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Çevrimiçi Uzaktan Eğitimde Kırsal Bölge Öğrencilerinin Uzamsal Becerilerini Geliştirmek için Sanal Manipülatif: İzometrik Çizim Aracı

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Öz

Çevrimiçi uzaktan eğitimde matematik öğretiminin etkililiği ve öğretimin etkililiğini artırmak için uygulanabilecek stratejiler hakkında çok az şey bilinmektedir. Bu çalışmanın amacı çevrimiçi uzaktan eğitimde izometrik çizim aracı kullanımını gerektiren etkinliklerde öğrencilerin uzamsal becerilerinde meydana gelen değişiklikleri incelemektir. Araştırmada tek gruplu öntest-sontest deneysel desen kullanılmıştır. Araştırmaya kırsal bölgede yer alan bir ortaokulun yedinci sınıfında okuyan beş öğrenci katılmıştır. Araştırmanın verileri ön ve son yapılandırılmış görüşmelerde uygulanmış uzamsal beceri testi, öğrenci çalışma kağıtları ve görüş formu aracılığıyla toplanmıştır. Araştırmada kullanılan veri toplama araçları üç aşamada analiz edilmiştir. İlk olarak, öğrencilerin uzamsal becerilerindeki değişiklikleri göstermek için uzamsal beceri testi bir rubrik kullanılarak değerlendirilmiştir. İkinci aşamada, uzamsal beceri gelişmelerini belirlemek için testler ve çalışma kağıtları üzerinde nitel betimsel analiz gerçekleştirilmiştir. Son olarak, uygulamayla ilgili öğrenci görüşlerini tespit etmek için görüş formlarının değerlendirilmesinde için içerik analizi kullanılmıştır. Araştırmanın bulguları, çevrimiçi uzaktan eğitim sırasında bir izometrik çizim aracı kullanmanın, öğrencilerin uzamsal becerilerini etkili bir şekilde geliştirdiğini göstermiştir. Öğrenciler araştırmanın başında izometrik çizim kağıdına küp çizemezken, çalışmanın sonunda öğrencilerin küpleri yan yana ve üst üste konumlandırarak doğru bir şekilde 3 boyutlu izometrik çizimler yapabildikleri görülmüştür. Genel olarak, öğrenciler sanal manipülatiflerin kullanımı hakkında olumlu görüşler ifade etmişlerdir. Bu çalışmanın bulgularına dayanarak, matematik eğitimcilerinin öğrencilerin uzamsal becerilerini geliştirmek için izometrik çizim araçları gibi sanal manipülatifleri çevrimiçi matematik öğretimlerine dahil etmeleri önerilmektedir.

Anahtar Kelimeler

Sanal Manipülatif, Uzamsal Beceriler, Çevrimiçi Uzaktan Eğitim, Kırsal Bölge

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A Virtual Manipulative to Support Rural Students in Developing Spatial Skills in Online Distance Education: Isometric Drawing Tool

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Abstract

Limited knowledge is currently available regarding the efficacy of mathematics education in online distance learning and the strategies that can be implemented to enhance its effectiveness. The purpose of this study is to investigate the changes in rural students' spatial skills when engaging in activities that necessitate the use of isometric drawing tool within the context of online distance education. A one-group pretest-posttest experimental design assessed the impact of an isometric drawing tool (IDT) on rural students' spatial skills in online education. This study involved five seventh-grade students from a rural secondary school. Data for this research included spatial skills test administered at the pre- and post-structured interviews, students' worksheets, and opinion forms. This study employed a three-stage analysis of data collection tools: first, assessing changes in students' spatial skills using a rubric; second, utilizing a qualitative descriptive analysis method on tests and worksheets to identify specific spatial skill improvements; and finally, conducting content analysis on opinion forms to capture student perspectives post-implementation. The results indicated that utilizing an isometric drawing tool during online distance education effectively improved rural students' spatial skills. While the students could not even draw cubes on isometric drawing paper at the beginning, it was observed that at the end of the study, they were able to accurately make 3D isometric drawings by positioning the cubes side by side and on top of each other. Overall, students expressed positive opinions about the use of virtual manipulatives. Based on the findings of this study, we recommend that educators consider incorporating isometric drawing tools and virtual manipulatives into their online mathematics teaching to enhance students' spatial skills.

Keywords

Virtual Manipulative, Spatial Skills, Online Distance Education, Rural Students

Citation

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Introduction

Mathematics is often seen as challenging, even under normal teaching conditions (Fritz et al., 2019). It is a controversial issue whether mathematics teaching can be effectively conducted in online distance education. Some researchers suggest it is not possible, as it does not provide students with the necessary support for mathematical thinking (Lowrie & Jorgensen, 2012), web-based mathematics teaching alone is not enough (Fedele & Li, 2008), and distance education lacks the cooperation between students that is essential for mathematics learning (Amin & Li, 2010). Moreover, Kilit and Güner (2021) have stated that teachers believe web-based distance education is not as effective or efficient for teaching mathematics, since it is believed that mathematics is best taught in a physical classroom environment. Contrary to this research results and the opinions of teachers, various studies conducted in recent years have determined that students' attitudes towards mathematics have improved, and conceptually effective learning has been realized in online mathematics teaching supported by various technological tools (Baki & Çakıroğlu, 2010; Kay, 2014). Research on distance education has predominantly been conducted at the higher education level, with few studies taking place at the secondary and high school levels (Almarashdi & Jarrah, 2021; Almuraqab, 2020). Further studies should be conducted to gain a better understanding of how distance education can best be utilized in these settings.

Prior to the pandemic period, distance education studies were conducted in normal circumstances, with the goal of enhancing the teaching and learning process (Hillmayr et al., 2020). Mathematics, however, was not often the primary focus of these studies (Astri, 2017). In the pandemic period, every mathematics teacher was required to experience emergency remote education of mathematics. Research has shown that students in rural areas and those with lower performance in mathematics were the most affected by the implementation of distance education (Ergün & Arık, 2020). Lowrie and Jorgensen (2012) suggest that, due to the fact that rural students have been identified as groups of learners who are at risk of poor performance in mathematics, there are structuring practices that could either provide enhanced or limit potentialities for learning mathematics. These practices can significantly impact the level of success achieved by these students. Therefore, greater attention should be paid to understanding how these practices can be used to improve outcomes for rural learners. Considering the need for tools to support online distance education for students, this research aims to examine the change in spatial skills of students in rural areas who are taught online using activities that require the use of a virtual mathematics manipulative. It is anticipated that this research will contribute to the existing literature on sample implementations that can be used in online distance education for rural students to learn mathematics. Such implementations could potentially provide more equitable access to educational opportunities for these students.

1. Spatial Reasoning and Virtual Manipulatives in Online Education

Spatial ability can be broadly defined as the capacity to visualize objects in space as they appear in reality, recognize the appearance of objects from different angles, and move them as a whole or in parts. Wai et al. (2009) emphasizes the importance of spatial ability in scientific and technical fields. They argue that individuals with advanced spatial skills, but not fully developed mathematical or verbal skills, are also essential for a variety of occupations. Based on this claim, it can be said that it is important to develop students' spatial skills. Studies show that spatial ability is related to success in mathematics (Battista, 1990; Fennema & Sherman, 1977; Guay & McDaniel 1977), painting (McWhinnie, 1994), physics (Pallrand & Seeber, 1984), and chemistry (Pribyl & Bodner, 1987). In addition, it has been stated that there is a relationship between spatial ability and problem-solving performance (Battista et al., 1982). Along with the studies revealing the importance of spatial skills, there are also studies showing that students lack spatial skills and have difficulty calculating the surface areas of three-dimensional objects (Liedtke, 1995).

