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The Effect of Using Virtual Manipulatives in Algebra Teaching

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ABSTRACT

Digital technology enhances mathematics education by aiding abstract concept understanding. This study examines the effect of using virtual manipulatives in algebra instruction on the mathematics achievement of 8th-grade students. The study used a quasi-experimental research design with the pretest posttest control group. The Mathigon application was used in the experimental group to teach the identity topic, while the direct teaching method was preferred in the control group. The study participants were 26 8th-grade students in a public school in the 2023-2024 academic year. As a data collection tool, students were asked 20 questions about the identity topic. The study data were analyzed using the SPSS package program. According to the results of the study, it was determined that there was no significant difference between the experimental group and the control group, but there was an increase in the mean scores in favor of the experimental group. As a result, in this study, the potential benefits of virtual manipulatives in mathematics teaching were evaluated and necessary information was presented for their more effective use in teaching processes.

Keywords: algebra teaching, virtual manipulatives, mathematics education

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Cebir Öğretiminde Sanal Manipülatif Kullanımının Etkisi

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ÖZET

Dijital teknolojiler, matematikte soyut kavramların anlaşılmasını kolaylaştırır. Mathigon, sanal manipülatif olarak interaktif materyaller, oyunlar ve animasyonlar sunarak öğrencilerin cebir kavramlarını görselleştirme ve somutlaştırma yoluyla öğrenmesini destekler ve öğrenme sürecini daha etkili hale getirir. Bu çalışma, cebir öğretiminde sanal manipülatif kullanımının 8. sınıf öğrencilerinin matematik başarısı üzerindeki etkisini incelemektedir. Çalışmada öntest sontest kontrol gruplu yarı deneysel araştırma deseni kullanılmıştır. Deney grubunda özdeşlik konusunu öğretmek için Mathigon uygulaması kullanılırken, kontrol grubunda doğrudan öğretim yöntemi tercih edilmiştir. Çalışmanın katılımcıları 2023-2024 akademik yılında bir devlet okulunda öğrenim gören 26 8. sınıf öğrencisidir. Veri toplama aracı olarak öğrencilere birim eleman konusuyla ilgili 20 soru sorulmuştur. Çalışma verileri SPSS paket programı kullanılarak analiz edilmiştir. Araştırmanın sonuçlarına göre deney grubu ile kontrol grubu arasında anlamlı bir fark olmadığı ancak ortalama puanlarda deney grubu lehine bir artış olduğu tespit edilmiştir. Sonuç olarak, bu çalışmada sanal manipülatiflerin matematik öğretimindeki potansiyel faydaları değerlendirilmiş ve öğretim süreçlerinde daha etkin kullanımları için gerekli bilgiler sunulmuştur.

Anahtar kelimeler: cebir öğretimi, sanal manipülatifler, matematik eğitimi

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INTRODUCTION

In the past two decades, the influence and reach of digital technology around the world have grown substantially. The swift advancements in science and technology have amplified the significance of mathematics in everyday life and have profoundly influenced the role of mathematics education in schools (Görgen & Tahta, 2005). Considering these changes, research has moved away from focusing on how computers can assist in learning to exploring how teachers can effectively utilize various digital technologies to offer students activities that improve their mathematical understanding (Clark-Wilson et al., 2014). Thus, technologies that can be used in teaching have gained importance. The field of instructional technology is a discipline that aims to facilitate learning by focusing on the effectiveness and efficiency of teaching, and studies on identifying problems related to teaching, designing and developing resources constitute the centre of this field (Reiser, 2012). Since using technology in mathematics teaching provides students with richer learning content, content that combines visual, auditory and applied elements students' engagement and enthusiasm for the lesson grows, and the use of technology opens the door to a more permanent learning process than memorisation by performing learning through concrete data (Danış et al., 2023).

Mathematics is complicated for students because it contains many abstract concepts (Battal & Çalışkan, 2021). In courses such as mathematics, where abstract concepts and relationships are handled, developing computer software called "virtual manipulatives" specific to the concept and relationship under study has gained importance with technology (Karakırık, 2008). Virtual manipulatives provide a student-centred learning experience and allow students to learn the subject with methods appropriate to their learning styles. Students realise their learning experiences at their own pace and on their journeys by using virtual manipulatives during their learning. Furthermore, virtual manipulatives enable students to investigate mathematical concepts by experimenting and learning from their mistakes.

