



# The Effect of Concrete and Technology-Assisted Learning Tools on Place Value Concept, Achievement in Mathematics and Arithmetic Performance

Mehmet Hayri Sarı<sup>a\*</sup>, Şeyhmus Aydoğdu<sup>b</sup>

<sup>a</sup> Nevşehir Hacı Bektaş Veli University, Faculty of Education, Department of Elementary Education, Nevşehir 50300, Turkey

<sup>b</sup> Nevşehir Hacı Bektaş Veli University, Faculty of Education, Department of Computer Education and Instructional Technologies, Nevşehir 50300, Turkey

---

## Abstract

The purpose of this study is to examine the effects of concrete and technology-assisted learning tools on developing the conception of place value, mathematical achievement and arithmetical performance of primary school 4th graders. The study group was comprised of three different primary schools. There were no group differences prior to intervention based on the scores obtained from “Place Value Test”, “Mathematics Achievement Test” “Arithmetic Performance Test”. The study has been conducted over 8 class hours with two experimental and a control group. Results showed that; place value conception, mathematical achievement and arithmetic performance achievement of experimental groups using concrete (trial 1) and technology-assisted (trial 2) learning tools was higher than the control group where no intervention has been made. No significant difference has been observed between the "Place Value Test" and “Mathematics Achievement Test” post-test and retention test score averages of Trial 1 and Trial 2 groups, but there was a significant difference between trial groups and control group. According to the retention test results, obtained three weeks after the practice, all the groups did remember what has been taught to them. In this sense, it is deemed to be important to use effectively designed teaching tools in mathematics education to improve the achievement levels of students.

© 2017 IJCI & the Authors. Published by *International Journal of Curriculum and Instruction (IJCI)*. This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (CC BY-NC-ND) (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

**Keywords:** arithmetic performance; concrete tools; digital material; mathematics achievement; place value

---

## 1. Introduction

The ever-growing importance of mathematical skills in reaching academic and professional success in the modern world is an undeniable fact. When teaching mathematics, the highly complicated processes of the subject-specific cognitive development must be taken into consideration. In general, the development of numerical skills takes place at a different rate for each child. In particular, the fact that individuals

---

\* Corresponding author name. Tel.: +90 384 228 10 00 / 21024  
E-mail address: [mehmethayrisari@gmail.com](mailto:mehmethayrisari@gmail.com)

with difficulties in learning mathematics lag two-years behind their peers (Shalev, 2004) led researchers to provide additional learning opportunities that aim to give education together with their peers in standard classes and increase their potential. Early detection of individuals with lower achievement levels in mathematics and the effectiveness of the education provided to such students are deemed to be important in leading them to achievement (Olkun, Altun, Cangöz, Gelbal & Sucuoğlu, 2012), since brain plasticity is at a very high level during early ages (Zamarian, Ischebeck & Delazer, 2009). As the brain is more flexible during the younger years in terms of learning, renewing and changing abilities, intervention (education) programs are now being developed for younger children (Griffin, Case & Siegler, 1994; Whyte & Bull, 2008; Wilson, Revkin, Cohen, Cohen & Dehaene, 2006). One of the areas where intervention programs are being used in mathematics education is the place value concept.

### *1.1. Place Value Concept*

Each figure in a multi-digit number takes-up a value depending on its position. This is called the place value. Place value is a complicated system that is difficult to indicate. Furthermore, place value (PV) concept also constitutes the basis of many areas of mathematics programs in schools. Because the number system we are using is a precondition in areas such as arithmetic and evaluation works. PV concept is the building stone of multi-digit operations, particularly for those related to arithmetic development.

Despite being very important for mathematics education, the concept of PV is probably the biggest challenge for kids up to that point regarding numbers. Because PV concept was not so important in the past for the learning processes of students and it was thought that children would grasp this concept in no time (Olkun & Toluk-Uçar, 2018). As a result, many children are facing difficulties in learning PV concepts and mastering related skills (Baroody, 1990).

### *1.2. The Relation between Mathematics Achievement, Arithmetical Performance and Place Value Concepts*

Individuals having difficulties in learning mathematics are also finding it difficult to understand simple number concepts and lack the intuition of perceiving numbers. They experience problems in learning numerical conditions and making calculations. Even if they provide correct answers to questions or use the right method, they may do it mechanically and without any confidence (Education-Skills, 2001). They have difficulties in performing simple arithmetic works (Shalev et al, 2001) and performing skills based on remembering when solving verbal problems (Geary, 2004). They have difficulties in estimating the size and dimension of numbers. They are insufficient in understanding the relation between numbers (Sharma, 2015). They are slow in grasping numbers and working with numbers (Geary, 2004).

