

Examination of the Effect of Virtual Reality-Based Virtual Museum Design on Student Achievement in Science Education

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ABSTRACT

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This research aims to create a virtual reality-based virtual museum about the seventh-grade course unit of "Pure Substance and Mixtures" on the topic of "Particulate Nature of Matter", and to observe the effect of this design on the academic achievement of students in a science course. The study group, selected by the convenience sampling method, consisted of seventh-grade students from a secondary school in Konya Province in the 2021-2022 academic year. A total of 46 students, in which 23 students (17 female and 6 male) in the experimental group and 23 students (9 female and 14 male) in the control group, is included in the study. The pretest-posttest control group quasi-experimental design was used as the research design, and the "Particulate Nature of Matter Achievement Test" (PNMAT) was used as the data collection tool. As the PNMAT items were formed according to the learning outcomes of the 2013 curriculum and the science curriculum was updated in 2018, four questions were removed from the achievement test. The current achievement test was implemented for 110 secondary school 7th-grade students. The reliability coefficient (KR-20) from the achievement test was found as .63 which showed the achievement test reliability. In the implementation process, a virtual museum was designed under the learning outcomes. Then, for four weeks, the design was implemented in the experimental group while the control group was taught as required in the science education curriculum. The data obtained from the PNMAT, which was applied as a pretest and posttest, were analyzed and tabulated using the SPSS 21 package program. As the result of this study, it was determined that the academic achievement of the experimental group students was significantly higher than the control group students in the science course.

Fen Eğitiminde Sanal Gerçeklik Temelli Sanal Müze Tasarımının Öğrenci Başarısına Etkisinin İncelenmesi

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Bu araştırmanın amacı yedinci sınıf "Saf Madde ve Karışımlar" ünitesi "Maddenin Tanecikli Yapısı" konusuna ilişkin bir sanal gerçeklik temelli sanal müze tasarlamak ve bu tasarımın öğrencilerin fen bilimleri dersindeki akademik başarılarına etkisini gözlemlemektir. Araştırmanın uygun örnekleme yöntemi ile seçilen çalışma grubunu, 2021-2022 eğitim-öğretim yılında Konya ilinde bulunan bir ortaokulun yedinci sınıf öğrencileri oluşturmaktadır. Toplamda 46 öğrencinin yer aldığı çalışmada deney grubunda 23 öğrenci (17 kız, 6 erkek), kontrol grubunda ise 23 öğrenci (9 kız, 14 erkek) bulunmaktadır. Yöntem olarak ön test – son test kontrol gruplu yarı deneysel desenin kullanıldığı çalışmada, veri toplama aracı olarak "Maddenin Tanecikli Yapısı Başarı Testi (MTYBT)" kullanılmıştır. MTYBT'deki sorular 2013 yılının öğretim programı kazanımlarına göre düzenlendiği için ve 2018



yılında fen bilimleri dersi öğretim programı yenilediği için güncel programda yer almayan bir kazanımı ölçen dört soru başarı testinden çıkarılmış böylece 110 ortaokul yedinci sınıf öğrencisine güncel başarı testi uygulanmıştır. Başarı testinden elde edilen verilerin güvenilirlik katsayısı (KR-20) .63 olarak bulunmuş ve başarı testinin güvenilir olduğu sonucuna ulaşılmıştır. Araştırmanın uygulama sürecinde öncelikle kazanımlara uygun şekilde sanal müze ortamı tasarlanmış ardından dört hafta boyunca deney grubunda sanal gerçeklik temelli sanal müze tasarımı kullanılarak, kontrol grubunda ise fen bilimleri dersi öğretim programındaki haliyle öğretim gerçekleştirilmiştir. Ön test ve son test olarak uygulanan MTYBT'den elde edilen veriler SPSS 21 paket programı kullanılarak analiz edilmiş ve tablolaştırılmıştır. Elde edilen bulgular sonucunda sanal gerçeklik temelli sanal müze tasarımı uygulanan deney grubu öğrencilerinin fen bilimleri dersinde gösterdikleri akademik başarılarının kontrol grubu öğrencilerinin fen bilimleri dersinde gösterdikleri akademik başarıdan anlamlı düzeyde daha yüksek olduğu tespit edilmiştir.