Since algebra is considered to be one of the most challenging areas in the mathematics learning process, mathematics educators have been directed to search for alternative methods to teach algebra more effectively (İspir & Palabıyık, 2011). Moreover, research has shown that students face challenges when moving from arithmetic to algebra that these difficulties continue during algebra learning, and that different learning difficulties are included in this process (Akkan et al., 2012). Kaput (1999) claimed that algebra is generally perceived as learning the rules of simplifying algebraic expressions, solving equations and using symbols, and therefore, almost everyone has negative feelings about algebra. The correct use of the teaching method, materials and activities that teachers will use in teaching algebra can also facilitate algebra learning for students and prevent the emergence of any misconceptions. In algebra teaching, it is stated that in addition to concrete materials in planned course activities, teaching environments that teachers and students can use simultaneously in online environments are also effective (Kabadaş & Yavuz Mumcu, 2022). The results of the studies show that using virtual manipulatives in teaching algebra, a sub-branch of mathematics, is very useful in concretisation and visualisation

(Creighan, 2014; Paek & Hoffman, 2014). These tools make abstract mathematical concepts more understandable and help students to comprehend the topics visually.

Mathigon application stands out as a platform that provides interactive learning experiences in the algebra learning domain. With its array of animations, games, and interactive materials, Mathigon offers students a unique opportunity to learn algebra in an engaging and interactive environment (Poçan, 2023). Mathigon combines the latest technology and an innovative maths curriculum. These manipulatives enable students to grasp mathematical concepts remotely (Manandhar, 2018). It also serves an essential function in helping students understand mathematical concepts and their interconnections (Moyer-Packenham & Bolyard, 2016).

AIM

In the curriculum, Algebra taught in the 6th grade is an area where students have difficulty concentrating and learning. However, it also has an essential place in other learning areas. Difficulties understanding algebra can negatively affect students' mathematics achievement and cause a decline (Özkan et al., 2023). A review of the literature reveals that incorporating virtual manipulatives in algebra instruction, a sub-branch of mathematics, is beneficial, especially in concretisation and visualisation (Creighan, 2014; Morris, 2013). In this study, the subject of identities from the algebra learning area was selected using the Mathigon application. Its effect on students' mathematics achievement was examined with a quasi-experimental study. Thus, taking into account the study's potential contribution to the field, the research question was formulated as follows:

1. Does the use of virtual manipulatives in algebra teaching affect students' mathematics achievement?

METHOD

Design

This research employed a quasi-experimental design featuring a pretest-posttest control group within the framework of quantitative research methods. The experimental research method involves comparing the impact of the independent variable on the affected variables (Fraenkel & Wallen, 1996). In this study, the students' academic achievement served as the dependent variable, while the independent variable was the implementation of virtual manipulatives in teaching identity. During the implementation phase, the experimental group received identity instruction through the use of virtual manipulatives, whereas the control group was taught using the direct teaching method outlined in the curriculum.

Participants

The study was conducted with 26 8th-grade students in a public school in Kilis province in the 2023-2024 academic year. Both the experimental and control groups consisted of 13 students each. Experimental and control groups with equivalent readiness were formed in the study. Students with

similar grades were meticulously placed in different groups according to their 1st-semester written results, ensuring the equality of the groups. This careful process instills confidence in the study's methodology.

Data Collection and Application Process

In this study, which investigated whether virtual manipulatives affected teaching identity, the problems related to identity were modelled in the Mathigon application with the experimental group of students during the application process. In the control group, direct teaching was done without any intervention.

