean rank of control group's mathematics achievement was 8.46. It was determined that the difference between the groups differed statistically in favor of the experimental group, U=19,00, p<,05. In other words, it was observed that mathematics courses designed according to augmented reality increased mathematics achievement compared to courses not designed according to AR.

Do AR applications affect third grade students' math anxiety level?

The Mann Whitney U-test, which was conducted to determine augmented reality-designed mathematics course on students' mathematics anxiety is shown in Table 6 and Figure 8,9,10,11. In Table 6, the mean rank, U score, and p significance value of the experimental and control groups of the participants are given based on dimensions and total score. In addition, the arithmetic mean($\bar{x}$) and standard deviations(Sd) of the scores between the post-test achievement scores and the pre-test success scores of the experimental and control groups are given in the table.

Table 6. *Mann Whitney U test results*

Sub-dimensions	*Group*	*$\bar{x}$*	*Sd*	*n*	*Mean Rank*	*U*	*p*
Avoidance- Worrying	Experiment	,38	1,04	13	15,54	58,00	,19
	Control	-,08	,40	13	11,46		
Positive Emotion towards Mathematics	Experiment	-75	,26	13	7,00	169,00	,00
	Control	,00	,16	13	20,00		
Attitude Towards Mathematics	Experiment	-,42	,53	13	10,15	128,00	,03
	Control	-,01	,26	13	16,85		
Total	Experiment	-,30	,35	13	10,12	128,00	,02
	Control	-,02	,24	13	16,88		