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INTRODUCTION

With the advancement of technology, the concept of virtual museums has evolved in parallel with the modern understanding of museology. When the words "Virtual" and "Museum" come together, they often refer to an online version of a real museum. Especially in recent years, with the increase in internet connection speeds and the rise of three-dimensional (3D) web technologies, significant changes have occurred in virtual museum and exhibition sites. Many museums continue their activities in both virtual and physical spaces. However, there are also completely virtual museums that do not rely on the existence of a physical museum (Lin, 2009).

Virtual reality can be defined as a multimedia environment designed to enhance interaction between individuals and computers, appealing to various senses of the person (Stone, 1991). In studies involving the use of 3D virtual reality in the context of educational technology, wearable technologies such as virtual reality display hardware and data gloves are commonly employed to strengthen the immersive experience. However, it is observed that this technology is not widely used at the expected level in schools today, possibly due to the high financial burden associated with it. Therefore, desktop-based virtual reality solutions are gaining prominence (Merchant et al., 2014). Virtual reality emerging 3D computer technologies, and graphic technologies are widely used in practical applications in various research fields and industries. Numerous articles were reported about 3D computer technologies, extensively used on the web to create virtual reality environments crucial for museum development (Mastoropoulou, 2001; Özer, 2016; Ross et al., 2003). Considering the significant benefits of virtual reality in education, entertainment, architecture, medicine, and advertising, substantial budgets are allocated to secure access to the virtual world in these fields (Yengin & Bayrak, 2018).

The inadequacy of traditional science teaching approaches in imparting field-specific skills (scientific processes, life skills, and engineering and design skills) as outlined in the curriculum can be overcome by constructivist teaching approaches that anticipate the most efficient utilization of available conditions. In this context, it is crucial for students to experience science concepts through various instructional technologies, rather than just reading them, by effectively utilizing technological possibilities (Durukan, 2019). There exists a complementary structure between instructional technologies and education-teaching-technology (Özdemir & Özdemir, 2019). One of these instructional technologies is virtual reality, which allows experiential learning by stimulating multiple sensory organs. Virtual reality facilitates meaningful learning as it provides the opportunity for experiential learning (Durukan, 2019). Although virtual museums are often thought of as the virtual reconstruction of real museums, alternatively, they can also emerge as entirely imaginary environments where museum collections exist (Styliani et al., 2009).

When the literature is examined, it is found that virtual reality programs have positive effects on secondary school students in studies involving topics within the scope of science courses. These effects include positive influences on academic achievement and retention (Aktamış & Arıcı, 2013), a significant increase in learning achievements, conceptual understanding levels, mental rotation, and visualization skills (Küçük Avcı, 2017), positive influences on problem-solving skills, motivation, and academic achievements (Aktı Aslan, 2019), positive effects on their learning experiences (Urhan, 2019), positive influence on academic achievements and attitudes towards the course (Sarioğlu, 2019), a meaningful reduction in course-related anxiety (Sarioğlu & Girgin, 2019), developing a positive attitude towards virtual reality technologies (Yeşiltaş, 2019), and expressing a desire to see more "online educational computer games" and "virtual applications" in their education (Avcı, 2019).

This research emerged from the design of the "Virtual Museum for the Particulate Nature of Matter" and the construction of a virtual museum that does not exist in the physical world but is built

in a web environment. The rationale behind this is to create a virtual reality-based museum design within the scope of science courses, with the belief that such a design would have a positive impact on students' achievements. In the current study, the virtual reality-based "Virtual Museum for the Particulate Nature of Matter" is designed to be explored both in 3D using VR headsets and in 2D on desktops and mobile devices. Additionally, it provides flexible accessibility across different devices and platforms, aligning with the economic principle in educational sciences.