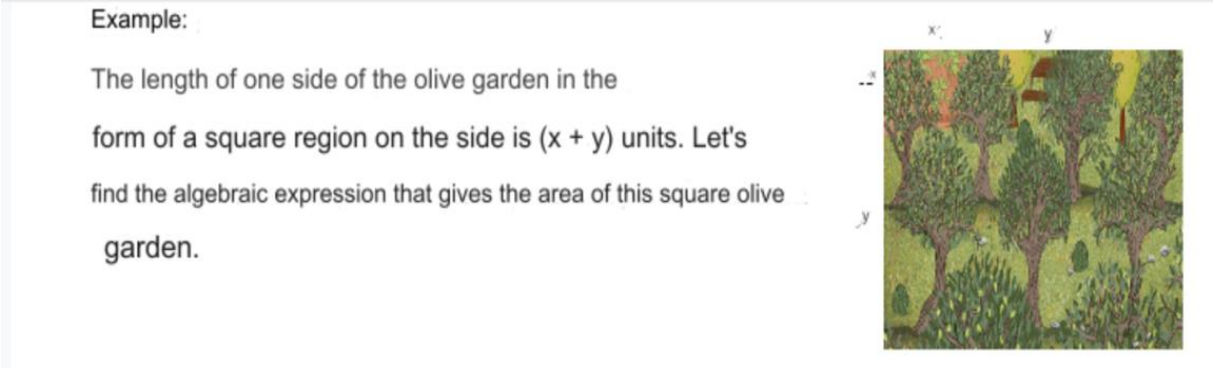

Figure 1. Problem given for the identity $(x + y)^2$

As shown in Figure 1, a square olive orchard is given, and it is stated that the length of the side is $(x + y)$ units. Students were tasked with calculating the area of the olive garden. During the implementation phase, they were instructed to model the problem scenarios presented in Figure 1 using the Mathigon application and to identify the relevant concepts.

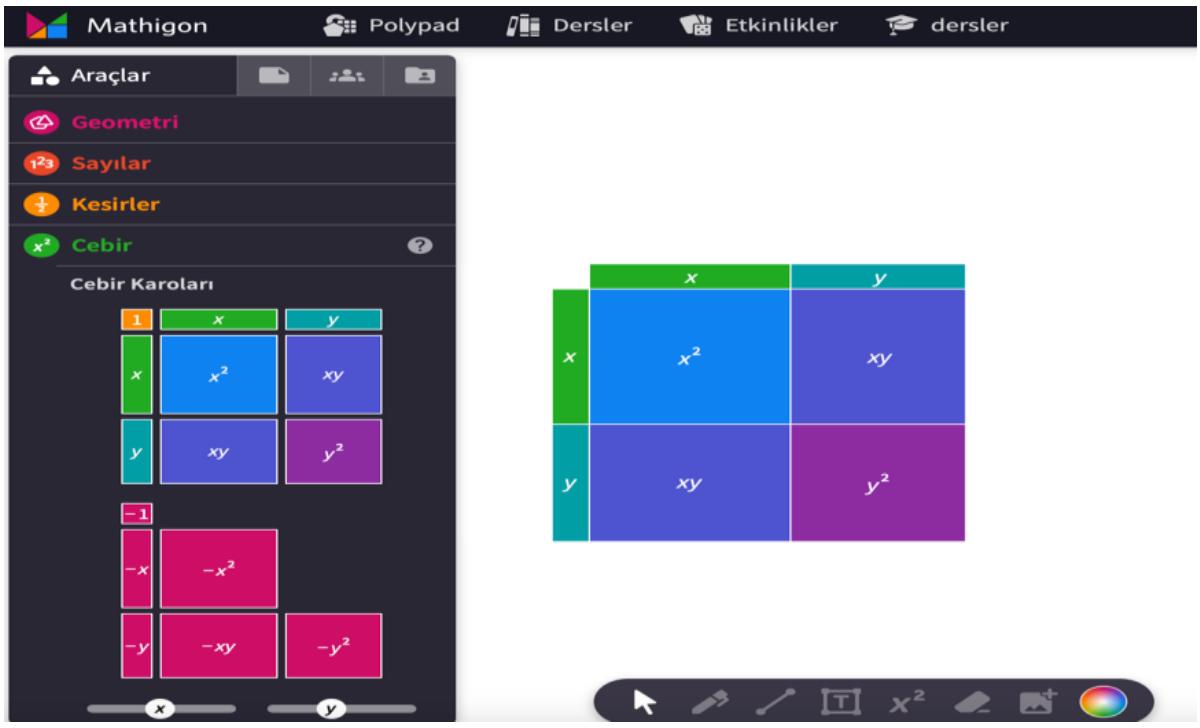

Figure 2. Modeling the identity $(x + y)^2$ in the Mathigon application

Students modelled the given identity in the Mathigon application and found the expansion of the identity with the areas formed (Figure 2). They reached the result by adding the areas to find the identity $(x + y)^2$. The problems given in other identities were modelled in the Mathigon application, and the expansion of the identities was reached. The application was planned and implemented for 5 class hours. Then, the data collection tool was applied to the students.