It has been reported that students with particular difficulties in understanding mathematics are finding it difficult in integrating numbers into place value structure (Dietrich, Huber, Dackermann, Moeller & Fischer, 2016). The difficulties in understanding the place value system is deemed as a great obstacle for the mathematical development of students (Chan et al., 2014; Nataraj & Thomas, 2007), because understanding PV is a basic numerical skill and forms the basis of the following numerical development. Understanding the PV concept is located right at the center of developing number sense and forms the basis of four basic operations of mathematics (addition, subtraction, multiplication and division) (Nataraj & Thomas, 2007). PV concept constitutes the infrastructure of many areas in school mathematics programs and a comprehensive grasp of this concept has a significant effect on learning many themes such as whole numbers, decimal numbers, problem solving, and percentages among others (Andreasen, 2006; Chan et al., 2014). Therefore, a grasp of PV concept by students acts as an important pre-condition skill factor for their future achievement in mathematics (McGuire & Kinzie, 2013; Nataraj & Thomas, 2007; Sarı & Olkun, 2019). In other words, a flexible understanding of place value plays an important role in learning and understanding mathematics (Ladel & Kortenkamp, 2016).

Despite the general assumption by researchers that PV concept is an important factor for the arithmetic achievement of students and understanding several areas of mathematics (percentage, fraction etc.), the studies conducted reveal that most of the students are deprived of the understanding of PV concept (Baroody, 1990; Cooper & Tomayko, 2011; Dinç-Artut & Tarım, 2006; Thomas, 2004; Ian Thompson, 2000; Thouless, 2014; Tosun, 2011). For instance; a study conducted by Cooper and Tomayko (2011) has reported that students deprived of the PV idea have considered the numbers “26” and “62” to be the same. Similarly, a study by Thouless (2014) reported that students had difficulties in understanding the concept of decimal base, which led them fail to develop a skill of correctly solving mathematic-based verbal problems. This is an indication that the students have a limited understanding of the PV concept.

The limited understanding of PV concept by students can be seen in the domestic body of literature too. A study by Dinç-Artut and Tarım (2006) asked primary school students to give as many tokens as the number seen in the units digit of number “16” and they did extend the correct amount of tokens (6 of them), however they only gave 1 token for the tens digit, instead of 10 units. Tosun (2011) reported that primary school 5th grade students were unable to distinguish between place value and face value and unable to understand the relation between them.

Looking at the findings in the domestic and international literature as a whole; it can be said that many students from all levels are experiencing significant difficulties with regards to PV concept. This failure in understating PV concept is limiting the future mathematics achievement of both normal developing children and of those having

difficulties in learning mathematics and causes hardships in the education of many children (Byrge, Smith & Mix, 2014). Insufficient development of PV concept can lead to negative consequences in terms of mathematics achievement of students. In primary school level mathematics in particular, basic arithmetic based on place value can obstruct or slow down conceptual understanding of algorithms (Cooper & Tomayko, 2011). In case this deficiency of understanding is not rectified, the gap arising from the place value idea will make it even harder for children to deal with more complicated algorithms (Cuffel, 2009).

### *1.3. Concrete and Technology-Assisted Tools in Mathematics Education*

Concrete (manipulative) tools are objects designed to clearly and tangibly represent abstract mathematical ideas (Moyer, 2001). In other words, concrete manipulatives or physical manipulatives are objects that are used as tools that help students to try and explore mathematical concepts (Demetriou, 2016). Concrete tools are important as they help mathematics to become meaningful for students by ensuring some concepts, theories and operations to be expressed tangibly; contribute to create an environment where students are made to feel that they are learning and ensure students gain a positive attitude towards mathematics (Bulut, Çömlekoğlu, Özkaya-Seçil, Yıldırım & Tuncay-Yıldız, 2006).

Concrete tools, along with advancements in technology, merge the beneficial aspects of concrete manipulatives and the unique capabilities of computer technology to create a new manipulative class (virtual or computer-based manipulatives) (Burns & Hamm, 2011). In this sense, technology-assisted (virtual) manipulatives are the interactive, web-based virtual presentations of dynamic objects that offer opportunities for creating mathematical information (Demetriou, 2016). Virtual manipulatives are tools that can be used by students to solve their troubles when creating connections between mathematical concepts and operations and they provide interactive environments where students can get instant feedback about their actions (Durmuş & Karakırık, 2006). In this sense, virtual manipulatives are dynamic, interactive, flexible and easy to manage (Petit, 2013).

A review of the body of literature indicates that the use of concrete and technology-assisted manipulatives in mathematics education have different kinds of impacts on the achievement of students. In other words, studies have yielded different findings with regards to the impact of using concrete and virtual manipulatives on the mathematics achievement of students in teaching mathematics. Some studies indicate that the use of concrete tools have an impact on the achievement of students (Kontaş, 2016; Larbi & Mavis, 2016; Olkun, 2003). For instance, Kontaş (2016) conducted a study with 7th graders, concluding that the use of concrete tools in geometry increased the achievement of students compared to those who did not use any and that it also had an impact on the attitudes of the students. Larbi and Mavis (2016) concluded that the concrete tools, algebra tiles, used in their study had an impact on the students' achievement in algebra.

Some studies indicate that the use of virtual tools have an impact on the mathematics achievement of students (Demetriou, 2016; Olkun, 2003; Reimer & Moyer, 2005). Demetriou (2016) reported that even though both concrete and virtual manipulatives are developing the symmetry capabilities of students, use of virtual manipulatives can increase the student performance more than the use of concrete manipulatives. Reimer and Moyer (2005), on the other hand, conducted a study with third grade students with regards to virtual manipulatives and fractions and reported a statistically meaningful development in the conceptual knowledge of students and a meaningful relation between the final test scores of the students in terms of their conceptual and procedural knowledge.