The main problem of the research is formulated as follows: "Does the virtual reality-based virtual museum design prepared for the 'Particulate Nature of Matter' topic in the 7th-grade 'Pure Substance and Mixtures' unit have an impact on student achievement?" In this context, the sub-problems identified in accordance with the purpose of the research are as follows:

1) Is there a significant difference in pretest PNMAT achievement scores between the participants in the experimental and control groups?

2) Is there a significant difference in pretest and posttest PNMAT achievement scores among participants in the experimental group?

3) Is there a significant difference in pretest and posttest PNMAT achievement scores among students in the control group?

4) Is there a significant difference in posttest PNMAT achievement scores between participants in the experimental and control groups?

METHOD

This section includes the methodology of the research. The research model, study group, data collection tools, and processes are discussed in this section.

Research Design

In this research, a quantitative research design known as the pretest-posttest control group quasi-experimental design was employed (Büyüköztürk et al., 2008). Within the experimental designs, quasi-experimental designs are commonly used, and among them, the non-equivalent control group pretest-posttest design is an experimental design approach where random assignment cannot be achieved in the selection of individuals for the experimental and control groups (Özmen, 2019).

Research Sample

In this research, a convenience sampling method was used. In this sampling method, the researcher selects participants or groups that are easily accessible (Büyüköztürk et al., 2008). Based on this, the study was conducted with 7th-grade students from a middle school in Konya province during the 2021-2022 academic year. The study included a total of 46 students, with the experimental group consisting of 23 students (17 female, 6 male) and the control group consisting of 23 students (9 female, 14 male).

Research Instruments

In the study, the Particulate Nature of Matter Achievement Test (PNMAT) developed by Kılıçoğlu (2019), was used to investigate the impact of the teaching process on student achievement. PNMAT is a multiple-choice achievement test developed in accordance with the objectives of the 2013 Science Course Curriculum. The reliability coefficient (KR-20) of PNMAT, prepared within the scope of the 'Particulate Nature of Matter' topic, was determined to be .85 in the relevant research, indicating its reliability.

When examining the 2018 science curriculum, it was observed that learning outcome 7.3.1.3 was removed from the relevant section when the same grade level, unit, and topic were considered. In line with this, questions related to this learning outcome were removed from the test, and the reliability of the PNMAT was recalculated. The reliability studies were conducted with 110 7th-grade middle school students who had previously taken the lesson on the 'Particulate Nature of Matter' topic in the 'Pure Substance and Mixtures' unit. The reliability coefficient (KR-20) of the achievement test was found to be .63. For multiple-choice tests with approximately 10-15 items, a KR-20 value of 0.50 is considered sufficient (Kehoe, 1994). Considering that the achievement test used in this research has 14 items and a KR-20 value of .63, which indicates that the test used is reliable.

The item analysis results of PNMAT have been calculated. The item difficulty index of the questions range from 0.35 to 0.70. The average difficulty index of PNMAT is found to be 0.51. The item discrimination index of the questions range from 0.31 to 0.60. The average item discrimination index value is found to be 0.41. In this context, no question with low item discrimination and insufficient item difficulty has been encountered. It is concluded that there is no need to remove additional questions from the test.

Data Collection Processes

Designing a Virtual Reality-Based Particulate Nature of Matter Virtual Museum

The design and creation of the virtual museum were completed within two months. During these two months, the exhibition to be displayed was prepared, relevant tables were connected to activity videos and three-dimensional objects, and a virtual museum building was created on the "Artsteps" website. Subsequently, previously recorded voice recordings by the researcher were added to the environment along with the artworks. Finally, guide points were determined for visitors who prefer not to navigate manually, completing the design of the virtual museum.