With the control group, identity instruction was implemented using the direct teaching method aligned with the curriculum. During this phase, the teaching focused on questions from the 8th-grade mathematics textbook, and identity questions were applied to the students.

Data Collection Tools

In the research, data were collected through questions pertaining to the topic of identities within the algebra learning domain. The questions were prepared as 24 questions to cover the objectives of the identity topic in the mathematics curriculum. While preparing the questions, textbooks and literature were utilized. A language expert was consulted to determine the comprehensibility of the questions. In order to ensure the content and internal validity of the questions, the opinions of an academician and two mathematics teachers who experts in the field of mathematics education were consulted, and four questions were removed as a result of the expert opinion and the data collection tool consisting of 20 questions was finalized.

Data Analysis

In the study, the effect of the use of virtual manipulatives on students' learning about identity was examined. The SPSS program was used to analyze the data in the study. In analyzing the data relevant to the research question, the normality of the data distribution was assessed. Considering the number of samples used in the study ($n < 30$), normality analysis was performed according to the Shapiro-Wilk test for normality test (Büyüköztürk, 2013). In addition, Tabachnick and Fidell (2013) also state that the standard skewness and kurtosis coefficients of small or medium-sized data groups can determine normality. When the skewness and kurtosis values fall between -1.5 and $+1.5$, the data is considered to be normally distributed (Tabachnick & Fidell, 2013).

Table 1. Normality test

	Statistics	df	p	Skewness	Kurtosis
Experimental Group	.944	13	.510	.310	-.814
Control Group	.936	13	.411	.049	-1.284

According to the Shapiro-Wilk test analysis, $p = .510$ and $p = .410$ were found in the experimental and control groups, respectively ($p > 0.05$), and it was concluded that the groups showed normal distribution. Additionally, the experimental group had a skewness value of $.310$ and a kurtosis value of

$-.814$, while the control group exhibited a skewness value of .049 and a kurtosis value of -1.284. According to Tabachnick and Fidell (2013), since the skewness and kurtosis values were between -1.5 and $+1.5$, it was concluded that the groups were normally distributed. Once it was determined that both the experimental and control groups followed a normal distribution, the independent samples t-test, a type of parametric test, was conducted.

FINDINGS

To align with the study's objectives, an independent samples t-test was conducted to assess whether a significant difference existed in the academic achievement of the participants. The results are displayed in Table 2.

Table 2. Statistical analysis

	Groups	**N**	**x̄**	**SS**
Achievement Scores	Experimental Group	13	50.76	19.87
	Control Group	13	45.76	18.00

According to the data obtained from Table 2, the arithmetic mean of the achievement scores of the experimental group was 50.76, while the arithmetic mean of the achievement scores of the control group was 45.76. According to this finding, the achievement of the students who used virtual manipulation (Mathingon) in teaching identity ($X = 50.76$) was at a higher level than the achievement of the students who were taught directly ($X = 45.76$). Although there was a difference of 5 points between the averages, the table below was examined to determine whether the difference was significant.

Table 3. Differences between experimental and control groups

							Levene	
Variables		**n**	**x̄**	**ss**	**sd**	**f**	**p**	**t**
Groups	Experiment	13	50. 76	19.87	24	.136	.716	.672
	Control	13	45.76	18.00				

The results presented in Table 3 indicate that using virtual manipulatives for teaching identity to 8th-grade students does not reveal a significant difference in academic achievement between the experimental and control groups $[t(24) = .672, p = .716]$.