There are other studies which conclude there are no meaningful differences between the use of concrete and virtual tools in teaching mathematics (Fung, 2005; Yuan, Lee & Wang 2010; Kablan, Baran, Işık, Kal & Hazar, 2013; Suh & Moyer, 2007; Yaman & Şahin, 2013). For instance, Fung (2005) reported the use of both concrete and virtual manipulatives develop the spatial capabilities of students. However, no evidence was produced with regards to one being better than the other. Similarly, an empirical study by Kablan, Baran, Işık, Kal and Hazar (2013) compared PowerPoint teaching materials with concrete teaching materials but no meaningful difference has been observed between the successes of groups.

All these findings are evidence that the use of manipulatives in teaching mathematics have a small or medium size impact on the learning capabilities of students (Carbonneau, Marley & Selig, 2013). However, the number of studies comparing the use of concrete and computer-assisted manipulatives is limited and it is difficult to generalize such studies among mathematical concepts and class levels (Burns & Hamm, 2011). Therefore, it is possible to say that there is a need for more studies where concrete and technology-assisted tools are used in learning environments.

In conclusion, the conducted studies have shown that scientific learning environments based on educational interventions are being designed to develop the concept of PV. Even though the educational interventions are providing the authors with some kind of idea about the development of PV concept, the limitations of these studies need to be tackled, through the currently designed study. This is deemed to be important so that the outcomes can be generalized at a wider scale and that these educational materials can be used in real classes. From this point of view, the purpose of this study is to examine the effects of concrete and technology-assisted tools on the place value achievement, mathematics achievement and arithmetic performance of primary school fourth grade students with lower achievement levels in mathematics. This study has made contributions in terms of comparing the effects of concrete and technology-assisted tools used in learning- teaching environments and to reveal such effect. In particular, trying to reveal the effects of learning environments achieved through concrete and technology-assisted education intervention oriented towards place value concept on the mathematics achievement and arithmetic

performance of students is another valuable aspect of this study. Within the scope of the mentioned purpose and importance, the problems and sub-problems of the study are given below:

**Problem:** Does a teaching process not including any concrete tools, technology-assisted materials and any interventions have any effect on the place value achievement, mathematics achievement and arithmetic performances of students studying in primary school 4th grade?

Under the scope of the aforementioned problem, answers have been sought for the following sub-problems:

- 1) Is there a meaningful difference between the “place value achievement test” pre-test-final test and retention test score averages of primary school 4th grade students in terms of the type of tool (concrete, technology-assisted, no intervention) used during the teaching process?
- 2) Is there a meaningful difference between the “mathematics achievement test” pre-test-final test and retention test score averages of primary school 4th grade students in terms of the type of tool (concrete, technology-assisted, no intervention) used during the teaching process?
- 3) Is there a meaningful difference between the “arithmetic performance test” pre-test-final test and retention test score averages of primary school 4th grade students in terms of the type of tool (concrete, technology-assisted, no intervention) used during the teaching process?

## **2. Method**

### *2.1. Research Design*

This research has been conducted as a 3x3 split-plot factorial (mixed) design. In mixed designs, there are at least two independent variables whose effects on dependent variable are being examined. One of these variables defines different empirical action conditions while the other defines the recurring measurements of participants in different times (Büyüköztürk, Çakmak, Akgün, Karadeniz & Demirel, 2016, p.215). The first parameter specified in factorial design refers to the type of tool used in the study group while the second parameter refers to the number of measurements made in each group. The independent variable of the study is the type of tool used during the teaching process. Independent variable has three dimensions, namely; not using any kind of tools at all, using concrete tools and use of technology-assisted materials. Dependent variables of the research are students' place value achievement, mathematics achievement and arithmetic performance levels. Symbolic view of research design is given in Table 1.

Table 1. Symbolic view of research design

Group	Pre-test		Post test	Retention test
G <sub>1</sub>	O <sub>1</sub> , O <sub>2</sub> , O <sub>3</sub>		O <sub>4</sub> , O <sub>5</sub> , O <sub>6</sub>	O <sub>7</sub> , O <sub>8</sub> , O <sub>9</sub>
G <sub>2</sub>	O <sub>1</sub> , O <sub>2</sub> , O <sub>3</sub>	X <sub>1</sub>	O <sub>4</sub> , O <sub>5</sub> , O <sub>6</sub>	O <sub>7</sub> , O <sub>8</sub> , O <sub>9</sub>
G <sub>3</sub>	O <sub>1</sub> , O <sub>2</sub> , O <sub>3</sub>	X <sub>2</sub>	O <sub>4</sub> , O <sub>5</sub> , O <sub>6</sub>	O <sub>7</sub> , O <sub>8</sub> , O <sub>9</sub>

G<sub>1</sub>: Learning environment where students are thought without any interventions (Control)

G<sub>2</sub>: Learning environment where concrete tools are used (Trial 1)

G<sub>3</sub>: Learning environment where technology-assisted learning tools are used (Trial 2)