It has been determined that teachers use concrete manipulatives to support their teaching in order to improve students' mathematical understanding (Swan & Marshall, 2010). Studies have shown that these manipulatives, when used effectively, increase students' success (Allen, 2007). In addition to concrete manipulatives, virtual manipulatives are also available to be used in interactive web-based environments. Virtual manipulatives are interactive, web-based visual tools that offer opportunities for building mathematical understanding (Moyer et al., 2002). For example, virtual manipulatives like unit cubes and pentominoes can be used to create isometric drawings. Numerous studies have demonstrated that virtual manipulatives can improve the quality of teaching in the classroom or support learning (Moyer-Packenham & Westenskow, 2013; Rafi et al., 2005; Steen et al., 2006; Yıldız & Tüzün, 2011).

Spatial skills are essential in the field of distance education not only for understanding mathematical concepts but also for interacting within the digital learning environment (Hegarty & Kozhevnikov, 1999). Spatial ability is defined as the capacity to mentally manipulate and visualize objects and their spatial relationships (Wai et al., 2009). According to research (Wai et al., 2009), spatial abilities and mathematical success are strongly correlated. Moyer-Packenham and Westenskow's (2013) study found that virtual manipulatives help students make mathematical connections between various abstract and graphical representations across multiple mathematical domains. According to the findings of this study, it is essential to select efficient virtual manipulatives and thoroughly assess how they affect certain individuals in order to enable students to comprehend and explore mathematical concepts.

It has become necessary to develop new methods and tools to improve spatial abilities as a result of the rapid shift in focus from classroom instruction to online distance learning. Additionally, the unexpected switch from traditional classroom settings to online platforms has created a number of difficulties. In the context of distance education, spatial abilities are considered important not only for understanding mathematical concepts but also for interacting with the digital learning environment (Telg, 1996). In distance education, the teaching and learning of spatial skills can be easily enhanced by the use of virtual manipulatives, such as isometric drawing tools (Moyer-Packenham & Westenskow, 2013). As a result, there is a need to explore effective methods and resources for teaching spatial skills within the context of distance education.

Virtual manipulatives enable teachers to easily communicate the material they want to convey to students in distance education (Moyer-Packenham & Westenskow, 2013; Steen et al., 2006). There are many virtual manipulatives available on various mathematics and geometry topics such as numbers and operations, algebra, geometry, measurement, and data analysis. Studies have been conducted with primary and secondary school students in grades 5 and 6 to investigate the impact of virtual manipulatives on their spatial skills (Kurtuluş & Yolcu, 2013; Yaman & Şahin, 2014; Yıldız & Tüzün, 2011). However, no studies have yet been conducted to examine the effect of virtual manipulatives on the spatial skills of students in distance education programs (Alshehri, 2017).

Consequently, this study examines rural students' ability to "create two-dimensional representations of three-dimensional objects from various perspectives" using isometric drawing activities implemented in online distance education.

2. Research Purpose and Problems

The purpose of this research is to examine the changes in rural students' spatial skills when activities that require the use of isometric drawing tool (IDT) are applied in an online distance education. This study aims to answer the following questions:

(1) How did the seventh-grade students' pre- and post-interview scores differ in online distance education?

(2) What changes occurred in the spatial skills of rural students during the activities carried out in online distance education?

(3) What are the students' opinions regarding the use of IDT in online distance education?

Methodology

In this study, a one-group pretest-posttest experimental design was used to investigate changes in the spatial skills of rural students when activities involving the use of an isometric drawing tool (IDT) were integrated into online distance education. This design requires the assessment of a single group both before and after the intervention (Fraenkel & Wallen, 2009). The strength of this methodology is its capacity to observe changes within the same group over a period, thereby facilitating to draw conclusions regarding the efficacy of the intervention.

1. Participants

This study is situated within a secondary school setting and focuses on students participating in mathematics education in a rural area. Five seventh-grade students from a rural secondary school participated in the study for a period of five weeks during the pandemic period when schools were on emergency remote education. The participating students were 12-13 years of age and were studying the seventh-grade level of mathematics curriculum. They participated based on a written consent form signed by the parents of the students. The IDT was introduced to the students by the teacher at the start of the implementation. The students were selected using an easily accessible sampling method from a predetermined class where the research was conducted. Fourteen students were asked to participate in the research, out of which eight agreed and provided parent consent forms; however, three of them were unable to continue to the implementation regularly due to insufficient opportunities. Ultimately, five students -four females and one male- participated in the research.

The objective of the study was to investigate spatial skills, specifically the front-top-side-back views of 2D and 3D objects, and the determination of the cube numbers of the given objects, which correspond to the seventh-grade level of mathematics curriculum applied in Turkey. In the curriculum, two objectives focus on understanding the perspectives of objects viewed from different angles. These objectives are allotted five instructional hours within the program. The curriculum's achievement descriptors state that "interactive studies incorporating suitable information and communication technologies can be integrated." IDT utilized in this research serves as a representation of the recommended technology. Furthermore, the impact of this tool on the online distance education was investigated as part of the research scope. In this study, conducted during the emergency remote education period, the design was independent of the school process and not an obligation (Bozkurt & Sharma, 2020). Consequently, the term "online distance education" was employed throughout the study to describe the context of the research.

2. Procedure

Within the scope of this research, an implementation was carried out to enhance the spatial skills of students. To start, a pre-interview was conducted with five students who were part of the research. This pre-interview evaluated the students' initial understanding of drawing the views of objects from different views. The results of the pre-interview were utilized to establish the material of the lessons to be taught. Prior to the online distance education, a fascicle was delivered to the students including an activity sheet for every week, isometric drawing papers, and homework.

As shown in Table 1, an implementation was conducted over a period of five weeks, with one-hour sessions held once a week via a video conferencing platform. Homework was assigned at the end of each lesson related to the topic discussed that week. The post-interview was conducted once more at the end of the implementation to measure the students' learning outcomes. Further details about the implementation can be found in Table 1.

Table 1

A comprehensive study plan for the implementation

	CONTENT	EXPLANATION
A. Pre-interview: The researcher administered the Spatial Skills Test to the students in individual, one-to-one interviews, requiring them to draw the views of objects from different 2D and 3D perspectives.		
Orientation	Informing students about the research process	To introduce students to the implementation process, to present the IDT, to inform students about expectations during the implementation.
B. An Implementation		
1. Lesson (1 hour)	Learn to draw unit cubes on isometric paper and create unit cubes using an IDT	To create cubes using isometric drawing paper, to note the invisible surfaces.
2. Lesson (1 hour)	Viewing the 3D structure from various perspectives	To identify the views of the 3D structures created are seen from the top, right and front by using IDT.
3. Lesson (1 hour)	Constructing the three-dimensional structure of the shapes based on two-dimensional views from various views	To ensure the creation of the desired shape with the help of unit cubes using the IDT of a 3-dimensional structure with front, top, right and left views.
4. Lesson (1 hour)	Drawing the view from the backside of the construction using views from different directions.	To draw the rear view of a structure given front, right, left and top views.
5. Lesson (1 hour)	Creating a 3D version of a structure given a 2D view from different directions	To create a 3-dimensional image of a structure with 2-dimensional views from all directions by means of isometric drawing.
C. Post-interview: The researcher administered the Spatial Skills Test to the students in individual, one-to-one interviews, requiring them to draw the views of objects from different 2D and 3D perspectives.		

In online education, students were provided with IDT, and activities were conducted using this tool. During the first week, an orientation lesson was held to ensure students were familiar with the tool and how to use it.

