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The Effect of Virtual Reality Assisted Robotics Coding Teaching on Spatial Visualization and Coding Skills

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Sanal Gerçeklikle Verilen Robotik Kodlama Eğitiminin Uzamsal Görselleştirme ve Kodlama Becerilerine Etkisi

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Abstract

The aim of this study is to examine the effect of virtual reality (VR) assisted robotic coding teaching, which is a different platform used in robotic coding education, on spatial visualization and coding skills. In order to achieve this aim, a research was designed according to the quasi-experimental design with pre-test post-test control group. 56 sophomore students studying in the Elementary Mathematics Teaching program were divided into experimental and control groups. In the experimental application, which lasted for 4 weeks in total, 8 hours of VR assisted robotic coding teaching was given to the experimental group. Students both created and coded the robots using virtual reality versions of the LEGO® Mindstorms EV3 robot sets. In the control group, the students physically used the LEGO® Mindstorms EV3 robot sets and coded the robots they prepared. Before and after the instruction, the spatial visualization and coding skills of the participants in the experimental and control groups were measured and their changes at the end of the process were examined. As a result of the research, it was determined that there was a significant increase in the coding skills and spatial development, spatial rotation and spatial view skills of the pre-service teachers in the Elementary Mathematics Teaching program, who designed and codes robots using virtual reality technology. Accordingly, it was concluded that the use of virtual reality technology instead of the physical sets used in robotic coding teaching had a similar effect on students' coding skills.

Article Info

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Sanal Gerçeklikle Verilen Robotik Kodlama Eğitiminin Uzamsal Görselleştirme ve Kodlama Becerilerine Etkisi

Öz

Bu çalışmanın amacı; robotik kodlama eğitiminde kullanılan farklı bir platform olan sanal gerçeklik teknolojisi tabanlı robotik kodlama eğitiminin uzamsal görselleştirme ve kodlama becerisine etkisini incelemektir. Bu amaca ulaşmak için ön-test son-test kontrol gruplu yarı deneysel desene göre bir araştırma desenlenmiştir. İlköğretim Matematik Öğretmenliği programında öğrenim gören 56 ikinci sınıf öğrencisi deney ve kontrol grubuna ayrılmıştır. Toplam 4 hafta süren deneysel uygulamada deney grubuna 8 saatlik sanal gerçeklik tabanlı robotik kodlama eğitimi verilmiştir. Öğrenciler LEGO® Mindstorms EV3 robot setlerinin sanal gerçeklik versiyonlarını kullanarak hem robotları oluşturmuş hem de robotları kodlamışlardır. Kontrol grubunda ise aynı konuları öğrenciler LEGO® Mindstorms EV3 robot setlerini fiziksel olarak kullanmış ve hazırladıkları robotları kodlamışlardır. Öğretim öncesinde ve sonrasında deney ve kontrol grubundaki katılımcıların uzamsal görselleştirme ve kodlama becerileri ölçülerek süreç sonundaki değişimleri incelenmiştir. Araştırma sonucunda sanal gerçeklik teknolojisi kullanarak robot tasarlayan ve kodlayan İlköğretim Matematik Öğretmenliği programındaki öğretmen adaylarının kodlama becerileri ile uzamsal oluşturma, uzamsal döndürme ve uzamsal görünüm becerilerinde anlamlı artışın olduğu belirlenmiştir. Buna göre, robotik kodlama eğitimlerinde kullanılan fiziksel setler yerine sanal gerçeklik teknolojisinin kullanımının öğrencilerin kodlama becerilerinde benzer etkiye neden olduğu sonucuna ulaşılmıştır.

Makale Bilgisi

Anahtar Kelimeler: Sanal Gerçeklik, robotik kodlama, uzamsal görselleştirme, kodlama

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Introduction

Technology, which is developing rapidly and affecting every field today, can be explained as the reflections of scientific studies and the products obtained from these studies on human life. However, technology not only comes into our lives but also changes our way of life. In the last thirty or forty years, the rapid change and variation in information processing technologies have also affected the discourse of "information society". In this sense, technology emerges as an important building block in change and innovation, and technological developments are increasingly impacting our lives (Aşkar, 2004).

Therefore, the rapid developments in communication science and technologies in recent years and the prevalence in practice are closely related to the existence of creative producers and consumers raised by advanced education systems (Karasar, 2004). In line with the developments in information and communication technologies (ICT), technology has taken its place in educational practices with many different tools. As Yalabık et al. (2006) stated, many situations such as mutual communication and interaction, which can hardly be fulfilled in traditional distance education, have become very easy with the development of the Internet and the World Wide Web. As technology changes social life, the general skill levels of the society change and the expectations from education on this issue increase (Davenport & Erarslan, 2006). The use of technology to support learning, especially focusing on ICTs, provides an environment where students can adjust their studies in the context of space, time and speed (Al-Ayyoub, 2004). The last of the changes and innovations experienced is virtual education, which is a product of the new world order created by ICTs. Virtual education is a system that increases the interactive education options offered to the students without the restriction of time and place. Since interaction is one of the basic elements of learning, in knowledge-based societies, students need to solve problems voluntarily instead of receiving organized materials. The benefit of this type of interaction is not only to give information to students, but also to increase the quality of learning through learner-teacher interaction (Harada et al., 1999).