O<sub>1</sub>: Place value achievement pre-test

O<sub>2</sub>: Mathematics achievement pre-test

O<sub>3</sub>: Arithmetic performance post test

O<sub>4</sub>: Place value achievement post test

O<sub>5</sub>: Mathematics achievement post test

O<sub>6</sub>: Arithmetic performance post test

O<sub>7</sub>: Place value achievement retention test

O<sub>8</sub>: Mathematics achievement retention test

O<sub>9</sub>: Arithmetic performance retention test

X<sub>1</sub>: Use of concrete tools

X<sub>2</sub>: Use of technology-assisted learning tools

Despite being a strong research model, factorial design does at the same time contain some weaknesses such as the risk of awareness mitigation of the subjects as multiple measurement tools are distributed to the groups. Therefore, it is suggested to perform some monitoring works a certain while after completing the empirical action (Heppner, Kivlighan & Wampold, 1999). In this sense, three weeks after the end of the trail a retention test has been conducted to see whether the impact of the teaching is still on.

## 2.2. Study Group

The study group of the research consisted of 4th grade students from three different public primary schools with intermediate socio-economic levels located in Nevşehir province. Group matching method has been employed for determining the study group of the research. This method works by defining groups that are equal and/or close in terms of the averages of relevant variables (quoted by Büyüköztürk from Eckhardt & Ermann, 2014, p. 22). In order to conduct such a group matching, 370 4th grade students from three different primary schools have been subjected to "Place Value Test [PVT]", "Mathematic Achievement Test [MAT]" and "Arithmetic Performance Test [APT]". In every school, the bottom 25% group who received low scores from each one of these tests has been included in the research. With regards to the general average of the groups, students below 6,91/ for PVT (The highest possible score from the test is 21), below 4,58/ for MAT (The highest possible score from the test is 24) and below 46,20/ for APT (The highest possible score from the test is 200) have been included in the study groups. The average and standard deviation values of the scores obtained by the groups through the measuring tools applied as pre-test are shown in Table 2.

Table 2. The Average and Standard Deviation Values Related to Pre-Test Scores Obtained by Trial 1, Trial 2 and Control Groups from Tests

Placement Test	Groups	N	$\bar{X}$	sd
Place Value Test	Trial 1**	19	5.36	3.16
	Trial 2***	23	5.91	1.86
	Control	21	4.38	2.11
Mathematics Achievement Test	Trial 1	19	4.05	1.61
	Trial 2	23	4.13	1.18
	Control	21	3.19	1.88
Arithmetic Performance Test	Trial 1	19	45.73	21.95
	Trial 2	23	44.08	13.94
	Control	21	41.47	15.21

\*\* Trial 1, Learning environment using concrete tools

\*\*\* Trial 2, Learning environment using technology-assisted learning tools

As indicated in Table 2, the place value test average of Trial 1 group (concrete) is  $\bar{X} = 5.36$ , Trial 2 group's (technology-assisted) average is  $\bar{X} = 5.91$  and Control group's average is  $\bar{X} = 4.38$ . Trial 1 group's mathematics achievement test average is  $\bar{X} = 4.05$ , Trial 2 group's average is  $\bar{X} = 4.13$  and Control group's average is  $\bar{X} = 3.19$ . And in terms of arithmetic performance test averages, Trial 1 average is  $\bar{X} = 45.73$ , Trial 2 average is  $\bar{X} = 44.08$  and Control group average is  $\bar{X} = 41.47$ .

### 2.3. Data Collection Tools

During the data collection phase of the current study; participants included in the trial and control groups have been subjected to place value test, mathematic achievement test and arithmetic performance test as pre-test, post-test and retention test.

Place value test has been developed by Sarı and Olkun (2019). The test contains a total of 21 questions containing grouping and ungrouping skills related to the place value concept. The questions are related to reading and writing numbers based on place value. A reliability study by Sarı and Olkun (2019) conducted on a total of 175 people reported the KR-20 coefficient as .84. In this study the KR-20 reliability coefficient has calculated as .86 over a total of 370 people.

Mathematics achievement test has been developed by Fidan (2013) based on primary school 4th grade mathematics curriculum (Ministry of National Education, 2015). It contains such topics as counting numbers, number patterns, four operation questions and problems and fractions among others. The KR-20 reliability coefficient of the test has been

calculated as .96, while the reliability coefficient of the current test has been calculated as .91. The duration of the test is one class hour.

Arithmetic performance test has been developed by De Vos (1992) and adopted into Turkish by Olkun, Can, and Yeşilpınar (2013) and it consists of arithmetic operations (addition, subtraction, multiplication and division). It consists of a total of 200 questions, with 40 questions in each column. First column is about addition, 2nd column is subtraction, 3rd column is multiplication, 4th column is division and 5th column is about mixed operations. Applied as a limited-time test, Olkun et al. (2013) found the KR-20 reliability coefficient as .95. KR-20 coefficient has been calculated as .94 in this study. Each column is distributed separately to the students during the test and the recommended duration for each column is 1 minute.