3. Isometric Drawing Tool

IDT, developed by the NCTM and offered free of charge, has two main buttons: Create (Figure 1) and Inspect (Figure 2). The Create tab contains 10 different functions. For example, the number 3 button in Figure 1 can be used to add unit cubes to the isometric dot drawing area (marked with number 16). Buttons 4, 5 and 6 can be used to draw the right, left and top views of the cube. Additionally, IDT has functions for drawing an edge of the cube, changing the position of the unit cubes, deleting drawn unit cubes, painting the faces of the unit cubes, viewing the objects from different directions by rotating them, displaying the projection of the object on the isometric paper and rotating the object around the x, y or z axes. In the implementation, students were given full access to the features of IDT. They were able to utilize all of its functions to complete their tasks.

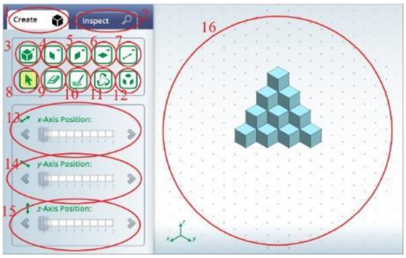

Figure 1.
IDT Create Section (https://www.nctm.org/Classroom-Resources/illuminations/Interactives/Isometric-Drawing-Tool/)

Secondly, the Inspect button in Figure 2 allows for both 3D and 2D views of the object to be examined. For example, the 2-dimensional drawing of the created object can have views from the front, back, top, right and left. Additionally, the coordinates of the created object can be arranged as (x, y, z) = (0, 0, 0), the output of the created figures and objects can be taken, the appearance of the coordinate lines can be changed, the transparency and mat view of the object can be adjusted, and the degree to which the image of the figure is aligned with the axes can be determined. IDT used within the scope of the research was chosen due to its ability to embody all the skills that the students aimed to acquire.

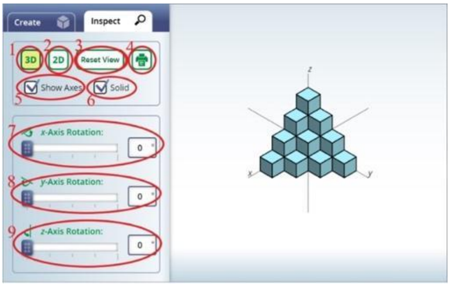

Figure 2.
IDT inspect section
(https://www.nctm.org/ClassroomResources/Illuminations/Interactives/Isometric-Drawing-Tool/)

4. Data Collection Tools

The data for this research consisted of pre- and post- structured interviews, students' worksheets, and opinion forms. Table 2 indicates which data collection tools were used to answer each research question.

Table 2

Data Collection Tools and Their Associated Research Questions

Research Questions	Data Collection Tools
(1) How did the seventh-grade students' pre- and post-interview scores differ in online distance education?	Pre- and post-structured interviews (Spatial Skills Test)
(2) What changes occurred in the spatial skills of rural students during the activities carried out in online distance education?	Pre- and post-structured interviews (Spatial Skills Test), Worksheets
(3) What are the students' opinions regarding the use of IDT in online distance education?	Opinion Forms

Spatial Skills Test and Worksheets

The Spatial Skills Test (SST) was developed for structured interviews to assess students' ability to represent 3D objects from different directions before and after the intervention. The formulated SST was administered to students through individual structured interviews, and the SST documents served as tools for evaluating their spatial skills. To ensure comprehensive responses, students were given the SST in a one-on-one interview context. This test included 7 open-ended questions, each containing up to 32 items with 2, 4, or 6 sub-items. Students had to create 3D models of the objects to complete the open-ended question items. For instance, item 18 asked the students to describe how 3D objects seem differently from each side. Students had to design the front, right, left, and top views of 3D objects in 2D for item 2 before building the thing in 3D using the provided 2D views. Two experts examined the SST utilized in the study to confirm its content validity. It was created based on the goals of the 7th grade mathematics curriculum. Before and after the implementation, the students were given the SST through one-on-one interviews. Besides the scores derived from the SST, students' worksheets were also employed as data collection instruments to identify the specific spatial skills cultivated by the students.

Opinion Forms

After the implementation, an opinion form was given to gather students' views on the use of IDT in distance education. To better understand students' views on the use of the Isometric Drawing Tool (IDT) in online distance learning, a structured interview form was created. Detailed and clear feedback was aimed to be gathered by this form, allowing a clear picture of students' experiences and thoughts to be obtained. The following questions were posed in the interview form: (1) What are your general thoughts on the use of IDT in online distance education?, (2) How is IDT's role in helping your understanding and learning perceived?, (3) Are there any suggestions to make IDT more effective in online distance education?, (4) How is the use of IDT in online distance education believed to affect your motivation?.

5. Data Analysis

To address the research questions posed in this study, data collection tools were analyzed in three stages. Initially, to determine the change in students' spatial skills between the pre-test and post-test, scores were calculated using a rubric. Subsequently, to identify specific spatial skills where students showed improvement, both tests and worksheets were examined using a qualitative descriptive analysis method, focusing on the spatial skill components intended for development in the study. Lastly, content analysis was applied to the opinion forms to understand student perspectives post-implementation.

In order to accurately analyze the change in spatial skills among the students in the study, a rubric was used to assess the responses of the students in the

SST administered during the pre-interview and post-interview. Goodrich (2001) refers to this method as a scoring guide used to accurately determine and track student progress. As this study aimed to assess the changes and improvements in students' spatial skills, a rubric was used to evaluate the students' SST responses. The rubric used to assess the students' responses is presented in Table 3.

Table 3

A Rubric for Scoring Spatial Ability Test

Explanation	Score
The student did not answer the question.	0 point
The student made a wrong answer.	1 point
The student's answer is only partially correct.	2 points
The student answered the question correctly.	3 points

Responses from students to the SST, given during both the pre- and post-interviews, were coded by two independent researchers utilizing a rubric. The second coder, responsible for ensuring the reliability of the analysis, is an expert in the field of mathematics education with a focus on spatial skills research. Based on this rubric, students can receive up to 3 points for each item on the SST, with a potential maximum score of 96 points for the entire test. As indicated in Table 3, if a student did not provide an answer to a question, no points were awarded. If the student provided a response to a question in the SST but it was not the correct answer, they were awarded 1 point, in contrast to questions that were left unanswered.

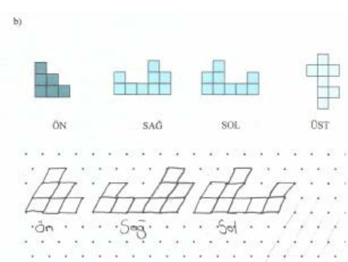

Figure 3.
Erroneous student's answer

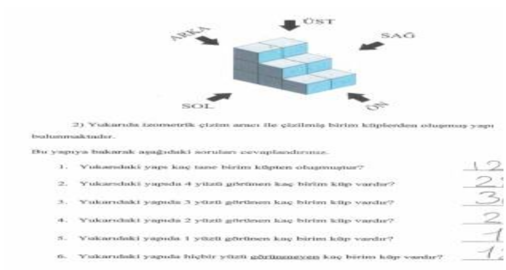

Figure 4.
Erroneous student's answer

An example of this can be seen in Figure 3, where students were asked to create 3D versions of a structure viewed from different directions. The student attempted to draw the 2D figures given above on the isometric paper above; however, their answer was considered incorrect and thus one point was given.