Although there are many technologies used in the creation of interactive virtual education environments, the newest and most effective one is virtual reality. Virtual reality (VR) is defined as an artificial and interactive environment where one or more people can participate electronically and physically interfere with objects, an analogy of reality or an artificial and interactive environment that has established its own reality (Karasar, 2004). In other words, virtual reality is a simulation in which computer graphics are used to create a realistic looking world (Burdea & Coiffet, 2003). They are presented as specially designed three-dimensional (3D) environments that allow intuitive, transparent interfaces in the sense that the computer interface is not visible to the user. In addition, the 3D representation of virtual reality and its interaction capabilities allow for significantly improved 3D perception and interaction compared to traditional 3D computer graphics (Bryson, 1996).

From an educational point of view, it is stated in the literature that virtual reality technology is used in different disciplines and has effects on different skills. Virtual reality technologies are used in special education, architecture, history, science and mathematics, medicine, military, and airline industries (Çavaş et al., 2004). To illustrate, it is stated that virtual reality technology in the field of mechanical engineering helps motivate students to explore these fundamental connections in a new, exciting educational environment that develops multidimensional thinking and real-world behaviors (Erenay & Hashemipour, 2003).

Another application area of virtual reality technology is robotic coding education. Robotic coding is to ensure that robotic objects are programmed with programming languages and have the ability to fulfill the desired task (Karataş, 2021). In particular, coding improves the problem-solving skills of individuals, and for this reason, it should be seen as a skill that every individual should have, rather than a private domain knowledge (Resnick, 2013). Moreover, coding is closely related to computational thinking (Lye & Koh, 2014). With coding education, students' learning habits such as digital literacy, analytical thinking and spatial thinking skills, and collaborative work can be improved (Demirer & Sak, 2016).

Integration of students with technology is an important pedagogical method to draw their attention to today's education and training processes and to increase their motivation. Robotic coding is an important tool to support this change and development. In constructivism theory, when children are given active learning opportunities that offer real-world experiences, students can support their learning by creating their own understanding of the world. Papert (1980) introduces the concept of constructivism, which suggests that learning occurs when personally involved are actively involved in the design and construction of a meaningful work. Research on the use of robotic applications in education is largely based on Papert's applied-experimental theory. Robotics platforms have been proposed as a tool for students to focus specifically on the Science, Technology, Engineering and Mathematics (STEM) curriculum (Benitti, 2012; Mubin et al., 2013). Robotics is an environment where students will develop their problem-solving, critical and algorithmic thinking, STEM and higher-order thinking skills.

Significance and Aim of the Study

In this context, the focus of the current research is to make pre-service teachers studying in the Elementary Mathematics Teaching program experience the robotic coding subject with virtual reality technology and to examine the effect of virtual reality technology on coding and spatial visualization skills. With the research, it was realized that elementary mathematics pre-service teachers could use virtual reality technologies and robotic coding was taught with innovative virtual reality technology. Thus, it is aimed that pre-service teachers both develop their awareness of technology and their knowledge and skills, as well as experience the use of these technologies in the teaching process and guide the knowledge they have acquired. In this direction, the questions that the research seeks to answer are as follows:

1. As a result of the teaching to be carried out, is there a statistically significant difference between the spatial visualization skills of the students in the experimental and control groups?
2. As a result of the teaching to be carried out, is there a statistically significant difference between the coding skills of the students in the experimental and control groups?
3. What is the effect of the instruction on the spatial visualization skills of the participants?
4. What is the effect of the teaching to be carried out on the coding skills of the participants?

The results obtained from the research offer crucial clues to researchers working in this field, both theoretically and practically. It is believed that the conducted research will be an important resource for other researchers, instructional designers, and programming educators in their studies and will fill the gap in the Turkish literature on robotic-assisted programming education. That is, the related literature suggests that robotic-based programming enhances students' critical thinking and inquiry (Ganesh et al., 2010; Sahin et al., 2014; Williams, et al., 2007), confidence, (Mac Iver & Mac Iver, 2014) or literacy skills (Erdogan et al., 2013). Thus, it becomes important to find the most suitable ways to provide robotics-based instructions. Anwar et al. (2019) share a systematic review of the studies on robotics education. With the consideration of the investigation of all related studies, they argue that alternative platforms to apply robotics education are required to have more adaptive designs for all educational settings. That is why, the educators can apply robotics education in every educational setting and with all children with different needs with an alternative method. Atman Uslu et al. (2022) also conducted a study on the systematic review on robotics studies, and they revealed that the studies on that includes educational robotics would contribute learning and teaching processes. From this point, investigating the effects of virtual reality assisted robotics coding teaching to discover the most suitable ways for students in robotics becomes important. For this reason, it is thought that the results obtained are important in terms of their contributions to the theoretical framework. In addition, it is thought that the research is functional in terms of increasing the experience of pre-service teachers about the integration of current technologies into the teaching process within the scope of the research.

Robotics Coding Education

Today, computer programs are used in almost every aspect of modern business and other daily life. The development and maintenance of these programs have great importance in reconstructing the future. Therefore, programming experts with deep knowledge of programming and coding concepts are required in those areas. In order to train these experts, it is essential to give coding teaching in education and teaching processes. Coding has become an important issue in education and engineering with the increasing use of computer systems in various fields. The importance of coding and coding education has increased as governments focus on STEM fields with the improvement and use of computer systems (National Research Council, 2011).