Application Process for the Experimental Group Students

The application process for the experimental group students was conducted within the framework of a four-week instructional plan. The details of this process are as follows: One week before starting the application, students were informed about the process. In this briefing, the "Artsteps" website was introduced, and topics such as "What is a virtual museum?", "What are the objectives of this research?", "How to log in to the website we are using?", and "What should we pay attention to during this process?" were discussed. At the same time, during this week, PNMAT was administered as a pretest. In the first two weeks of the application, the experimental group students were provided with the opportunity to explore the entire museum on the desktop in the school's computer laboratory. In the third week of the application, to serve the purpose of the virtual reality-based virtual museum, each student continued with the virtual museum application for two class hours, allowing them to explore the virtual museum with VR headsets for 20 minutes each. The link to the virtual museum environment was sent to the school's communication group for them to revisit until the next week, aiming to reinforce the information they had learned. In the fourth week of the application, the experimental group of students continued to visit the virtual museum using VR headsets for one class hour each, taking turns. In this way, all 23 experimental group students were able to explore the 3D museum environment. Additionally, PNMAT was administered as a posttest in this week.

Research Processes

The topic on 'Particulate Nature of Matter' within the 'Pure Substance and Mixtures' unit, under the scope of the science curriculum, was taught to the 23 seventh-grade students comprising the

control group in accordance with the curriculum. In the lessons, various teaching methods and techniques such as direct instruction, discussions, and question-answer methods were employed. Prior to the PNMAT application, a pretest was administered, and after the application, a posttest was conducted. The recommended 6 class hours for the 'Particulate Nature of Matter' topic were successfully completed without any disruptions as planned. In both the experimental and control groups, the same topic was taught by the same instructor, and to prevent potential implementation errors, lesson plans were prepared before the instruction, and efforts were made to adhere to these plans as closely as possible. Both the experimental and control groups received the same instructional content for the 2021-2022 academic year. The only difference between the two groups was the use or non-use of the virtual reality-based virtual museum environment in the learning environment.

Data Analysis

The data set of this study, conducted in the form of a pretest-posttest experimental design, was entered into the SPSS 21 package program, with each student's total scores on the test calculated, assigning 1 point for correct answers and 0 points for incorrect answers. The normality of the total scores obtained by students was examined. In examining the normality of the data, the Shapiro-Wilk test was considered, given that the sample size of the study group was less than 50 (Büyüköztürk et al., 2020; Yazıcı & Asma, 2007).

When examining the results of the Shapiro-Wilk tests for the experimental and control groups in Table 1, and considering that the study group has less than 50 participants, according to the results of Shapiro-Wilk test, it can be accepted that the data for the control group's pretest ($p=.073 > .05$), control group's posttest ($p=.702 > .05$); experimental group's pretest ($p=.053 > .05$), and experimental group's posttest ($p=.364 > .05$) are normally distributed (Büyüköztürk et al., 2020). Based on the normal distribution of the data, the results were interpreted using the independent samples t-test and paired samples t-test, which are parametric tests.

Table 1

Shapiro-Wilk Normality Test Results for the Achievement Test Data of Experimental and Control Groups

Test	Group	Shapiro-Wilk		
		Statistics	df	p
Pretest	Control	.92	23	.073
	Experimental	.91	23	.053
Posttest	Control	.97	23	.702
	Experimental	.95	23	.364

FINDINGS

The question of whether there is a significant difference between the pretest PNMAT achievement scores of participants in the experimental and control groups was examined using the independent samples t-test to determine if there was a significant difference in pretest achievement scores between the control and experimental group participants. The results of the test analysis are shown in Table 2 below.

Table 2

The Independent Samples T-Test Results for the Pretest Score Averages of the Experimental and Control Groups

	Group	N	M	sd	df	t	p
Pretest	Experimental	23	6.22	1.380	44	.397	.694
	Control	23	6.00	2.236			

When examining Table 2, no significant difference was found in the scores of the Particle Structure Achievement Test, used as the pretest, between the control and experimental group participants [$t(44)=.397$; $p>.05$].

In the dimension of the question 'Is there a significant difference in the pretest and posttest of PNMAT achievement scores of the experimental group?', the data obtained from the PNMAT achievement test conducted before and after the application to the experimental group were examined. The paired samples t-test was applied to determine whether there was a significant difference between the pretest and posttest scores of the experimental group. The results obtained are presented in Table 3 below.