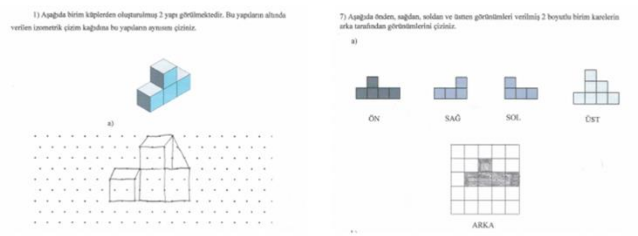

Figure 5.
Partially correct student answers

In the partially correct answer scoring, it was observed that the student had the correct thought process regarding the question but was not able to make the desired drawing. Consequently, two points were awarded for such answers. Upon examining the student's answer given in Figure 5, it is evident from the drawing that the student was thinking that a cube would be placed next to the two cubes already in a row, and that the corners of the two cubes to the right of the two cubes should be linear. However, the student was unable to accurately apply this thought on isometric paper. In another student's drawing in Figure 5 (the right one), where a partially correct answer was observed, they were shown views of a building from different sides and expected to draw the view from the back side. Upon examination, it was found that they had drawn the same front view as the rear view. It was concluded that the student had not realized that the rear view was a reflection of the front view, and they were thus awarded two points. If the student successfully answers the questions, they can be awarded 3 points, as displayed in Figure 6.

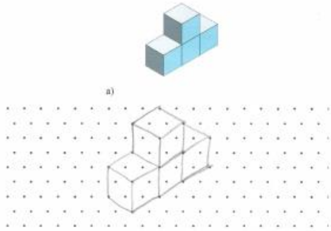

Figure 6.
Correct student answer

Based on the scoring conducted by the two researchers using the rubric, there was complete agreement between their evaluations.

Besides scoring the SSTs administered during the pre- and post-interviews, these tests, along with the worksheets completed by students during lessons, were coded using a qualitative descriptive analysis method. This coding focused on the spatial skill components intended for development in this study, as outlined in Table 3. This approach allowed for a qualitative evaluation of each student's individual progress. This coding was also conducted by two independent coders. In the descriptive analysis of the SST papers and worksheets, there was complete agreement between the coders, with all codes being accepted by consensus.

Table 3

Spatial Skill Codes and Explanations Utilized in Analysis

Code	Explanation
SS1	Draw a cube on isometric paper.
SS2	Draw adjacent cubes on isometric paper.
SS3	Draw top views of the cubes on isometric paper.
SS4	Construct different structures with identical unit cubes.
SS5	Determine how many unit cubes a structure consists of.
SS6	Predict that there may be unseen unit cubes in a structure.
SS7	Calculate the number of cubes on the visible face of a structure.
SS8	Draw the front view of a building in two dimensions.
SS9	Draw the right view of a structure in two dimensions.
SS10	Draw the left side view of a structure in two dimensions.
SS11	Draw the top view of a structure in two dimensions.
SS12	Create a three-dimensional version of two-dimensional shapes that are viewed from different directions.
SS13	Draw the rear view of a structure with images from different directions.

Once coding was finalized, discussions with the coding researcher determined which responses would be included in the presentation of the findings. Furthermore, detailed explanations of the research findings were provided, with examples taken from photographs of the students' responses.

Finally, the students' opinions on IDT were assessed through content analysis. Responses from students on the opinion forms were subjected to content analysis. The feedback was categorized into three primary themes: the advantages of IDT, potential areas for improvement, and the tool's influence on motivation. These themes provided insights into students' comprehensive experiences and perceptions of IDT. Direct quotations from students' feedback were incorporated within each theme to strengthen the trustworthiness and integrity of the findings.

6. Validity and Reliability

Multiple assessments were implemented to confirm the validity and reliability of the findings in order to guarantee the study's consistency. The methodological approach, which was created with a focus on repeatability, makes it easier for other researchers to replicate it. Similar student outcomes can be expected with a similar group of students. For availability of replication, every material and procedure used in the study is fully described. By creating a measurement tool that also was directly related to the research problems, validity was ensured. This measurement tool's reliability and validity were confirmed by experts whose views were requested during development. Pre- and post-structured interviews, students' worksheets, and student opinion forms were the three instruments utilized to gather the data. This multidimensional approach provided a rich data set, offering a comprehensive perspective on skill development. Data triangulation was done to make the findings more reliable. Cross-verification of the data gathering tool results allowed for the evaluation of the phenomenon from several angles. Potential biases were reduced by using this approach, and it was possible to develop a more detailed understanding of how the isometric drawing tool affected students' spatial abilities in an online learning environment. The triangulation method, which added another degree of confidence to the findings, validated the finding that using the isometric drawing tool had a positive impact on the development of spatial skills.

Findings

This research aimed to examine the development of secondary school students' spatial skills in online distance education designed using IDT. In order to do this, the improvement of the students' spatial skills was evaluated using the pre- and post-interview scores. Visual representations of the solutions the students emerged with during assessments were also added to show how their spatial abilities had evolved. Finally, the opinions of the students on the use of IDT in online distance learning were recorded.

1. Comparison of Pre- and Post-interview SST Scores among Students

Seventh-grade students' pre- and post-interview scores were analyzed using the rubric, and the results are shown in Table 4 together with the data representing the students' overall pre- and post-interview scores.

Table 4

Students' total points

Test/Students	S1	S2	S3	S4	S5	Mean
Pre-interview	26	41	34	44	36	36,2
Post-interview	82	80	72	78	68	76

When the pre-interview scores of the students were examined, it was found that the average score was 36.2. Upon examining the post-interview scores, it became evident that the average was 76. On a question-by-question basis, it was observed that two students had no points in the first question, one student had no points in the fifth question, two students had no points in the sixth question, and three students had no points in the seventh question. When the post-interview scores of the students were examined for each question, it was determined that four students had full points in the first question, five students had full points in the second question, and two students had full points in the fifth question. Table 4 showed the most notable result with student S1. Before the post-interview, S1 had not answered any of the last three questions correctly; however, during the post-interview, the student got full points in the fifth question and had the greatest difference between pre- and post-interview scores. Additionally, when all the questions were examined, the seventh question was determined to be the one in which the students had the lowest scores in the post-interview.

2. Comparison of Students' Spatial Skills based on their Written Answers in depth

In addition to the pre- and post-interview scores of the students, the skills of the students were examined. According to this analysis, Table 5 and Table 6 provide the skills that the students had in the pre-interview and post-interview, respectively.

Table 5

Students' Spatial Skills in the Pre-interview Assessment

			Students				
Codes	**Skill**	**Question numbers related to skills**	**S1**	**S2**	**S3**	**S4**	**S5**
SS1		Q1a-Q1b-Q6a-Q6b	+			+	
SS2	Drawing cube/s in different positions	Q1a-Q1b-Q6a-Q6b				+	
SS3		Q1a-Q1b-Q6a-Q6b				+	
SS4		Q2a-Q3a-Q4a	+	+	+	+	+
SS5		Q2f-Q3f-Q4f		+		+	+
SS6	Counting the number of cubes in the constructions in different positions	Q2b-Q3b-Q4b		+			
SS7		Q2c-Q3c-Q4c		+	+		+
SS8		Q2d-Q3d-Q4d		+	+		+
SS9		Q2e-Q3e-Q4e		+	+		+
SS10		Q5a1-Q5b1		+	+	+	+
SS11	Drawing various 2D views of 3D constructions	Q5a2-Q5b2				+	
SS12		Q5a3-Q5b3				+	

SS13		Q5a4-Q5b4	+
SS14	Drawing various 3D representations of 2D views on isometric paper	Q6a-Q6b	
SS15	Draw the rear view of 3D representations	Q7a-Q7b	

Examining Table 5 revealed that none of the students possessed 3D isometric drawing skills in the pre-interview. However, students S2, S3, and S5 had some capacity to count cubes in structures when viewed from different directions, while Student S4 was the only one able to draw 3D representations of simple constructions (SS1, SS2, and SS3). This student also had the ability to draw 2D views of 3D constructions from different directions. However, the pre-interview showed that none of the students could draw 3D representations using 2D views, nor could they draw back views of 2D images from different directions.