Another alternative that will facilitate learning coding in coding education is coding teaching with robots. In order to understand what robotics means, it is vital to first examine the concept of robot in it. The Turkish Language Institution defines robots as "a person who does business at the behest of others and does not use his/her own mind and will" (TDK, 2022). Robotics, on the other hand, is a concept related to the use of robots for the desired purpose. The Turkish Language Institution defines robotics as "the whole of studies and techniques related to the preparation of mechanisms that can replace humans in certain functions" (TDK, 2022). In general, robotic coding is the process of programming robots to achieve desired goals through software. The use of robots has become widespread not only in the field of engineering but also in education (Yolcu & Demirer, 2017).

Robotic coding means ensuring that robotic objects are programmed with programming languages and have the ability to fulfill the desired task (Karataş, 2021). Students actualize to assign objects with the codes they write. Over time, coding has become one of the educational topics. With robotic coding, students have started to witness many developments closely. The fact that students can move objects with the codes they write makes it more fun to learn programming. Apart from traditional coding education, in coding education with robots, students can program the robots they have designed and developed and have the chance to observe the results of the program they have developed instantly. Coding with robots training provides students with practical experience in understanding technology, mechanical language and systems, and provides the opportunity to apply knowledge to real situations. In addition, with the increasing interest in STEM education, it is thought that robotics can be an innovative solution to remove complexity in coding education (Zeidler, 2016).

The use of robotics can contribute to education in many ways. Robots have a flexible structure that allows trainers to suggest different models for a wider range of training (Spolaôr & Benitti, 2017). A beneficial learning environment can emerge when the characteristics of robots, such as the ability to perform repetitive tasks precisely (repeatability), flexibility, ability to present digital data, interaction, and the option to present a humanoid appearance including the body, are matched with the teaching objectives (Chang et al., 2010). Generally, the use of robots provides students with enjoyable activities and hands-on experiences that help create an engaging, eye-catching and interactive learning environment (Alimisis, 2013). For this reason, it has been revealed that robots are motivating, interesting and effective tools for students to increase their motivation and learning performance (Chang et al., 2010; Chen & Wang, 2011; Klassner & Anderson, 2003; Mitnik et al., 2009). Also, it is stated in the literature that robotic coding has positive effects on students' problem-solving skills (Çavaş & Çavaş, 2005; Konyaoğlu, 2019; Özer Şanal & Erdem, 2017). In this context, the subject of robotic coding, which is seen as one of the important issues of today, has been discussed in the current study.

Virtual Reality Technology

Virtual reality is defined as a virtual environment in which technology is used to develop an environment with realistic visuals (Burdea & Coiffet, 2003). In other words, virtual reality is a simulation in which computer graphics are used to create a realistic-looking world. According to Boz (2019), virtual reality, on the other hand, is an environment created by multi-sensory input-output devices, consisting of a helmet or headset consisting of glasses and stereo headphones, a special suit or glove that detects body movements. In another definition, virtual reality is a 3D simulation model that gives participants a real feeling and allows mutual communication with a dynamic environment created by computers (Sırakaya, 2015). It is seen as a very effective technology in learning, that is, in creating behavior change, increasing the communication between human and machine, and appealing to human emotions. This technology has emerged as a result of trying to increase human-machine interaction through feeling, not content with visual and auditory transmission. The sound, light and interaction features of virtual reality environments are customized in a way that activates all the senses of the users. In short, it is a system in which the user can effectively control this simulation environment through very special-purpose devices worn on her/his body, within a computer-generated 3D simulation of a real-world situation.

Virtual reality is a technology that has evolved over the past two decades and is currently used in science, mathematics, and medical education, as well as in the military and airline industry. Virtual reality technology can be used especially in the examination of very dangerous events/places that exist in reality for educational purposes but do not have the opportunity to examine and explore, or even in the creation of environments that are not normally possible to create. In addition, virtual reality technologies, which are interactive and well-designed multimedia environments that appeal to more than one sense, not only enable the learner to participate actively in the process but also help to have permanent learning. Virtual reality applications provide new and exciting opportunities for users, allowing the user to interact with objects and the user to explore objects (Liang & O'Grady, 2003). Virtual and augmented reality technologies provide students with a learning experience and help them to understand abstract concepts (Erbaş & Demirer, 2014). These technologies offer students the opportunity to use multimedia materials such as pictures, sounds, 3D objects, animations and videos suitable for their educational goals in and out of the classroom (Kara, 2018; Kuzgun, 2019). Today, the importance of virtual reality for education and training in fields such as games, medicine, engineering and science is increasing. Some of the world's leading technology companies such as Microsoft, Sony, Google, Facebook, Apple, and Samsung allocate important time and effort to develop virtual reality hardware and applications (Metcalfe, 2018).

In order to make a virtual reality application, three basic elements must be brought together. The first of these is a computer, console or smartphone that can run the application or game. The second is a VR glasses set that fixes and protects the screen in front of the user. The third and final one is the various inputs used to control the device such as head tracking, hand tracking, controls, on-device buttons or touch panels (Sokhanych, 2021). Today, there are many VR glasses used in virtual reality technologies. The most well-known of these are Samsung Gear, HTC Vive, Oculus Rift, Lenova Mirage, Windows Mixed Reality, and Google Daydream.