#### 2.4. Research Process

The stages followed during the research process are shown in Figure 1. During the first stage of the research process, the concrete tools to be used in the study have been identified and the technology-assisted material has been developed. The process of developing technology-assisted materials and the scope of the material has been explained by Sarı, Aydoğdu and Özaydın-Aydoğdu (2019).

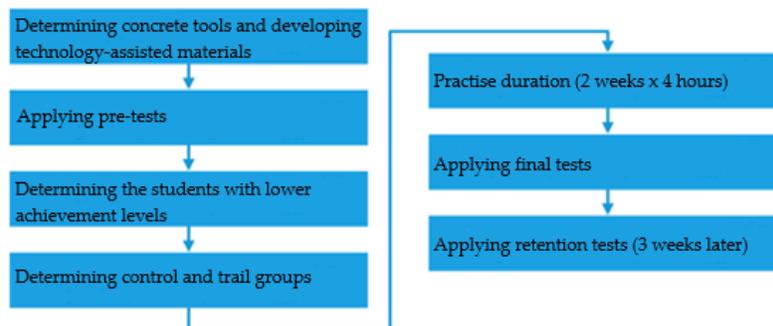


Figure 1. Stages followed during the research process

As already specified under the study group title, pre-tests have been conducted to identify the students to take part in the research. Students with lower achievement rates in the pre-tests have been included to the research. Afterwards, the control and trial groups of the research have been formed. Groups have been randomly assigned as trial or control groups.

The actual practice for both trial groups and control group lasted 8 class hours (2 weeks). Groups have been subjected to retention test following a three-week break. Mathematics classes in trial and control groups have been held for 4 hours per week.

In Trial 1 group, concrete tools have been used to perform activities oriented towards the place value concept. As concrete tools, Dienes blocks and Snapcube have been used. In Trial 2 group, educational digital materials, related to place value concept have been used.

The concrete tools and digital materials were described in ESM (see Appendix A). No intervention has been made during the learning-teaching process of the control group. Students continued to receive education in their own classrooms. During the pre-test, final-test and retention test stage, students have been taken from their classes and subjected to the tests.

### 2.5. Data Analysis

Before deciding on which analysis technique is to be used, data have been reviewed to see if they meet normality assumptions. One of the other conditions of checking normality assumption is to interpret Skewness and Kurtosis values. Data of independent variables indicate that Skewness and Kurtosis values are lower than the accepted threshold of 1.96 (Can, 2014). In this sense, it has been decided that data are distributed normally and parametric statistical analysis methods could be used. One-Way Analysis of Variance (ANOVA) has been used for the comparison of pre-test score averages obtained from the groups (Büyüköztürk, 2010, p.48-54; Can, 2014, p.147-158).

In order to interpret the "Place Value Test", "Mathematic Achievement Test" Arithmetic Performance Test" scores obtained during the pre-test, final-test and retention test stages of the experimental design, Two-Way ANOVA method for Mixed Measurements has been used. With regards to the groups formed in accordance with the methods used for the research, Two-Way ANOVA method for Mixed Measurements can be used to test the difference between the scores obtained by the groups in the repetitive measurements and also to test the difference between measurements regardless of groups (Büyüköztürk, 2010). Analyses have been conducted by using SPSS 20.00 package program.

## 3. Findings

### 3.1. Findings Related to the Difference between Control and Trial Groups' Place Value Achievement and Pre-test, Final-test and Retention Scores

ANOVA results related to the average pre-test score differences for place value achievement are given in Table 3.

Table 3. ANOVA results related to the place value achievement pre-test scores of the control and trial groups of the study

Groups		N	Df	Mean of Squares	F	p*
Between groups	26.229	19	2	13.115	2.279	.111
Inter-groups	345.200	23	60	5.753		
Total	371.429	21	62			

\*p<.05

Looking at the results of One-Way Analysis of Variance (ANOVA) (Table 3), held to determine if there are any meaningful differences between the pre-test score averages obtained by trial and control groups from place value test, there are no meaningful differences between the place value [F[2-60]= 2.279,  $p > .05$ ], pre-test score averages of the groups involved in the research. Therefore, it is safe to say that groups were on an equal level in terms of place value achievement pre-test scores before the commencement of the research.

The average and standard deviation values per group of the scores obtained by students from pre-test, post-test and retention tests are given in Table 4.

Table 4. Place value achievement test average and standard deviation values

Groups	PRE-TEST			POST-TEST			RETENTION		
	N	$\bar{X}$	S	N	$\bar{X}$	S	N	$\bar{X}$	S
Control group	21	4.38	2.11	21	7.38	4.59	21	8.14	4.13
Concrete Tools	19	5.37	3.17	19	13.11	4.95	19	13.32	4.96
Technology-assisted	23	5.91	1.86	23	13.35	2.90	23	14.70	2.98

Regarding the place value achievement test of the control group students, their pre-test average score is  $\bar{X}=4.38$ , final-test average score is  $\bar{X}=7.38$  and retention test average score is  $\bar{X}=8.14$ . The average scores obtained from the same test by the students taught by using concrete tools are  $\bar{X}=5.37$  for pre-test,  $\bar{X}=13.11$  for final- test and  $\bar{X}=13.32$  for retention test. Finally, the students taught by using technology-assisted tools scored a pre-test score average of  $\bar{X}=5.91$ , final-test score average of  $\bar{X}=13.35$  and retention test score average of  $\bar{X}=14.70$  from the same test. ANOVA test results comparing the average scores of groups and measurements are given in Table 5.