Table 3

The Dependent Samples T-Test Results for the Pretest and Posttest Score Averages of the Experimental Group

	N	M	sd	df	t	p
Pretest	23	6.22	1.38	22	9.634	.000
Posttest	23	10.96	2.12			

According to Table 3, a significant difference was found between the pretest and posttest academic achievement test scores of the experimental group individuals [$t(22)=9.634$, $p<0.05$]. According to the analysis results, the pre-application test score mean ($M=6.22$) and the post-application test score average ($M=10.96$) were determined. Based on these values, it can be stated that the posttest scores after the virtual reality-based virtual museum application significantly differed in favor of the posttest compared to the pre-application test scores.

The pretest and posttest results of the control group participants, who did not receive instruction with virtual reality-based virtual museum design, were examined. The research question "Is there a significant difference between the pretest and posttest PNMAT achievement scores for the control group students?" was addressed. To determine if there was a significant difference between the pretest and posttest scores of the control group, the paired samples t-test was applied. The obtained results are presented in Table 4.

Table 4

The Dependent Samples T-Test Results for the Pretest and Posttest Score Averages of the Control Group

	N	M	sd	df	t	p
Pretest	23	6.00	2.236	22	8.178	.000
Posttest	23	8.65	2.058			

When Table 4 is examined, a significant difference is found between the pretest and posttest academic achievement test scores of the control group participants [$t(22)=8.178$, $p<.05$]. According to the analysis results, the pretest score mean ($M=6.00$) before the 'Particulate Nature of Matter' topic

was taught in its current form in the curriculum, and the posttest score average ($M=8.65$) after the application was determined. In this context, it can be said that teaching the topic of the Particulate Nature of Matter in its current form in the existing curriculum has a certain degree of impact on academic achievement.

The posttest PNMAT achievement scores of the experimental group, where virtual reality-based virtual museum design was implemented, and the control group, where the current curriculum was implemented, were examined in the dimension of the research question 'Is there a significant difference between the posttest PNMAT achievement scores applied to the participants in the experimental and control groups?' To determine whether there is a significant difference between the groups, the independent samples t-test was applied. The results of the test analysis are shown in Table 5.

Table 5.
The Independent Samples T-Test Results for the Mean Scores of the Experimental and Control Groups on the Posttest

	Group	N	M	sd	df	t	p	η^2
Posttest	Experimental	23	10.96	2.121	44	3.739	.001	0.241
	Control	23	8.65	2.058				

When examining Table 5, the mean score of the control group on the posttest PNMAT ($M=8.65$) is lower compared to the mean scores of the experimental group on the posttest PNMAT ($M=10.96$). In other words, it is observed that the academic achievement of the experimental group students who were exposed to virtual reality-based virtual museum design in the science course on the particulate nature of matter is higher than that of the control group students. Furthermore, according to the t-test results conducted between the posttest scores of the experimental and control groups, there is a statistically significant difference in favor of the experimental group [$t=(44) 3.739, p<.05$]. These results can be interpreted as indicating a significant relationship between the academic achievement scores and the virtual reality-based virtual museum design method applied in the experimental group. Based on the analysis results, both the control and experimental groups have shown an increase in academic achievements; however, the experimental group has demonstrated a more significant increase in academic achievement in the "Particulate Nature of Matter" topic compared to the control group. Therefore, it can be concluded that a virtual reality-based museum design for the topic of the 'Particulate Nature of Matter' is more effective in academic achievement compared to the traditional teaching methods included in the current curriculum.

To determine how much of the significant achievement difference between the experimental and control groups is attributed to the experimental process, the eta-squared value was calculated as $\eta^2=0.241$, and using Cohen's d measurements, Cohen's d was calculated to be 0.797. Thus, it was observed that the effect size is large (Cohen, 1988). In other words, the difference between the achievement scores of the individuals in the experimental and control groups on the posttest PNMAT is equivalent to 0.79 standard deviations. According to this result, it is concluded that the procedure applied in the experimental group using the virtual museum has a significant effect on students' academic achievement (Öztürk Gübeş, 2021).