Virtual technologies used for educational purposes can be used in two different ways. These are non-immersive and immersive virtual reality technologies (Simpson, 2002). In externally interacted virtual reality technology, users can connect to computer-generated 3D environments with characters called avatars, without using any other device other than a computer, and can navigate in the virtual environment without any sensory interaction. In this type that is considered the simplest form of virtual reality, users move or zoom in and out of a 3D image created on a personal computer in a certain direction, usually using keys or a mouse. For example, on the platform called Second Life, users can navigate the virtual world with the avatars they create after logging into the platform, talk to other users, and interact with the materials placed in the virtual environment. In the immersive virtual reality technology, the users can visit the virtual environment according to their point of view by taking part in the virtual environment using virtual reality glasses connected to the computer. Moreover, it can move virtual objects with control devices called touch panel and experience the feeling of reality by doing real-life operations (holding, bending, jumping, etc.) virtually. Users of this type can perform more complex operations with the help of screens that fit the eye (VR glasses). Finally, it can interact with other users in the environment (Karasar, 2004).

In the teaching process using virtual reality technology, students gain many acquisition. Constructivist learning environments created with virtual reality allow students to learn interactively and enable students to do their homework and projects in cooperation with each other (Sarısakal, 2003). With the help of virtual learning environments, students observe some features and important points of the subject to be learned more realistically than other methods and find opportunities for constructing new information. Students can see their thoughts about a situation in a concrete way with the help of virtual reality such as the transformation of the world into an ice age, the shape of the Martian surface, and the structures of viruses. In addition, each student experiences according to his/her own learning speed and thus, he/she realizes the learning event more effectively. Virtual reality significantly removes the concept of time, which is among the limitations of constructivist teaching, and provides students with a wider time interval rather than giving them experience in limited classroom environments. Since there will be a mutual interaction with the help of virtual reality, students are enabled to switch from passive to active, encouraging creativity and creating a social atmosphere (Çavaş et al., 2004).

When the studies on the use of virtual reality technology in the teaching process in the literature were examined, important findings were obtained. For example, in the study, Demir (2019) determined that the Religious Culture and Moral Knowledge course taught with VR glasses, the pre-service teachers liked the course and they were motivated. Özdemir et al. (2019) examined the virtual reality studies carried out in the field of special education and mentioned that there is a virtual reality system that can provide many skills developed for individuals with autism spectrum disorder, mental and physical disabilities, hearing impairment and learning difficulties. Kandemir and Demir (2020), on the other hand, carried out to make the students experience the feeling of being in the classroom compared to homeschooling. As a result of the study, they determined that the morale and motivation of the students who attended the lesson by using VR glasses and cameras increased compared to the ones who attended homeschooling. In addition, as stated in the literature, virtual reality technology offers students the opportunity to learn by themselves (Baysan & Uluyol, 2016), develops a different perspective (Yuen et al., 2011), and provides the opportunity to learn by doing and experiencing by actively participating in the process (Singhal et al., 2012), critical thinking, problem solving and communication skills (Güngördü, 2018), providing the opportunity to improve spatial abilities (Cheng & Tsai, 2013), ensuring permanent learning and reducing misconceptions (Yoon et al., 2017). In addition, this technology takes teachers' attention because virtual reality technology increases the attention span of students and affects their academic success positively (Abdüsselam & Karal, 2012), improves their creativity by using their imagination (Ateş, 2018), supports the curriculum (Çevik et al., 2017), puts the student in the center. (Delello, 2014), creating an interactive learning environment (Chen, 2008), and being easy to use (Tomi & Rambli, 2013).

In this context, it is thought that the coding education to be given with virtual reality technology has an effect on the coding and spatial visualization skills of the pre-service teachers thanks to both the experience of the use of innovative technologies in the teaching process and the constructivist learning environment offered by the virtual reality technology.

Method

Research Model

In the current study, a quasi-experimental design with pretest-posttest control group design, which is one of the quantitative research methods, was utilized. Experimental designs are research designs that aim to discover cause and effect relationships between variables (Büyüköztürk et al., 2015). Measurements are carried out in groups before and after the experiment in this model. Presence of pretests in the model helps to know the similarity levels of the groups before the experiment and to organize the post-test results accordingly (Karasar, 2013). The research model is shown in Table 1.

Table 1. Research Model

Group	Pretest	Procedure	Posttest
Experimental	CAT-1 PSVT-1	VR Assisted Robotic Coding Training	CAT-2 PSVT-2
Control	CAT-1 PSVT-1	Non-VR Assisted Robotic Coding Training	CAT-2 PSVT-2

CAT: Coding Achievement Test
PSVT: Purdue Spatial Visualization Test
VR: Virtual Reality

In the research carried out within the scope of the research, the participants were divided into two groups as experimental and control. Before the experimental procedure, participants' coding skills and spatial visualization skills were measured. The participants in the experimental group both created the robots and coded the robots using the virtual reality versions of the LEGO® Mindstorms EV3 core sets. The participants in the control group physically used the LEGO® Mindstorms EV3 core sets on the same subjects and coded the robots they prepared. After four weeks (8 hours in total), the coding skills and spatial visualization skills of the participants in the experimental and control groups were re-measured and their changes at the end of the process were examined.