Table 5. ANOVA results of place value achievement test pre-test-final test-retention scores

Variance source	SS	df	SM	F	p*	$\eta^2$
Between Subjects	2613.619	62				
Group (Concrete tool-tech-assisted-control group)	813.644	2	406.822	13.561	.000	.311
Error	1799.975	60	30.000			
Inter-Subjects	2528.257	126				
Measurement (pre-test – final-test - retention)	1752.162	2	876.081	184.202	.000	.754
Group*Measurement	205.365	4	51.341	10.795	.000	.265
Error	570.730	120	4.756			
Total	5141.876	188				

\* $p < .05$

Data given in Table 5 indicates that group\*measurement factor has a joint effect on dependent variable. According to this, there is a meaningful difference between the place value achievement test scores of students learning in different learning environments  $F(4,120)=10.795$ ,  $p<.05$ . In order to identify the two sub-groups whose difference has caused this effect, one of the post-hoc methods, “Scheffe” test has been applied.

Table 6. Post-hoc results of place value achievement test scores

Group	Measurement	Control group			Concrete tool			Technology-assisted		
		Pre-test	Post-test	Retention	Pre-test	Post-test	Retention	Pre-test	Post-test	Retention
Control group	Pre-test	-	-3.00	-3.76	-.99	<b>-8.72*</b>	<b>-8.93*</b>	-1.50	<b>-8.97*</b>	<b>-10.31*</b>
	Post-test		-	-.76	2.01	<b>-5.72*</b>	<b>-5.93*</b>	1.47	<b>-5.97*</b>	<b>-7.31*</b>
	Retention			-	2.77	<b>-4.96*</b>	<b>-5.17*</b>	2.23	<b>-5.20*</b>	<b>-6.55*</b>
Concrete tool	Pre-test				-	<b>-7.74*</b>	<b>-7.95*</b>	-.54	<b>-7.98*</b>	<b>-9.33*</b>
	Post-test					-	-.21	<b>7.19*</b>	-.24	-1.59
	Retention						-	<b>7.40*</b>	-.03	-1.38
Technology-assisted	Pre-test							-	<b>-7.43*</b>	<b>-8.78*</b>
	Post-test								-	-1.35
	Retention									-

\* $p<.05$ 

According to the multiple comparison results between groups and measurements (Table 6), there is a meaningful difference between the pre-test ( $\bar{X} = 5.37$ ) – post-test ( $\bar{X} = 13.11$ ) and pre-test ( $\bar{X} = 5.37$ ) – retention test ( $\bar{X} = 13.32$ ) scores of the students who learned by using concrete tools. Furthermore, the analysis result indicates that there is no meaningful difference between the post-test ( $\bar{X} = 13.11$ ) and retention test ( $\bar{X} = 13.32$ ) score averages of the students in this group. Based on this finding, it can be said the place value achievement of the students using concrete tools has increased following the trial. In addition, the fact that there is no meaningful difference between the final test and retention test results of the students makes it possible to say that the knowledge learned with regards to place value concept has not been forgotten.

Following the post hoc analysis, a meaningful difference has been observed between the pre-test ( $\bar{X} = 5.91$ ) – final test ( $\bar{X} = 13.35$ ) and pre-test ( $\bar{X} = 5.91$ ) – retention test ( $\bar{X} = 14.70$ ) scores of students who used technology-assisted learning materials. There is no meaningful difference between the score averages obtained by these students from final-test ( $\bar{X} = 13.35$ ) and retention test ( $\bar{X} = 14.70$ ). According to this, after the experiment there was an increase in the place value achievement of students using technology-assisted

learning materials. Furthermore, having no difference between the final test and retention test is an indication that the students did not forget what they have learned about place value concept.

No meaningful difference has been observed between the pre-test score average ( $\bar{X} = 4.38$ ) – final test score average ( $\bar{X} = 7.38$ ) and retention test score average ( $\bar{X} = 8.14$ ) scores obtained from the place value achievement test by the control group students. In the non-intervention group, the place value achievement of the students had continuously increased according to the measurements. Even though there was an increase in the place value achievement of the students in this group, comparing the differences between the groups leads us to the conclusion that students subjected to an experimental action are more successful. Measurement differences between groups have been compared and can be found below.

According to the multiple comparison analysis, there is a meaningful difference between the place value post-test achievement score average ( $\bar{X} = 13.11$ ) of the students using concrete tools and the post-test achievement score ( $\bar{X} = 7.38$ ) of the control group not subjected to any interventions. Similarly, there is a meaningful difference between the place value post-test achievement score average ( $\bar{X} = 13.35$ ) of the students using technology-assisted materials and the post-test achievement score ( $\bar{X} = 7.38$ ) of the control group not subjected to any interventions. However, there is no meaningful difference between the place value post-test achievement score average ( $\bar{X} = 13.11$ ) of the students using concrete tools and the place value post-test achievement score average ( $\bar{X} = 13.35$ ) of the students using technology-assisted materials. This finding suggests that the place value achievement of students in trial groups is higher than those in the control group. The fact that there is no difference between the students using concrete tools and the students using technology-assisted material is an indication that these tools have similar effects on the place value achievement of the students.