When the visuals showing the drawings made by the students in the pre-interview were examined, it was seen that student S1 was able to draw the cube partially correctly, while student S4 drew the 3D representations of the cubes, both singly and side by side and on top of each other. Examples of the drawings of these students are given in Figure 7.

Figure 7.
Sample student responses in the pre-interview

It is evident that the students' spatial abilities improved after the implementation. Figure 8 shows an example of the student's 2D drawings of the 3D structures from different directions.

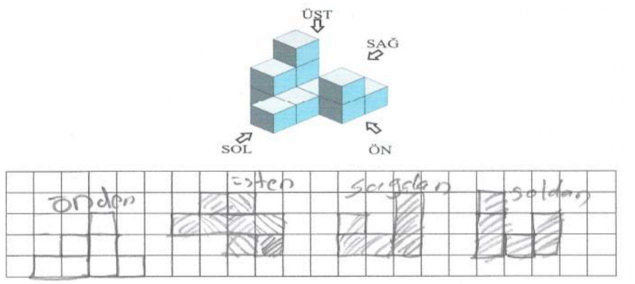

Figure 8.

S4's drawings showing SS10-SS13 skills in the pre-interview

When the students' skills in the post-interview were examined, it was seen that they could make 2D views of the structures given their 3D representations, count the cubes in the desired part of the structures whose views were given from different directions, and draw the 2D views of the structures given the 3D representation from different directions. Furthermore, none of the students were able to draw 3D isometric representations from 2D views (SS14), while only two students (S2-S5) were able to draw back views of the drawings given 2D images from the front-right-left-top (SS15). The skills that the students had in the post-interview are summarized in Table 6.

Table 6

The spatial skills that students have in the post-interview

Skill /Student	**Question numbers related to skills**	**Codes**	**S1**	**S2**	**S3**	**S4**	**S5**
Drawing cube/s in different positions	Q1a-Q1b-Q6a-Q6b	SS1	+	+	+	+	+
	Q1a-Q1b-Q6a-Q6b	SS2	+	+	+	+	+
	Q1a-Q1b-Q6a-Q6b	SS3	+	+	+	+	+
Counting the number of cubes in the constructions in different positions	Q2a-Q3a-Q4a	SS4	+	+	+	+	+
	Q2f-Q3f-Q4f	SS5		+	+	+	+
	Q2b-Q3b-Q4b	SS6	+	+	+	+	+
	Q2c-Q3c-Q4c	SS7	+	+	+	+	+

	Q2d-Q3d-Q4d	SS8		+	+	+	+
	Q2e-Q3e-Q4e	SS9	+	+	+	+	+
Drawing various 2D views of 3D constructions	Q5a1-Q5b1	SS10	+	+		+	+
	Q5a2-Q5b2	SS11	+	+	+	+	+
	Q5a3-Q5b3	SS12	+	+	+	+	
	Q5a4-Q5b4	SS13	+	+	+	+	
Drawing various 3D representations of 2D views on isometric paper	Q6a-Q6b	SS14					
Draw the rear view of 3D representations	Q7a-Q7b	SS15		+			+

A comparison of the students' drawings in the pre-interview and post-interview revealed that they had improved their ability to accurately depict a structure composed of four cubes. For instance, student S1 was only able to partially draw the structure in the pre-interview, with a 3-dimensional image, but was able to draw the representation correctly in the post-interview, as illustrated in Figure 9.

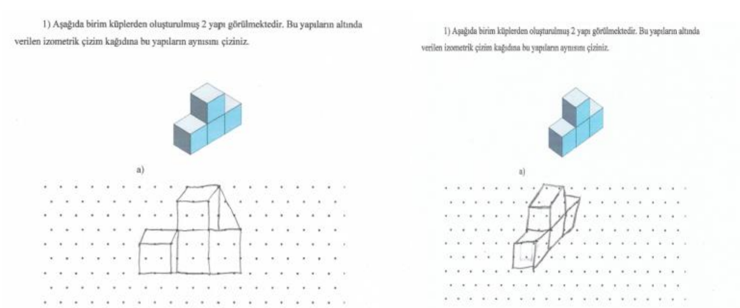

Figure 9.
Student S1's pre- and post-interview drawing

In addition to the 3D representation drawings of the students, it was observed that their cube-counting skills improved as a result of the implementation. At the beginning of the study, the students were able to determine the number of cubes in structures when all of their faces were visible. However, in the post-interview, they were able to determine the number of cubes in structures given from different views (e.g., the number of cubes with 3 faces). Nevertheless, when presented with more complex 3-dimensional structures, containing more cubes and in which no faces of the cubes were visible, the students had difficulty in determining the number of cubes. It was found that when students were asked about the number of unit cubes in the structure given in the 3rd and 4th questions of the pre-interview, and the number of cubes with different numbers of faces, they made mistakes. However, it was observed that the same students correctly answered these questions in the post-interview, but still experienced difficulty in determining the number of cubes with no visible faces. Figure 10 illustrates S4's pre- and post-interview responses. As seen in the figure, S4's drawing on the pre-interview was developed on the post-interview. This indicates that S4 improved their isometric drawing skills after the intervention.

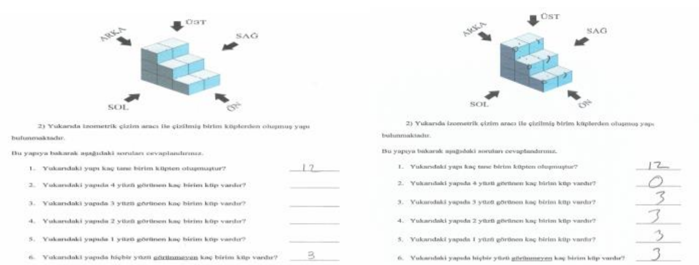

Figure 10.

S4's pre- and post-interview answer

In the questions where students were asked to make 2D drawings of the structures given in 3D images from different directions, it was determined that they could make the correct drawings in the post-interview. While the students were unable to determine the two-dimensional (2D) views of the three-dimensional (3D) structures from the right, left, and top at the start, they were able to do so in the post-interview. An example of the answers given in the pre- and post-interview and the worksheet, in which the students drew the structures with 3D images from different directions, is presented in Figure 11.

Pre-interview drawing of S5	S5's drawings on the worksheet	Post-interview drawings of the S5

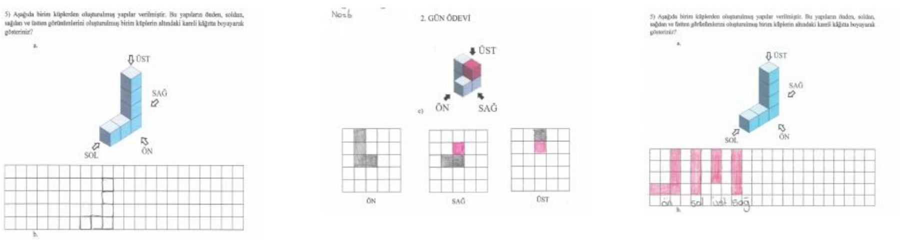

Figure 11.