Participants

As the study group in the research, sophomore students studying in Tokat Gaziosmanpaşa University, Faculty of Education, Elementary Mathematics Teaching program were included. The reason for choosing these students is that they are settled with the quantitative score type and that they are a sub-field within the STEM approach. In addition, the research was carried out within the scope of the "Instructional Technologies" course in the related program. A total of 56 pre-service teachers enrolled in the course were randomly assigned to the experimental and control groups of 28 people. Afterwards, an information meeting was held with the pre-service teachers in the experimental and control groups, and information was given about the process. Demographic information of pre-service teachers participating in the study is given in Table 2.

Table 2. Participants of the Study

Variable	Sub-variable	Frequency (F)	Percent (%)	$\bar{X}$
Group	Experimental	28	50.0	
	Control	28	50.0	
Gender	Female	42	75.0	
	Male	14	25.0	
Age	19	15	26.8	20.13
	20	23	41.1	
	21	14	25.0	
	22	4	7.1	
Daily internet usage time (hours)	1	1	1.8	4.63
	2	6	10.7	
	3	12	21.4	
	4	12	21.4	
	5	12	21.4	
	6	7	12.5	
	8	2	3.6	
	10	3	5.4	
	14	1	1.8	

As seen in Table 2, both the experimental and control group consisted of 28 pre-service teachers. The majority of the pre-service teachers participating in the research are female and the average age is 20.13. In addition, pre-service teachers use the internet for an average of 4.63 hours daily.

Data Collection Tools

The main data collection tools of the research carried out within the scope of the research were; Purdue Spatial Visualization Test and Robotic Coding Achievement Test developed by researchers.

Purdue Spatial Visualization Test

The original form of the Purdue Spatial Visualization Test (PSVT) was developed by Guay (1976). The test, which was developed to determine students' spatial visualization skills, consists of 36 multiple-choice and five-option questions. The first part of the test, which consists of three parts in total, is Developments (PSVT-D). In the PSVT-D section, there are 12 questions to determine how well the folding of three-dimensional (3D) objects can be visualized. The second part of the test is Rotations (PSVT-R). The PSVT-R section contains 12 questions to determine how well 3D objects can be rotated. The third and final part of the test is Views (PSVT-V). The PSVT-V section contains 12 questions to determine how well the views of 3D objects from different perspectives can be visualized (Guay, 1976; Sevimli; 2009; Maeda & Yoon, 2013, Kösa & Karakuş, 2018; Toplu, 2020). In addition to these, necessary permissions were obtained for the use of the pre-research test.

Robotic Coding Achievement Test

The robotic coding achievement test developed by the researchers within the scope of the research consists of 25 multiple-choice questions in total for the operations on the coding platform for the LEGO® Mindstorms EV3 core sets. During the development of the achievement test, primarily the trainings to be given during the experimental process were planned. Accordingly, in the robotic coding trainings to be given within the scope of the experimental process, it is planned to maintain line tracking, obstacle detection and reaction activities using controls, servo motor, ultrasonic sensor, and color sensor. After that, draft questions with multiple choice and four options were created in line with the planned training content. After the specification table (Table 3) for the questions was prepared, the draft questions were presented to the opinions of two field experts in Computer Education and Instructional Technologies. With the consideration of the opinions of the experts, necessary arrangements were made in the questions in the achievement test, and an achievement test was applied to the students who had previously received robotic coding training to ensure the validity and reliability of the study.

Table 3. Robotic Coding Achievement Test Specification Table

Subject	Related Questions
Sensor usage	4, 16, 19, 20
Connection ports	2, 3, 5, 18
Code block structure	1, 6, 7, 8, 9, 10, 21, 22, 23, 24, 25
Coding	14, 15, 17
Loops	11, 12, 13

After the answers given to the achievement test applied to 8 students were transferred to the computer environment, item difficulty (p) and item discrimination (r) indexes were calculated within the scope of the reliability study. The item difficulty and item discrimination indexes obtained after the pre-application of the achievement test were determined.

The item difficulty index is the ratio of those who answered the item correctly to the total number of respondents. This index takes a value between 0 and 1, and as the difficulty index approaches 0, the item is interpreted as a difficult item, and as it approaches 1, it is interpreted as an easy item. Item discrimination, on the other hand, is the measure of distinguishing between those who know and those who do not, which is obtained by proportioning the correct answers of the respondents in the 27% upper group with a high level of success and those in the lower group. If the item discrimination index of the items to be included in the test is 0.19 and below, that item should not be included in that test; If it is between 0.20 and 0.29, that item can be corrected and included in the test; If it is between 0.30 and 0.39, it is interpreted that the discrimination of the item is at a good level, and if it is 0.40 or more, it is interpreted as that the item can distinguish between those who know and those who do not know (Erkuş, 2003). The items that needed to be corrected in line with the item discrimination index were rearranged. Accordingly, in the final version of the developed robotic coding achievement test, it was determined that there were 3 difficult, 15 medium and 7 easy questions, and the total difficulty of the test was moderate. In addition, KR-20 reliability coefficient was calculated for the reliability of the developed achievement test. Thus, the KR-20 reliability coefficient of the final version of the robotic coding achievement test was calculated as .74.