DISCUSSION, CONCLUSION AND SUGGESTIONS

Technological developments have continued to impact education for the past 70 years, and virtual reality studies have shown an increase in the last 20 years. The rise in studies conducted in the last 10 years of these 20 years has drawn attention to virtual reality research. In evaluating the virtual

reality dimension of this study, it can be stated that virtual reality studies in the field of science education have intensified in recent years (Güler & Sarsar, 2021).

This research aimed to design a virtual reality-based virtual museum for the "Particulate Nature of Matter" section of the "Pure Substance and Mixtures" unit and to investigate its impact on student achievement. According to the analysis results of this study, both the control group and the experimental group have increased their academic achievement levels. However, the experimental group has shown a more significant increase in academic achievement concerning the "Particulate Nature of Matter" compared to the control group. Therefore, it is concluded that teaching through a virtual reality-based virtual museum design related to the "Particulate Nature of Matter" section is more effective in terms of academic achievement than the teaching carried out with the current curriculum. Similar studies (Aktamış & Arıcı, 2013; Aktı Aslan, 2019; Sarıçam, 2019; Sarıoğlu, 2019; Tepe, 2019; Topuz, 2018; Urhan, 2019; Yeşiltaş, 2019) aiming to explore the impact of virtual reality applications on students' academic achievements exist in the literature, in which positive effects have been observed.

Numerous studies have investigated the impact of virtual museums on academic achievement in various subjects (Daşdemir, 2019; Doğanlı, 2019; Durmuş, 2012; Işıl Gılıç, 2020; Kalıncı, 2015; Özer, 2016; Ustaoglu, 2012; Yıldız, 2016). Additionally, Aydoğdu, Aydoğdu, and Aktaş' study (2021) indicated that using a virtual museum as an educational tool contributed to learning mathematics for the majority of students. Işıl Gılıç (2020) found positive effects of virtual museum-supported collaborative learning activities on English reading comprehension. Durmuş (2012) demonstrated that a virtual museum with an educational interface agent positively affected students' academic achievements. Kalıncı (2015) concluded that interactive virtual museums positively influenced students' achievements in visual arts. These findings align with and support the results of this research.

While the number of studies examining virtual museum applications in the field of science education is relatively limited, Arslan and Görgülü Arı's study (2021) on an online science course using virtual museums for the "human and environment" unit revealed a positive impact on fifth-grade students' academic achievements and attitudes toward science. This study in science education corresponds to the current research results.

Although there are studies with results differing somewhat from the findings of this study, generally similar outcomes suggest that the results obtained from this study may vary depending on the educational content, student profile, and materials used. Taking into account that virtual museums are also learning environments, Özönur's study (2013) evaluating a learning environment designed in the virtual reality environment of Second Life did not find any significant difference in academic achievement between the experimental and control groups.

In summary, the results obtained from this study generally align with other research findings. There are relatively fewer studies showing differences with the results of this study. Encountering these research results raises the idea that the outcomes of educational use of virtual museums may vary depending on the educational content, student profile, and materials used. Regarding the "Particulate Nature of Matter" within the "Pure Substance and Mixtures" unit, no study directly investigating the use of virtual reality-based virtual museums has been found in the literature. In this context, it can be said that this research will contribute to the literature both in terms of the virtual museum dimension and the virtual reality dimension, specifically focusing on the "Particulate Nature of Matter" section.

Suggestions for future studies include:

Researching the use of not only the "Artsteps" website but also other virtual exhibition sites based on virtual reality to create a virtual museum environment.

Designing and implementing more comprehensive virtual reality-based museums covering different grade levels and various science topics, organized to include more participants and units.

Researching students designing virtual museums for the "Particulate Nature of Matter" section in science lessons.

Conducting research examining teacher opinions on virtual reality-based virtual museum design.

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Ethical approval

The Ethics Committee for Scientific Research in Social and Human Sciences of Necmettin Erbakan University issued a decision (No: 2021/507) stating that there is no ethical objection to the implementation of the research. The research was conducted in accordance with the document obtained from the ethics committee, focusing on secondary school students.

Conflict of Interest

The authors have no conflict of interest to declare.

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