Drawings of S5's 2D images from different directions

It was observed that the students struggled to make progress in the questions regarding drawing 3D isometric and 2D rear views of the structures, based on two-dimensional images from different directions. In the post-interview, two students (S1 and S3) made an error, incorrectly drawing their views from the front instead of the back. Figures 12 and 13 show the answers of S1 and S3, respectively.

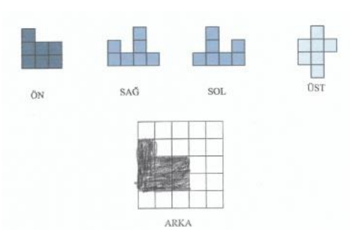

Figure 12.

Post-interview drawing of S1

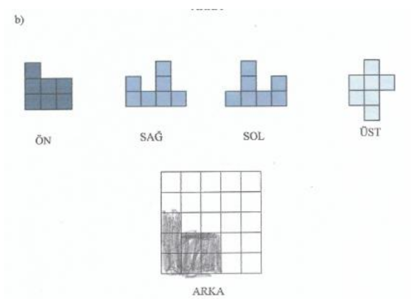

Figure 13.

Post-interview drawing of S3

It was observed that two students, S4 and S5, responded differently to the question. S4 left the question blank, while S5 answered it incorrectly. Additionally, it was seen that S2 and S5 both provided correct answers in the post-interview when presented with two-dimensional images of structures from different angles. The answer of S2, one of the students who gave correct answers, is shown in Figure 14. It includes the pre-interview, worksheet, and post-interview drawing.

Pre-interview drawing of S2	S2's drawings on the worksheet	Post-interview drawing of S2

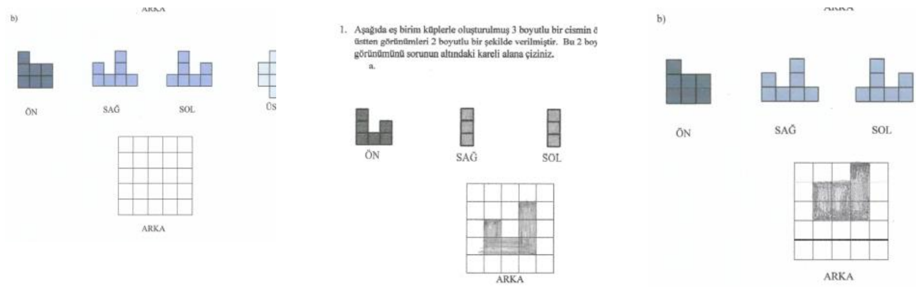

Figure 14.

S2's drawing of 2D rear view of structures

3. Exploring Students' Perspectives on Utilizing IDT in an Online Setting

After the implementation of online distance education incorporating IDT, students' written feedback on its usage was categorized into three primary areas: the benefits of IDT, potential areas of improvement, and the tool's impact on motivation.

Many students expressed positive views about IDT. For instance, S2 remarked, "Using IDT simplified my understanding and visualization of three-dimensional objects, particularly aiding in drawing complex shapes." Another student expressed a similar viewpoint, stating, "In online classes, the movable feature of IDT made drawing easier, improving my understanding of the topics." The majority of students had a positive opinion of IDT, often describing it as "effective" and highlighting its "dynamic" abilities, which they believed sped up their drawing and enhanced their skills.

While many students found the IDT tool beneficial, some identified areas that could be improved. One student commented, "Initially, certain features of the software were hard to understand. I would have liked more hands-on time with the tool." While the feedback was largely positive, some students faced challenges. For example, S4 mentioned, "Using IDT on my phone presented issues in rotating shapes, making it difficult to visualize certain views, especially from the rear." This feedback indicates that visualizing certain perspectives remains difficult even with IDT, suggesting the importance of using appropriate technological devices for the optimal experience.

Furthermore, students found lessons incorporating virtual tools like IDT more understandable and engaging than traditional sessions. One student (S1) explained, "With IDT, math lessons became more enjoyable. In difficult topics, this tool increased my motivation and comprehension." Students also expressed a want for more virtual tools in online education, believing it would further improve engagement. As S5 stated, "I wish such tools were integrated into all subjects. It would help in understanding complex topics and make lessons more enjoyable."

In summary, students expressed satisfaction with online distance education that used IDT, noting that it enhanced their understanding and increased their motivation during lessons.

Conclusion, Discussion, and Suggestions

At the conclusion of this study, it was demonstrated that the utilization of an IDT during online distance education was effective and caused changes in promoting rural students' spatial skills. While the students could not even draw cubes on isometric drawing paper at the beginning, it was observed that at the end of the study, they were able to accurately make 3D isometric drawings by positioning the cubes side by side and on top of each other. In the literature, there are studies that develop students' spatial skills through virtual manipulatives (Kay, 2014; Yıldız & Tüzün, 2011). In these studies, it was stated that there was an improvement in students' spatial skills in computer-assisted teaching. In this respect, the results of this research strongly support the findings of the studies previously conducted in the literature.

The IDT used in this research has features that support all the skills (Table 3) that are aimed to be acquired by the students. However, in online distance education, it was observed that students had difficulties in constructing 3D isometric views of formations that were given 3D views from the back and 2D formations that were given views from different directions. This is likely due to the limited use of the study and the inexperience of the students participating in the research. The feedback from one student highlighted challenges in adapting to the isometric drawing tool, especially when accessed via a mobile device. This student wanted more hands-on time with the tool to overcome these challenges. Battista et al. (1982) stated that students need a long time for their spatial visualization, while Olkun and Altun (2003) found that the spatial thinking skills of students who previously knew how to use computers improved more. Therefore, it is possible that the students' inexperience with both the IDT and virtual mathematics manipulatives may have been a factor in their difficulties constructing 3D isometric views.

In this study, the use of virtual manipulatives in online distance education, with some students accessing training on tablets or phones instead of computers, presents a limitation. Vlachogianni and Tselios (2022) highlight the deep impact of usability on both the learning experience and outcomes. This stresses the importance of the usability of technological tools, especially on different devices. Therefore, when adding such tools to teaching, focusing on the user design and experience is essential. Durmuş and Karakırık (2006) also emphasized the need to design virtual manipulatives that focus on the mathematical concepts they aim to communicate, making sure their action is as clear as possible. This indicates that while virtual manipulatives can help with understanding concepts, their design and the way they're used are important for their successful addition to the learning progression.

In particular, situations requiring consecutive manipulation were identified as areas where students did not demonstrate significant development within the scope of the study. The challenges faced by the students in this study, particularly in constructing 3D isometric views, can be further illuminated by recent literature. Spatial visualization integrates mental rotation and spatial orientation (Mix et al., 2016). Such visualization often requires complex, multi-step mental processes and transformations (Hegarty & Waller, 2004; Tversky, 2011). This complexity may explain the difficulties encountered by students, given their limited exposure to the IDT and virtual mathematics manipulatives. For middle school students, like those in this study, visualization skills are vital for tasks involving orientation, with many relying on visualizing motion to understand different perspectives (Samsudin & Mohd Eshaq, 2011). This research suggests more extensive spatial visualization training could potentially enable students to visualize more effectively, resulting in improved performance on orientation tasks.