Data Collection Process

The data collection process in the research was collected within the scope of the "Instructional Technologies" course in the Elementary Mathematics Teaching program in the spring semester of the 2021-2022 academic year. In the study, the data were collected from pre-service teachers. Research and publication ethics were followed. For this research, the ethical approval was obtained from the Social and Human Sciences Research Ethics Committee of Tokat Gaziosmanpaşa University (Date: 29 April 2021, Number: E-33490967-044-36286). Pre-service teachers who participated the Instructional Technologies course in the relevant period were divided into two separate groups as experimental and control groups. Before the experimental procedure, data collection tools were applied to both groups as a pretest. The students in the experimental and control groups were given a 4-week, 8-hour LEGO® Mindstorms EV3 robotic coding training by the researcher, the details of which are given in Table 4.

Table 4. LEGO® Mindstorms EV3 Robotic Coding Training Program

Basic concepts	Parts of LEGO® Mindstorms EV3 core sets LEGO® Mindstorms EV3 coding software
Connection ports	Connection ports on LEGO® Mindstorms EV3 core sets Connecting cables to LEGO® Mindstorms EV3 core sets
Sensors	Color sensor Ultrasonic sensor Touch sensor Gyro sensor
Code block structure	Motor move code block structure Code block structure for using the touch sensor Code block structure for using the color sensor Code block structure for using ultrasonic sensors
Coding and Loops	The equivalents of code blocks in the coding program Repeating code blocks as many times as desired

The subjects in the training program in the experimental group were taught using VR glasses over the VR application of Robotics on the STEAM platform. For this aim, access to the STEAM platform has been authorized by the Computer Center of Tokat Gaziosmanpaşa University for off-campus access to the Robotics VR application of the computers in the Computer Laboratory 1 of the Faculty of Education, where the experimental process is carried out. In the control group, the subjects included in the training program were covered over LEGO® Mindstorms EV3 sets. In other words, while the pre-service teachers in the experimental group processed all the topics on robotics using a virtual reality-based robotic coding environment, the students in the control group covered all the topics using robotic sets. At the end of the four-week training, the spatial visualization skills and coding skills of the pre-service teachers in both groups were re-tested as a posttest. According to the results of the measurements, the effect of VR assisted and non-VR assisted robotic coding instruction on pre-service teachers' spatial visualization and coding skills was tried to be determined. Figure 1 shows the images of the trainings carried out within the scope of the research.

Figure 1. Images of the Activities Performed within the Scope of the Research

Analysis of Data

SPSS Statistics 22 package program was used in the analysis of quantitative data in the research. The significance level was taken as .05 in all quantitative analyzes. The reliability coefficient was calculated according to the Kuder-Richardson KR-20 formula to determine the post-application reliability of the robotic coding achievement test and the PSVT. Accordingly, the robotic coding achievement test pretest and posttest reliability coefficients were calculated as $KR\text{-}20_{pretest}$=.67 and $KR\text{-}20_{posttest}$=.71, and the PSVT reliability coefficients were calculated as $KR\text{-}20_{pretest}$=.77 and $KR\text{-}20_{posttest}$=.79. In addition, the normality of the distributions for all examined variables (spatial visualization and coding skills) were tested. Since the distributions were normal as a result of the Kolmogorov-Simirnov normality test performed (K-S (54)=.221, p>.05 and K-S (54)=.556, p>.05), in order to examine the effect of virtual reality-assisted robotic coding experiences of elementary mathematics pre-service teachers on their coding skills and spatial visualization skills, a paired-samples t-test was conducted. In addition, an independent samples t-test analysis was performed to statistically test the difference in scores between the experimental and control groups.

Validity of the Study

Internal validity is about if the relationships between study variables are affected by any other variable out of the study aim or not (Fraenkel & Wallen, 2006). Subjects' characteristics, mortality, location, history, data collector characteristics, data collector bias, and implementation were the treatments that might have an effect on the current study. First of all, the subjects' characteristics mean that the differences observed in the study results might be because of the individual differences among the participants (Fraenkel & Wallen, 2006). To obstruct this threat, participants were randomly assigned to the experimental and control groups, and the researchers applied pretests to describe the participants' status before the intervention and to decide if there is a statistically significant difference between the experimental and control group. Mortality is another threat that the researchers might face in the case in which participants have to quit the study (Fraenkel & Wallen, 2006). Because the study is conducted in the scope of the "Instructional Technologies" course, the students were motivated to continue the study all semester. Location is another threat that means having differences because of the location differences among groups (Fraenkel & Wallen, 2006). For the current study, this threat was tried to be obstructed by conducting all the research processes in the same classroom. Moreover, historical threats can affect the research findings. That is, unusual events that happen during the research process might affect the results gathered from the participants (Fraenkel & Wallen, 2006). To limit the effects of this threat, the researchers administer the data collection tools at the same time to all participants. When there are two data collectors, data collector characteristics might affect the differences among the groups (Fraenkel & Wallen, 2006). Because the researcher maintained the process for both the experimental and control group by himself, this threat has been obstructed. Thanks to having one data collector, implementation threat was also obstructed. That is, the differences that might be occurred due to the differences in implementers' behaviors and personal biases of experimental and control groups (Fraenkel & Wallen, 2006).