Figure 8. *Avoidance-Worrying sub-dimension results*

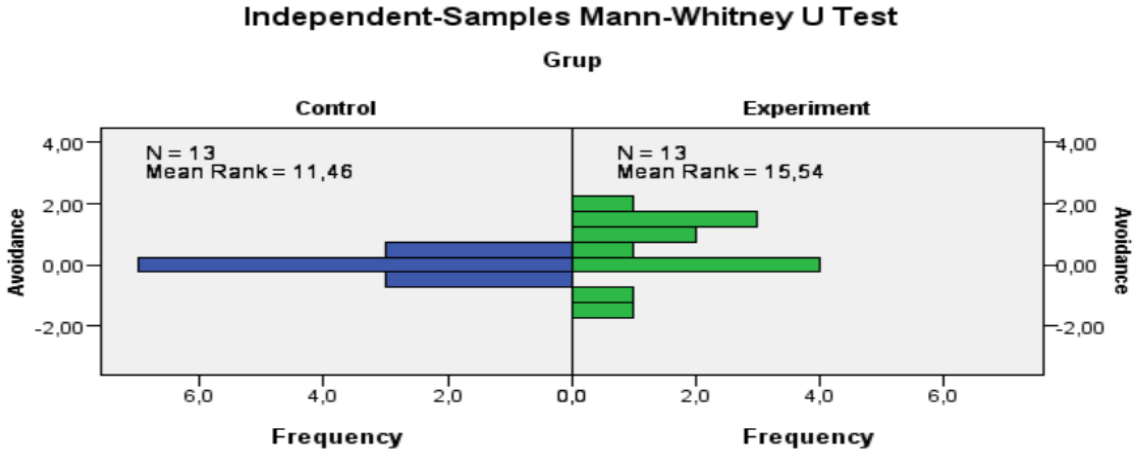


Figure 9. *Positive emotion towards mathematics sub-dimension results.*

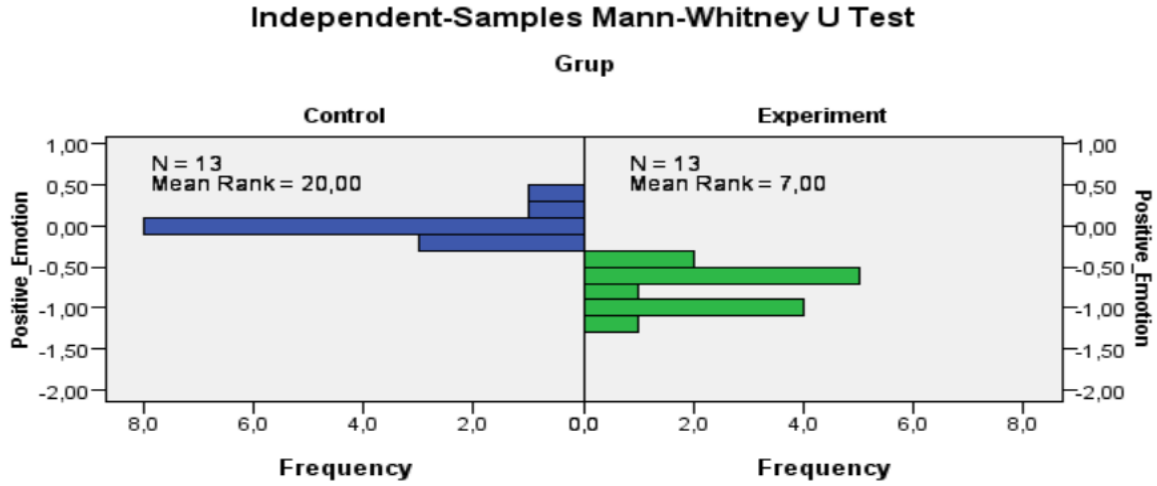


Figure 10. *Attitude towards mathematics sub-dimension results.*

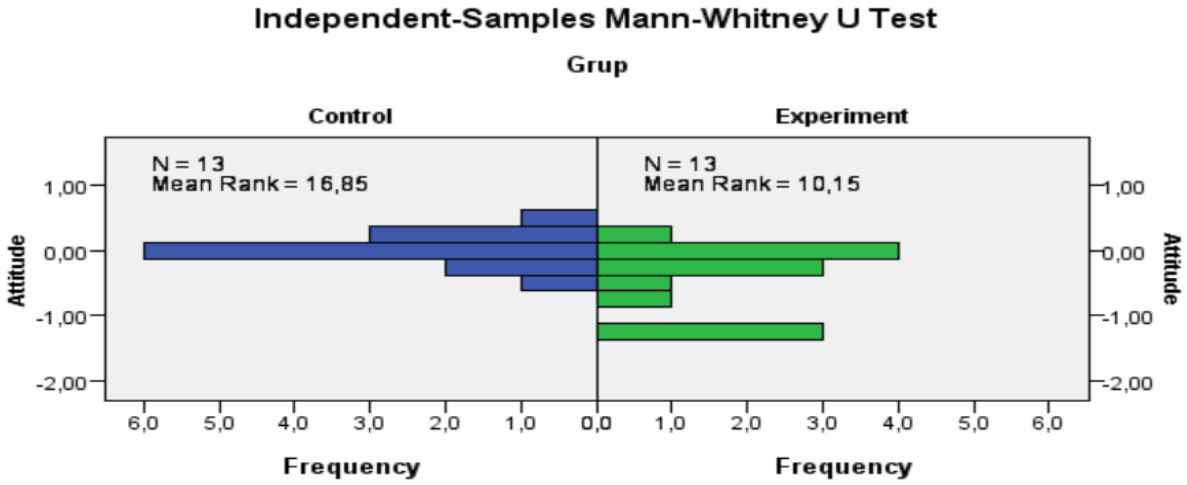
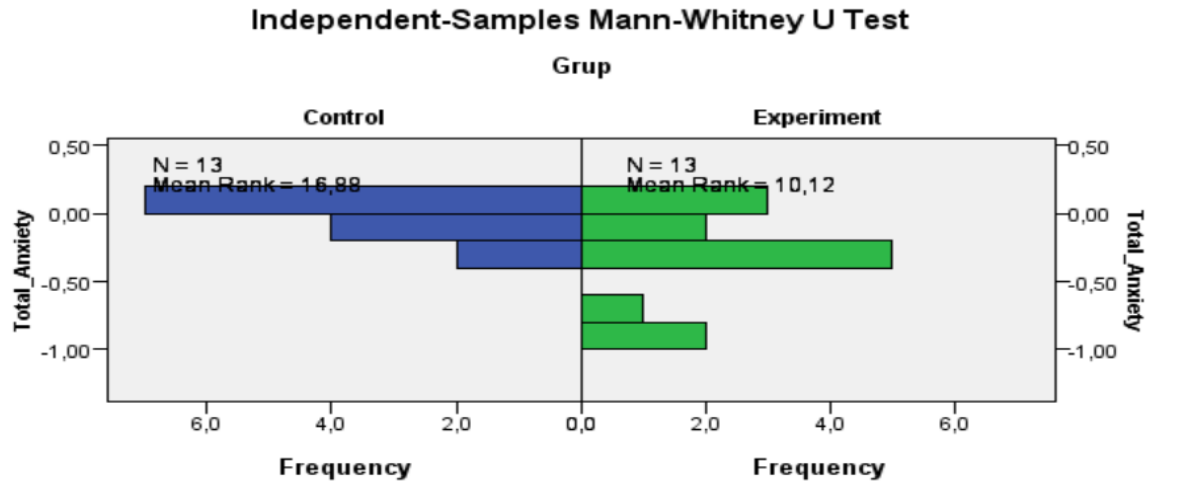