The acquisition of spatial skills is an extended and complex endeavor (Battista, 1990). A major limitation of this study is that it was conducted over just 5 weeks and only examined online distance learning. The literature reveals that spatial training programs can vary substantially in duration. As Lowrie et al. (2019) stated, this variability raises questions about the optimal length required for a virtual spatial training program to elicit meaningful learning outcomes. For instance, while Cheng and Mix (2014) implemented a single-session intervention, Lowrie et al. (2017) conducted a more extended ten-week program, resulting in broader enhancement of mathematical concepts, especially in areas like measurement and geometry. Additionally, Lowrie et al. (2019) investigated the effects of a 3-week spatial intervention. Their findings showed that even within this brief period, there were marked improvements in both mathematics and spatial performance, especially in geometry, word-based math problems, spatial orientation, and visualization. This suggests that while this 5-week online intervention provides valuable insights, modifying the duration and content of the intervention, especially in the context of distance education, could potentially lead to more comprehensive outcomes. Consequently, it is suggested that the curriculum should allocate more time to learning objectives that necessitate spatial skills. Moreover, further research should be conducted to evaluate the long-term impact of such tools on student learning. This would provide valuable insights into how rural students can best be supported in their learning process and how teachers can improve the learning experiences of students with limited opportunities.

This research was conducted online with rural students during the emergency online distance education process. Yaman and Şahin (2014) conducted a study in which they used concrete and virtual manipulative together during the teaching of the lessons. They concluded that the students made progress in drawing the three-dimensional views of the given structures and they perceived the concept of depth better; observed that students corrected their mistakes in group work. However, since this study was conducted in an online distance education, students worked individually and no concrete material support could be provided. This lack of concrete material and peer support in the online environment can be seen as a potential barrier to the development of some of the students' less developed skills (Amin & Li, 2010). When integrating technology into education, Durmuş and Karakırık (2006) emphasized that while virtual manipulatives can simulate concrete ones, they are more abstract due to the lack of touch-based interaction. They argued that the main purpose of manipulatives is not to make concepts touchable but to highlight the main features of the concept taught. This implies that virtual manipulative design should be customized to fit specific concepts, making sure they emphasize the main elements of the topic. Additionally, Durmuş and Karakırık (2006) noted that virtual manipulatives might have advantages by removing some limitations. In this study, the limitations stemming from students' lack of access to concrete materials and insufficient peer support were addressed through the use of virtual manipulatives. For instance, the dynamic nature of the virtual manipulative employed in this research enabled students to rotate the given object, facilitating easier identification of the cube faces in various perspectives. To address the research limitations stemming from the absence of concrete material and peer support in online settings, it is proposed that educators integrate virtual group activities or peer-to-peer sessions to replicate the collaborative environment of traditional classrooms. Additionally, mathematics educators are encouraged to collaborate closely with technology developers to ensure that virtual manipulative are specifically customized to align with mathematical concepts.

Finally, the students expressed overwhelmingly positive opinions about the implementation in online distance education and virtual manipulative. The students reported that the virtual manipulative made it easier to understand the concepts and that the lessons were more engaging and enjoyable with this tool. The favorable opinions expressed by the students suggest that the use of virtual manipulatives can enhance their enthusiasm and engagement in the learning process. This result is in line with the findings of other studies, which demonstrate that web-based tools can help to foster positive attitudes towards mathematics (Alshehri, 2017; Mutluoğlu & Erdoğan, 2019). In sum, these findings suggest that the use of IDTs and virtual manipulatives in online distance education may be a promising approach to improve students' spatial skills. Boszkurt and Sharma (2020) argued that "the right approach should not be learning from technology, but rather, learning with technology" (p. 3). Consequently, the IDT employed in this study offers rural students the opportunity to learn in conjunction with technology.

Based on the findings of this study, we recommend that educators consider incorporating IDTs and virtual manipulatives into their online mathematics teaching to enhance students' spatial skills. The IDT used in this research has features (i.e., dynamic features) that support the development of all the necessary skills, as outlined in Table 3. However, it should be noted that students may initially struggle with constructing 3D isometric views, particularly when given complex formations from different perspectives. Therefore, it is critical to provide adequate support and scaffolding to help students overcome these challenges. Further research should be conducted to assess the long-term impact of virtual manipulatives on student learning and to identify effective strategies for supporting students in their use. In addition, we suggest that future studies examine the potential benefits of combining concrete and virtual manipulatives, as this approach may better support students with less developed skills. The overwhelmingly positive feedback from students regarding the use of virtual manipulatives indicates that educators should continue to explore the use of virtual tools to increase students' enthusiasm and engagement in the learning process.

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Genişletilmiş Özet

Giriş

Matematik, normal öğretim koşullarında bile genellikle zorlayıcı bir ders olarak görülmektedir (Fritz ve diğ., 2019). Çevrimiçi uzaktan eğitimde ise matematik öğretiminin etkili bir şekilde yürütülüp yürütülemeyeceği tartışmalı bir konudur. Bazı araştırmacılar, uzaktan eğitimde öğrencilere matematiksel düşünme için gerekli koşulların oluşamayacağını (Lowrie ve Jorgensen, 2012), web tabanlı matematik öğretiminin tek başına yeterli olmadığını (Fedele ve Li, 2008) ve uzaktan eğitimde matematik öğrenimi için gerekli olan öğrenciler arasındaki iş birliğinin yetersiz kaldığını (Amin & Li, 2010) öne sürmektedirler. Ayrıca Kilit ve Güner (2021) öğretmenlerin matematiğin en iyi fiziksel sınıf ortamında öğretildiğine, çevrimiçi uzaktan eğitimin ise matematik öğretimi için etkili veya verimli olmadığına inandıklarını belirtmişlerdir. Bu araştırma sonuçlarının ve öğretmen görüşlerinin aksine, son yıllarda yapılan çeşitli araştırmalar teknolojik araçlarla desteklenen çevrimiçi matematik öğretiminde öğrencilerin matematiğe yönelik tutumlarının geliştiğini ve kavramsal olarak etkili öğrenmenin gerçekleştiğini göstermiştir (Baki ve Çakıroğlu, 2010; Kay, 2014). Uzaktan eğitim araştırmaları ağırlıklı olarak yüksek öğretim düzeyinde yürütülmüş, ortaokul ve lise düzeylerinde çok az sayıda çalışma yapılmıştır (Almarashdi & Jarrah, 2021; Almuraqab, 2020). Çevrimiçi ortamlarda uzaktan eğitimin en iyi şekilde nasıl yürütülebileceğinin daha iyi anlaşılması için ortaokul düzeyinde daha fazla araştırmaya ihtiyaç bulunmaktadır.

Pandemi dönemi öncesinde, öğretme-öğrenme sürecini geliştirmek amacıyla normal şartlarda uzaktan eğitim çalışmaları da yürütülmüştür (Hillmayr vd., 2020). Ancak matematik dersi genellikle bu çalışmaların odak noktasında yer almamıştır (Astri, 2017). Pandemi döneminde ise her matematik öğretmeninin acil uzaktan matematik öğretimini deneyimlemesi gerekmiştir. Araştırmalar, uzaktan eğitim uygulamalarında kırsal kesimde okuyan ve matematik performansı düşük olan öğrencilerin en fazla etkilenen grup olduğunu göstermiştir (Ergün ve Arık, 2020). Lowrie ve Jorgensen (2012) kırsal kesimdeki öğrencilerin matematikte düşük performans gösterme riski taşıyan gruplar olarak tanımlanmalarından dolayı, matematik öğrenimi için gelişmiş veya sınırlı potansiyeller sağlayabilecek uygulamaların, öğrencilerin başarı düzeyini önemli ölçüde etkileyebileceğini ifade etmiştir. Bu nedenle, bu uygulamaların kırsal kesimdeki öğrencilerin öğrenme başarılarını iyileştirmek için nasıl kullanılabileceğinin anlaşılmasına önem verilmelidir. Öğrenciler için çevrimiçi uzaktan eğitimi destekleyecek araçlara duyulan ihtiyacı göz önünde bulunduran bu araştırma, çevrimiçi uzaktan eğitimde sanal matematik manipülatif kullanımı gerektiren etkinliklerde kırsal kesimlerdeki öğrencilerin uzamsal becerilerindeki değişimi incelemeyi amaçlamıştır. Bu araştırmanın sonuçlarının kırsal kesimdeki öğrencilerin matematik öğrenmelerine yönelik çevrimiçi uzaktan eğitimde kullanılabilecek örnek uygulamalarla ilgili mevcut alanyazına katkı sağlayacağı düşünülmektedir.