A review of the place value achievement scores obtained from the retention test indicates a meaningful difference between the score averages of students using concrete tools ( $\bar{X} = 13.32$ ) and control group students ( $\bar{X} = 8.14$ ). Similarly, there is a meaningful difference between the place value achievement score average obtained from retention test by students using technology-assisted material ( $\bar{X} = 14.70$ ) and the achievement score average of control group students ( $\bar{X} = 8.14$ ). Finally, in all of the measurements there is no meaningful difference between the place value achievement test average scores of the students using concrete tools ( $\bar{X} = 13.32$ ) and students using technology-assisted material ( $\bar{X} = 14.70$ ). This finding indicates that the effect of the experimental action continues in a similar way in trial groups. At the same time, comparing the retention test scores of trial and control groups indicates a higher place value achievement in favor of the trial group students.

3.2. Findings Regarding the Difference between Mathematics Achievement and Pre-test, Post-test and Retention Scores of Control and Trial Groups

ANOVA results related to the average score differences, between and inter-groups, by the students obtained from mathematics achievement pre-test, is given in Table 7.

Table 7. ANOVA results related to the mathematics achievement test pre-test scores of the control and trial groups

Groups		N	df	Mean of Squares	F	p*
Between groups	11.523	19	2	5.762	2.323	.107
Inter-groups	148.794	23	60	2.480		
Total	160.317	21	62			

\*p<.05

Looking at the results of the One-Way Analysis of Variance (ANOVA), held to determine whether there are any meaningful differences between the pre-test scores averages obtained by the trial and control groups from mathematics achievement test (Table 7), there is no meaningful difference between the mathematics achievement test [F[2-60]= 2.323, p> .05] pre-test score averages of the groups involved in the study. This finding is an indication that the groups were at a similar mathematics achievement level before the trial.

Concerning the second sub-problem of the research, “Is there a meaningful difference between the “mathematics achievement test” pre-test-post-test and retention test score averages of primary school 4th grade students in terms of the type of tool (concrete, technology-assisted, no intervention) used during the teaching process?”, the average and standard deviation values obtained by students in pre-test, post- test and retention tests is given in Table 8.

Table 8. Mathematics achievement test average and standard deviation values

Groups	PRE-TEST			POST-TEST			RETENTION		
	N	$\bar{X}$	S	N	$\bar{X}$	S	N	$\bar{X}$	S
Control group	21	3.19	1.89	21	4.67	3.61	21	5.00	3.54
Concrete Tools	19	4.05	1.61	19	10.16	4.17	19	8.68	3.62
Technology-assisted	23	4.13	1.18	23	10.09	2.68	23	7.70	2.44

According to the mathematics achievement test score averages given in Table 8, mathematics achievement test pre-test average score of the control group students is  $\bar{X}$  =3.19, post-test average score is  $\bar{X}$  =4.67 and retention test average score is  $\bar{X}$  =5.00. The

average scores obtained from the same test by the students using concrete tools have been calculated as  $\bar{X}=4.05$  for pre-test,  $\bar{X}=10.16$  for post-test and  $\bar{X}=8.68$  for retention. Students using technology-assisted tools had pre-test score average of  $\bar{X}=4.13$ , final test score average of  $\bar{X}=10.09$  and retention test score average of  $\bar{X}=7.70$  for the same test. ANOVA results testing the difference between the average scores are given in Table 9.

Table 9. ANOVA results of mathematics achievement test pre-test-final test-retention scores

Variance source	SS	df	SM	F	p*	$\eta^2$
Between Subjects	424.509	2	212.255	11.726	.000	.281
Group (Concrete tool-tech-assisted-control group)	1086.062	60	18.101			
Error	1248.635	126				
Inter-Subjects	686.190	2	343.095	100.241	.000	.626
Measurement (pre-test – final-test - retention)	151.719	4	37.930	11.082	.000	.270
Group*Measurement	410.726	120	3.423			
Error	2759.206	188				
Total	424.509	2	212.255	11.726	.000	.281

\*p&lt;.05

According to the ANOVA results, given in Table 9, of the score averages obtained from mathematics achievement test, the group\*measurement factor has a joint effect on the dependent variable. According to this finding, there is a meaningful difference in the mathematics achievement test scores of the students, depending on the type of material they are using  $F(4, 120)=11.082$ ,  $p<.05$ . Scheffe test has been performed to identify the groups and measurements where these differences have occurred.