Figure 11. *Total mathematics anxiety results.*



It is evident on Table 6 that the effect of augmented reality-based mathematics courses on students' mathematics anxiety was examined based on dimensions. According to the avoidance and worrying sub-dimension, while the mean rank of the experimental group was 15,54, the mean rank of the control group was determined as 11.46 for the mathematics course. It was determined that the difference between the groups was not statistically significant, U=58,00, p>,05. (Table 6 and Figure 8). In other words, it is understood that mathematics courses designed with augmented reality applications do not affect students in the dimension of avoidance-worrying.

When Table 6 and Figure 9 are examined, the mean rank of the mathematics courses designed with augmented reality applications in the dimension of positive emotion about mathematics was 7,00 in the experimental group, while it was 20,00 in the control group. While the items in this dimension were coded, the items were reverse coded to calculate the total score of the positive scale. The difference in scores between the groups was statistically significant in favor of the experimental group, U=169,00, p<,05. In other words, augmented reality applications enabled students to form a positive view of mathematics. In addition, in the dimension of attitudes towards mathematics, the mean rank of the experimental group was 10,15, while it was 16,85 in the control group. This difference was statistically positive in favor of the experimental group, U= 128,00, p<,05. (Table 6 and Figure 10). In other words, students' negative attitudes towards mathematics decreased with augmented reality

applications. In addition, it was determined that the total mathematics anxiety scores were 10,12 in the experimental group and 16,88 in the control group. This difference was statistically significant in favor of the experimental group, U=128,00, p<,05. (Table 6 and Figure 11). In other words, augmented reality-based applications generally have an effect that reduces students' math anxiety.

DISCUSSION, CONCLUSION AND SUGGESTIONS

This research examines whether or not the applications prepared in AR-based environments for mathematics courses affect primary school 3rd-grade students' anxiety and academic achievement in mathematics. In the research, a quasi-experimental design with a pre-test post-test control group was used. For this purpose, AR-based applications were conducted on the students in the experimental group for the achievements under the theme of "Liquid Measurement" in the mathematics course. On the other hand, the students in the control group studied the course usually. When the research results are examined, it is evident that the mathematics achievement of the experimental group students who were trained with AR-based applications was higher than the control group students who were not trained with AR-based applications. It is thought that this difference between the groups in terms of academic achievement is due to the advantages of AR-based applications such as helping students to concretize abstract concepts (Olim & Nisi, 2020) and increasing the sense of reality (Carmigniani & Furht, 2011), improving spatial thinking skills (Papakostas et al., 2021) and increasing attention span (Bos et al., 2019).

According to the studies in the literature, AR-based applications are effective for method in concretizing abstract concepts (Sırakaya & Seferoğlu, 2016; Özdemir, 2017; Sirakaya & Sirakaya, 2018; Tulgar, 2019). Kose, et al., (2013) underlined that with AR-based applications, students could be provided with appropriate environments that will enable them to understand the concepts related to the courses with the help of three-dimensional models, and it will be possible for students to observe the concepts instead of visualizing them directly. It is believed that the use of AR-based applications in mathematics education will improve academic success, since it has a significant place in concretization, developing mathematical thinking skills, giving meaning to mathematical concepts, and increasing problem-solving skills in mathematics education (Dündar, et al., 2012; Temel, et al., 2015; Yılmaz & Argun, 2018)

Various researchers state that spatial thinking skills, which is another advantage in increasing students' mathematics achievement, can be improved with AR-based applications (Carrera & Asensio, 2016; George, et al., 2019; İbili et al., 2019). Having spatial thinking skills in mathematics is considered necessary in terms of increasing the academic success of students, helping them find unique solutions to problems and contributing to the increase of their learning experience (Messner, 2003; Cited in Toptaş, et al., 2012; Frank, 2005; Taylor & Hutton, 2013). For this reason, it is thought that academic success can be increased by using AR-based applications in mathematics teaching. This research supports this hypothesis.