Yöntem

Bu araştırma kırsal bölgedeki bir ortaokulun yedinci sınıfında okuyan öğrencilere odaklanmaktadır. Araştırma, okulların acil uzaktan eğitime geçtiği pandemi döneminde beş haftalık bir sürede gerçekleştirilmiştir. Araştırmada tek gruplu öntest-sontest deneysel desen kullanılmıştır. Araştırmaya kırsal bölgede yer alan bir ortaokulun yedinci sınıfında okuyan beş öğrenci katılmıştır. Bu araştırma kapsamında, öğrencilerin uzamsal becerilerini geliştirmeye yönelik bir uygulama gerçekleştirilmiştir. Çevrimiçi uzaktan eğitim uygulaması başlamadan önce öğrencilere etkinlik kağıtları, izometrik çizim kağıtları ve ödevlerden oluşan bir fasikül dağıtılmıştır. Her dersin sonunda, öğrencilere o hafta işlenen konuyla ilgili ödev verilmiştir. Araştırmanın verileri ön ve son yapılandırılmış görüşmelerde uygulanmış uzamsal beceri testi, öğrenci çalışma kağıtları ve görüş formu aracılığıyla toplanmıştır. Araştırmada kullanılan veri toplama araçları üç aşamada analiz edilmiştir. İlk olarak, öğrencilerin uzamsal becerilerindeki değişiklikleri göstermek için uzamsal beceri testi bir rubrik kullanılarak değerlendirilmiştir. İkinci aşamada, uzamsal beceri gelişmelerini belirlemek için testler ve çalışma kağıtları üzerinde nitel betimsel analiz gerçekleştirilmiştir. Son olarak, uygulamayla ilgili öğrenci görüşlerini tespit etmek için görüş formlarının değerlendirilmesinde için içerik analizi kullanılmıştır. Verilerin analizini iki farklı araştırmacı bağımsız olarak gerçekleştirmiştir.

Bulgular

Öğrencilerin ön ve son görüşmede almış oldukları toplam puanları arasında belirgin bir artış olduğu görülmektedir. Öğrencilerin ön görüşme puanları incelendiğinde, puan ortalamasının 36,2 olduğu; son görüşme puanları incelendiğinde ise ortalamalarının 76 olduğu görülmektedir.

Ön görüşmede hiçbir öğrencinin verilen iki boyutlu görüntülerin üç boyutlu izometrik çizimlerini yapamadığı, ayrıca hiçbir öğrencinin ön-sağ-sol-üstten iki boyutlu görüntüleri verilen çizimlerin arkadan görüntülerini çizemediği belirlenmiştir. Öğrencilerin son görüşmede sahip oldukları beceriler incelendiğinde ise öğrencilerin uzamsal becerilerinde gelişim olduğu görülmüştür. Öğrencilerin üç boyutlu görünümleri verilen cisimlerin izometrik çizimlerini gerçekleştirebildikleri, farklı yönlerden görünümleri verilen cisimlerde farklı durumları istenen küpleri sayabildikleri, üç boyutlu görünüşü verilen cisimlerin farklı yönlerden iki boyutlu görünümlerini çizebildikleri belirlenmiştir. Son görüşmede ise öğrencilerin hiçbirinin iki boyutlu görüntülerden üç boyutlu izometrik çizim yapamadığı (BC14), yalnızca iki öğrencinin (Ö2-Ö5) ise ön-sağ-sol-üstten iki boyutlu görüntüleri verilen çizimlerin arkadan görüntülerini çizebildikleri (BC15) görülmüştür.

Verilen cisimlerin izometrik çizimlerine ek olarak öğrencilerin küp sayma becerisi incelendiğinde, öğrencilerin ön-son-test yanıtlarında da gelişim görülmektedir. Öğrenciler küp sayarken yapının içindeki bütün küplerin sayısını başlangıçta da belirleyebilirken, son görüşmede farklı durumlarda verilen küp sayısını belirleyememiştir. Son görüşmede ise öğrencilerin farklı durumları verilen küp sayısını (örneğin, üç yüzü görünen küp sayısı gibi) belirleyebildikleri görülmüştür. Ancak öğrencilerin daha karmaşık olan, küplerin hiçbir yüzünün görünmediği durumları içeren ve daha fazla küp sayısı içeren üç boyutlu yapılarda, küplerin sayısını belirleyemedikleri belirlenmiştir. Farklı yönlerden iki boyutlu görüntüleri verilen yapıların üç boyutlu izometrik ve iki boyutlu arkadan görüntülerinin çizimlerine yönelik sorularda ise öğrencilerin çok fazla gelişim gösteremediği görülmüştür.

Sonuç, Tartışma ve Öneriler

Bu çalışmanın sonucunda, çevrimiçi uzaktan eğitim sırasında izometrik çizim aracı kullanımının etkili olduğu ve kırsal bölge öğrencilerinin uzamsal becerilerinde değişiklikler sağladığı görülmüştür. Öğrenciler araştırmanın başlangıcında izometrik kâğıda küp dahi çizemezken, çalışmanın sonunda küpleri yan yana ve üst üste yerleştirerek hatasız bir şekilde üç boyutlu izometrik çizim yapabildikleri belirlenmiştir. Bu araştırmada kullanılan izometrik çizim aracı, öğrencilere kazandırılması amaçlanan tüm becerileri destekleyen özelliklere sahiptir. Ancak çevrimiçi uzaktan eğitimde öğrencilerin arkadan üç boyutlu görünümü verilen oluşumların üç boyutlu izometrik görünümlerini ve farklı yönlerden görünümü verilen iki boyutlu oluşumları çizmekte zorlandıkları gözlemlenmiştir. Bu durumun izometrik çizim aracının sınırlı kullanımından ve araştırmaya katılan öğrencilerin deneyimsizliğinden kaynaklandığı söylenebilir. Özellikle ardışık manipülasyon gerektiren çizimler, öğrencilerin bu araştırma kapsamında daha az gelişim gösterdikleri alan olarak belirlenmiştir. Bu durumda Battista'nın (1990) uzamsal becerilerin kazanılmasının uzun ve karmaşık bir süreç olduğunu destekler niteliktedir. Bu nedenle, öğretim programında uzamsal beceri gerektiren kazanımlara daha fazla zaman ayrılması önerilmektedir. Ayrıca, bu tür araçların öğrencilerin öğrenmesi üzerindeki uzun vadeli etkisini değerlendirmek için daha fazla araştırmaya ihtiyaç bulunmaktadır. Son olarak, öğrenciler çevrimiçi uzaktan eğitimde sanal manipülatif kullanımı hakkında olumlu düşünceler ifade etmişlerdir. Özetle, bu bulgular çevrimiçi uzaktan eğitimde sanal manipülatiflerin kullanımının öğrencilerin uzamsal becerilerini geliştirmek için umut verici bir yaklaşım olabileceğini düşündürmektedir.