CONCLUSION AND DISCUSSION

This study aimed to investigate the effectiveness of virtual manipulatives in algebra teaching concepts to 8th-grade students. By comparing an experimental group using virtual manipulatives to a control group using traditional methods, we sought to determine whether significant differences in student achievement existed. Statistical analysis revealed no significant difference in academic achievement between the two groups. While the experimental group had a slightly higher average score (50.76) than the control group (45.76), this difference was not statistically significant. However, the t-test results conducted to evaluate the statistical significance of this difference showed no significant difference between the experimental and control groups.

The study's findings show that the use of virtual manipulatives did not significantly affect teaching identity. This situation provides essential information that virtual manipulatives should be integrated more effectively into current teaching methods. Teachers must carefully select and prepare manipulatives and activities to support the introduction of abstract symbols (Hartshorn & Sue, 1990). Virtual manipulatives allow students to experience mathematical concepts and structures through different representations while exploring them (Moyer et al., 2002). In mathematics teaching, topics can be related to daily life; however, if teaching is limited to formulas and operations and if it is not made interesting for students, their motivation to learn decreases and may negatively affect the learning level of the subject (Özer & Şan, 2013). Therefore, virtual manipulatives are technology-based because they are interactive and exciting, and their most important feature is that they are interactive and accessible anytime, anywhere (Bouck & Flanagan, 2010; Moyer & Bolyard, 2002).

Cockett and Kilgour (2015) discovered that students exhibited greater engagement when using manipulatives, enjoyed their learning environments more, and showed improvements in both comprehension and productivity. However, Pişkin-Tunç et al. (2012) concluded that some virtual manipulatives do not have the same effect on algebra teaching as others and that students working with virtual manipulatives may be confused. In this study, virtual manipulatives did not reveal significant differences in academic achievement in the subject of identity, which students learned for the first time in the 8th grade according to the mathematics curriculum. At the same time, the results obtained by Yuan (2009) emphasize that virtual manipulatives help introduce new mathematical concepts and comprehend them meaningfully.

In this study, which investigated the effect of the use of virtual manipulatives in algebra teaching on students' mathematics achievement, it is thought that the lack of a significant change in students' academic achievement with the use of virtual manipulatives in teaching identity may be due to the small number of participants. According to the findings of Cavanaugh et al. (2005), virtual manipulatives positively reveal the relationship between symbols and representations in algebraic operations. However, in this study, while students were expected to learn representations more meaningfully and efficiently using virtual manipulatives in teaching identity, the small number of participants was one of the study's limitations. Therefore, applications with groups including more participants may yield more

meaningful results. Therefore, more carefully selecting the virtual manipulatives and contents used in the study will facilitate students' relation to the identity topic and understanding of the topic more deeply. There was no significant difference in academic achievement between the experimental and control groups. These tools can be beneficial if teachers are knowledgeable about incorporating manipulatives into their instructional methods (Bouck & Flanagan, 2010). The strategies proposed by Ross and Kurtz (1993) provide an essential framework). The improving the effectiveness of manipulative-based instruction. Implementing these strategies can help teachers plan lessons more effectively and help students better understand mathematical concepts. Interpretations based on the research results are limited, and other factors (teacher's pedagogical approach, students' motivation, etc.) should also be considered, as they may impact success.

RECOMMENDATIONS

In future studies on teaching identity, in order for the results of the research to be more meaningful, researchers can conduct studies in which the effects of virtual manipulatives can be better understood by working with more participants and adding a long-term follow-up process. In addition, in future studies of the Mathigon application, the effect of using not only algebra tools but also geometry, numbers and fraction tools in teaching activities on students' academic achievement can be investigated. Thus, extensive information on the effective use of the application in teaching activities can be obtained.

Ethical Text

In this article, journal writing rules, publishing principles, research and publication ethics rules, and journal ethics rules have been followed. Responsibility for any violations that may arise regarding the article belongs to the author.

Author(s) Contribution Rate

In this research, the contribution of the authors is equal.

Conflicts of Interest

The article has no financial conflict of interest with an institution, organization or person.

Ethical Approval

This research was conducted within the scope of the ethical approval granted by the Ethics Committee of the Kilis 7 Aralık University.

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