Another essential factor in mathematics achievement is the attention span of the students to the course. Various researchers state that the attention span of students can be increased with AR-based applications (Özdamlı & Karagözlü, 2018; Bos et al., 2019; Karagözlü, 2021). It is assumed that the use of AR-based applications in mathematics teaching will contribute to the prolongation of attention spans and increase in mathematics achievement since students' having longer attention spans in the mathematics learning process ensures higher mathematics achievement (McClelland, et al., 2013). This research supports this hypothesis.

When the results of the study on the mathematics anxiety dimension were examined, it was observed that there was no significant difference between the experimental and control groups in terms of avoidance and worrying, and there was a significant difference in favor of the experimental group students concerning the dimensions of positive emotion towards mathematics and attitudes towards mathematics. As a result of the applications, when compared with the control group, it was observed that the students in the experimental group experienced less anxiety towards the mathematics course; they started to have positive feelings towards the mathematics course, and their attitudes towards the mathematics course changed positively. It is thought that this difference between the groups in terms of mathematics anxiety is because AR-based applications increase the level of motivation and help create a collaborative learning environment with applications that can be done together.

There are many studies in the literature based on the view that AR-based applications increase the level of motivation (Di Serio, et al., 2013; Mat-jizat, Jaafar & Yahaya, 2017; Khan, et al., 2019; Muhammad, et al., 2021). Considering that individuals with a high level of motivation are doubtful to experience anxiety about any course (Sheu, 2017; Ahmetovic, et al., 2020), it is possible to increase students' motivation levels for the course and to indirectly minimize their anxiety levels by using AR-based applications in mathematics education. When the results of this research were examined, it was observed that the experimental group students developed more positive attitudes towards mathematics, had positive emotions, and generally decreased their anxiety levels through AR-based applications.

One of the 21st century skills is cooperative learning (Johnson & Johnson, 2014). Studies have determined that cooperative learning environments reduce anxiety in students (Suwantarathip & Wichadee, 2010; Toyama & Mori, 2017; Fatimah, 2019). Considering that AR-based applications encourage students to learn collaboratively (Kaufmann, 2003; Klopfer, et al., 2005; Martin-Gutierrez, et al., 2014; Phon, et al., 2014), it is believed that the level of anxiety towards mathematics can be reduced through AR-based applications. The results obtained from this study support this hypothesis.

Because of its abstract structure and the stereotypes existing in society, the mathematics course is seen as a feared and anxious course with a low percentage of academic achievement of many students. It is thought that there is a need to develop activities that will attract students' attention, excite them and increase their interest and motivation in the course in order to get rid of these anxieties and increase their academic success. In this research, AR-based applications were used to reduce students' anxiety about mathematics and increase their academic success. In this process, AR-based activities were prepared for the achievements in the theme of "Liquid Measurement" using the Unity program. These prepared activities were transferred to the tablet via the Xcode program, and the activities were made to become three-dimensional by using data matrix papers. These applications were presented to the students in the experimental group for five weeks. In order to determine the effectiveness of the research, students in the experimental and control groups were given an achievement test for mathematics and an anxiety scale for mathematics. When the research results were examined, it was evident that the academic achievement of the experimental group students was higher than the control group students and their math anxiety decreased. In other words, in this study, it was emphasized that AR-based mathematics courses increased student academic achievement and reduced mathematics anxiety compared to routine mathematics courses.

The applications in this research were prepared by considering a theme in the 3rd-grade primary school mathematics course and the acquisitions. This research was conducted on the mathematics anxiety and academic achievement of 3rd grade students. Apart from this research, researches on

attitude towards mathematics lesson can be done. In addition, the findings are limited to the AR-based applications developed within the scope of this research.

In this research, marked augmented reality technology was conducted because a data matrix was used. It is thought that the preparation of markerless augmented reality-based activities with virtual objects intertwined with the natural world will increase the students' motivation, and learning that is obtained in this way will be permanent. Anxiety and failure of students towards any lesson in the first stages of primary education may cause them to approach this lesson with prejudice in the future. For this reason, to prevent such prejudices of students, it is recommended to teach AR-based courses to concretize abstract concepts in the first stages of primary education. With this respect, various training can be given to teachers to use AR-based applications effectively in the courses.

AUTHOR CONTRIBUTION

The first and second authors contributed equally to the current research with all part of article such as design data collection, data analysis and revision.

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