Findings

In this section, the findings obtained as a result of the analysis of the data collected in line with the sub-objectives of the research are given.

Findings Regarding Changes in Participants' Spatial Visualization Skills

Table 5 shows the distribution of points according to the results of PSVT regarding the change of VR assisted and non-VR assisted robotic coding activity, which is the first and third research question of the research on the spatial visualization skills of elementary mathematics pre-service teachers.

Table 5. PSVT Score Distribution

		Spatial Development		Spatial Rotation		Spatial View	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Pretest	Experimental	6.57	3.06	6.79	2.44	5.43	2.43
	Control	6.54	2.50	5.68	2.72	4.71	2.61
Posttest	Experimental	8.82	2.54	8.32	2.63	7.32	3.27
	Control	6.89	2.73	6.75	2.08	5.00	1.85

As can be seen in Table 5, it is seen that the experimental group got higher scores than the control group in the spatial development, spatial rotation and spatial view dimensions in the pretest scores of the PSVT sub-scores of the participants. However, there was no statistically significant difference between the experimental and control groups in terms of pretest scores, $t(54)=-.048$, $p>.05$; $t(54)=-1.603$, $p>.05$ and $t(54)=-1.061$, $p>.05$.

The results of the analysis regarding the difference between the PSVT and its sub-dimensions, spatial development, spatial rotation, and spatial appearance posttest scores of the participants in the experimental and control groups, are given in Table 6.

Table 6. Comparison of PSVT Posttest Scores by Groups

	Group	N	$\bar{X}$	SD	df	t	p
Spatial Visualization (PSVT)	Experimental	28	24.46	6.46	54	-3.740	.000*
	Control	28	18.64	5.11			
Spatial Development (PSVT-D)	Experimental	28	8.82	2.54	54	-2.739	.008*
	Control	28	6.89	2.73			
Spatial Rotation (PSVT-R)	Experimental	28	8.32	2.63	54	-2.481	.016*
	Control	28	6.75	2.08			
Spatial View (PSVT-V)	Experimental	28	7.32	3.27	54	-3.274	.002*
	Control	28	5.00	1.85			

* $p<.05$

As a result of the analysis, as seen in Table 6, there was a statistically significant difference between the PSVT posttest scores of the pre-service teachers in the experimental and control groups ($t(54)=-3.740$, $p<.05$). In addition, spatial development ($t(54)=-2.739$, $p<.05$), for spatial rotation ($t(54)=-2,481$, $p<.05$) and spatial view ($t(54)=-3.274$ $p<.05$) of the PSVT, there was a statistically significant difference in sub-dimensions.

The pretest and posttest scores of the participants who participated in the VR assisted and non-VR assisted robotic coding teaching carried out within the scope of the research were compared in terms of spatial visualization skills. The results are presented in Table 7.

Table 7. Paired-Samples t-Test Results of PSVT Pretest-Posttest Scores

	Pretest		Posttest		df	t	p
	$\bar{X}$	**SD**	**$\bar{X}$**	**SD**			
Spatial Visualization (PSVT)	18.79	6.87	24.46	6.46	54	-3.187	.002*
Spatial Development (PSVT-D)	6.57	3.06	8.82	2.54	54	-2.994	.004*
Spatial Rotation (PSVT-R)	6.79	2.44	8.32	2.63	54	-2.267	.027*
Spatial View (PSVT-V)	5.43	2.43	7.32	3.27	54	-2.462	.017*

* p<.05

As the Table 7 displays, there is a statistically significant difference between the spatial development, spatial rotation and spatial view posttest scores and pretest scores of the participants in the experimental group who participated in the VR assisted robotic coding training, $t(54)=-2.994$, $p<.05$, $t(54)=-2.267$, $p<.05$ and $t(7)=2.462$, $p<.05$.

Findings Regarding Changes in Participants' Coding Skills

Table 8 shows the distribution of points according to the results of the robotic coding achievement test regarding the change of the VR assisted and non-VR assisted robotic coding activity, which is the second and fourth research question of the research on the coding skills of elementary mathematics pre-service teachers.

Table 8. Robotic Coding Achievement Test Scores Distribution

		$\bar{X}$	**SD**
Pretest	Experimental	35.86	9.46
	Control	36.29	10.32
Posttest	Experimental	66.86	11.51
	Control	62.21	12.50

As seen in Table 8, when the pretest scores of the participants in the study regarding the robotic coding achievement test are examined, it is seen that the pretest scores of the control group are higher than the posttest scores of the experimental group. In addition, when the posttest scores were examined, it was found that the posttest scores of the experimental group were higher than the posttest scores of the control group. However, there was no statistically significant difference between the experimental and control groups in terms of pretest scores, $t(54)=0.162$, $p>.05$.

The analysis results regarding the difference between the posttest scores of the participants in the experimental and control groups after the experimental application in the robotic coding achievement test are given in Table 9.

Table 9. Comparison of Robotic Coding Achievement Test Posttest Scores in terms of Groups

Group	**N**	**$\bar{X}$**	**SD**	**df**	**t**	**p**
Experimental	28	66.86	11.51	54	1.446	.154
Control	28	62.21	12.50			

As the result of the analysis revealed, as seen in Table 9, there is no statistically significant difference between the robotic coding achievement test posttest scores of the pre-service teachers in the experimental and control groups, $t(54)=1.446$, $p>.05$. The pretest and posttest scores of the participants in the experimental group who received VR assisted robotic coding training within the scope of the research were compared in terms of robotic coding achievement test, and the results are presented in Table 10.

Table 10. Paired-Samples t-Test Results of Robotic Coding Achievement Test Pretest-Posttest Scores

Experimental Group	$\bar{X}$	SD	df	t	p
Pretest	35.86	11.51	27	-11.211	.000*
Posttest	66.86	9.46			

* p<.05

The result of the analysis showed that, as seen in Table 10, there is a statistically significant difference between the posttest scores of the robotic coding achievement test and the pretest scores of the participants in the experimental group who participated in the VR assisted robotic coding teaching, $t(27)=-11.211$, $p<.05$. The pretest and posttest scores of the participants in the control group who received non-VR assisted robotic coding teaching within the scope of the research were compared in terms of robotic coding achievement test, and the results are presented in Table 11.

Table 11. Paired-Samples t-Test Results of Robotic Coding Achievement Test Pretest-Posttest Scores

Control Group	$\bar{X}$	SD	df	t	p
Pretest	36.29	10.32	27	-9.332	.000*
Posttest	62.21	12.50			

* p<.05

The result of the analysis showed that, as seen in Table 11, there is a statistically significant difference between the posttest scores of the robotic coding achievement test and the pretest scores of the participants in the control group who participated in the non-VR assisted robotic coding teaching, $t(27)=-9,332$ $p<.05$.

Discussion, Conclusion, and Recommendations

The results of the research process, in which it was aimed to examine the changes in the VR assisted and non-VR assisted robotic coding experiences of elementary mathematics pre-service teachers on both their coding skills and spatial visualization skills, are presented.

There was a significant increase in the academic achievement and spatial rotation skills of the experimental and control group. The spatial development, rotation and view scores of the experimental group were significantly higher than the scores of the control group. Again, in general, there are similar results in spatial visualization skills, too. Accordingly, it is possible to say that the VR assisted robotic coding experiences of the pre-service teachers create a positive increase in their spatial expansion, spatial rotation and spatial view skills. Moreover, in general, it was seen that spatial visualization skills increased positively as a result of the application. It can be concluded that VR assisted robotic coding education has a positive effect on pre-service teachers' spatial visualization skills. The findings obtained as a result of the research are parallel to the positive effect of computer-assisted painting and computer games on geometric thinking skills (Olkun & Altun, 2003). In addition, this finding is in line with the finding of Yolcu and Kurtuluş (2010) that seeing the views of 3D shapes from different angles with 3D computer software increases the visualization ability. Similarly, with the finding that the success of the CAD modeling program is positively related to spatial skills (Branoff & Dobelis, 2012), 3D-related courses cause an increase in spatial skills (Orion et al., 1997), a high correlation between spatial ability and 3D modeling ability, (Huk, 2006) and spatial skills are associated with success in problem-solving-based engineering education (Sorby & Baartmans, 2000).

However, no significant difference was found between the experimental and control group posttests regarding the robotic coding achievement. This may be due to the fact that the pre-service teachers of the elementary mathematics teaching department follow the same robotics lesson plan, no matter how different tools are used, and receive robotics training for the first time. However, it was determined that there was a significant difference between the pretest and posttests in both the experimental group and the control group. According to this finding, it can be said that the VR assisted robotic coding experiences and non-VR robotic coding experiences of the pre-service teachers create a positive increase in their coding skills. This finding is similar to the finding by Cam and Kiyici (2022) that robotic assisted programming education contributes positively to academic success. The results of the current study overlap with the results of the previous studies in the related literature. In addition, the researchers, who participated as instructors during the experimental process, observed that the students in the experimental group showed great interest in virtual reality and metaverse applications.

The related literature displayed that, spatial visualization and mental rotation abilities have been measured with virtual environment and mostly real environment applications (Rafi et al., 2008; Uygan, 2011). However, in the literature, studies have been made with real environments and objects related to robotics and Lego Mindstorms. No study has been found that examines virtual reality and robotics education. In this study, in which virtual reality and real tools were used, pre-service teachers' spatial visualization skills and robotic coding achievement were measured. Thus, it is thought that measuring spatial visualization and academic achievement by comparing virtual reality and real robotic environment will fill the gap in the literature. In addition, at the end of the research, it was seen that the use of innovative technologies such as VR in robotics coding training contributed more positively to coding skills. For this reason, it is recommended to use more innovative technologies in the design of robotics coding trainings. The research has some limitations. The first of these is that the study was conducted with primary school mathematics teachers. Considering this limitation, in future studies, the spatial visualization and robotic coding skills of teacher candidates studying in different departments can be examined. Moreover, the research focused only on spatial visualization and robotic coding success. The effects of VR assisted coding training on reflective thinking and computational thinking skills can be investigated with further research. Finally, the contribution of creative problem-solving skills experiences supported by virtual world and metaverse technologies to spatial visualization skills can be examined. In addition, it will be a source for future research with the progress of metaverse and virtual worlds.

Contribution Rate of the Researchers

All authors contributed to the study equally.

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Conflict of Interest

Authors declare that no potential conflict of interest.

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