Table 10. Post-hoc results of mathematics achievement test scores

Group	Measurement	Control group			Concrete tool			Technology-assisted		
		Pre-test	Post-test	Retention	Pre-test	Post-test	Retention	Pre-test	Post-test	Retention
Control group	Pre-test	-	-1.48	-1.81	-.86	<b>-6.97*</b>	<b>-5.49*</b>	-.94	<b>-6.90*</b>	<b>-4.51*</b>
	Post-test		-	-.33	.61	<b>-5.49*</b>	<b>-4.02*</b>	.54	<b>-5.42*</b>	-3.03
	Retention			-	.95	<b>-5.16*</b>	<b>-3.68*</b>	.87	<b>-5.09*</b>	-2.70
Concrete tool	Pre-test				-	<b>-6.11*</b>	<b>-4.63*</b>	-.08	<b>-6.03*</b>	<b>-3.64*</b>
	Post-test					-	1.47	<b>6.03*</b>	.07	2.46

	Retention	-	4.55*	-1.40	.99
Technology-assisted	Pre-test		-	-5.96*	-3.57*
	Post-test			-	2.39
	Retention				-

\* $p < .05$

According to Scheffe test findings (Table 10), there is no meaningful difference in the pre-test ( $\bar{X} = 3.19$ ), post-test ( $\bar{X} = 4.67$ ) and retention ( $\bar{X} = 5.00$ ) test score averages of the control group students in their mathematics achievement. According to this finding, no progress has been observed in the development of mathematics achievement of the students not subjected to any intervention.

There is a meaningful difference between the mathematics achievement test score averages pre-test ( $\bar{X} = 4.05$ ) – post-test ( $\bar{X} = 10.16$ ) and pre-test ( $\bar{X} = 4.05$ ) – retention test ( $\bar{X} = 8.68$ ) results of the students using concrete tools. But there is no meaningful difference between the post-test ( $\bar{X} = 10.16$ ) and retention test ( $\bar{X} = 8.68$ ) score averages of the students in this group. This finding could be an indication that there is an increase in the mathematics achievement of students using concrete tool after the experiment and also that the effect is still on-going.

Similarly, there is also a meaningful difference in the mathematics achievement test score averages pre-test ( $\bar{X} = 4.13$ ) -post-test ( $\bar{X} = 10.09$ ) and pre-test ( $\bar{X} = 4.13$ ) - retention ( $\bar{X} = 7.70$ ) test of the students using technology-assisted materials. There is no meaningful difference between the score averages obtained by these students in post-test ( $\bar{X} = 10.09$ ) and retention ( $\bar{X} = 7.70$ ) test. According to this, it can be said that the achievement rate of the students using technology-assisted material has increased following the experiment and the effect of the experiment is still ongoing.

Analyzing the differences between groups on the basis of the measurements taken in post-hoc analysis, there is a meaningful difference in the mathematics achievement post-test score averages; between the control group students ( $\bar{X} = 4.67$ ) and students using concrete tool ( $\bar{X} = 10.16$ ) and control group students ( $\bar{X} = 4.67$ ) and students using technology-assisted material ( $\bar{X} = 10.09$ ), but there is no meaningful difference between students using concrete tool ( $\bar{X} = 10.16$ ) and students using technology-assisted material ( $\bar{X} = 10.09$ ). According to this finding, mathematics achievement of the students subjected to experimental action was higher than that of the control group students. In addition to this, there was no difference in terms of mathematics achievement between trial groups (concrete-technology-assisted). This can be interpreted as concrete tools and technology-assisted materials have similar kind of effects on the development of mathematics achievement of students.

Looking at the score averages of the retention test, there is a meaningful difference between control group students ( $\bar{X} = 5.00$ ) and the students who used concrete tools ( $\bar{X} = 8.68$ ).

### 3.3. Findings Regarding the Difference between Arithmetic Performance Test Achievement and Pre-test, Final-test and Retention Scores of Control and Trial Groups

The results of ANOVA, held to analyze the difference between the pre-test score averages obtained by students from the arithmetic performance test, is presented in Table 11.

Table 11. ANOVA Results Related to the Arithmetic Performance Test Pre-test Scores of Trial 1, Trial 2 and Control Groups

Groups		N	df	Mean of Squares	F	p*
Between groups	186.109	19	2	93.054	.318	.729
Inter groups	17580.748	23	60	293.012		
Total	17766.857	21	62			

\*p<.05

According to the One-Way Analysis of Variance (ANOVA) results (Table 11), held to identify any meaningful differences between the pre-test score averages obtained by the groups from the arithmetic performance test, there is no meaningful difference between the groups in terms of arithmetic performance test [F[2-60]=.318, p> .05] pre-test score averages.

Table 12. Arithmetic performance test average and standard deviation values

Groups	PRE-TEST			POST-TEST			RETENTION		
	N	$\bar{X}$	S	N	$\bar{X}$	S	N	$\bar{X}$	S
Control group	21	41.48	15.21	21	51.10	17.63	21	55.86	21.71
Concrete Tools	19	45.74	21.95	19	64.37	23.61	19	58.05	20.91
Technology-assisted	23	44.09	13.95	23	66.48	17.68	23	65.61	17.61

According to the arithmetic performance test results given in Table 12, the average score obtained by the control group students from pre-test is  $\bar{X} = 41.48$ , average score obtained from post-test is  $\bar{X} = 51.10$  and average score obtained from retention test is  $\bar{X} = 55.86$ . The average score values obtained from the same test by students using concrete tools has been calculated as  $\bar{X} = 45.74$  for pre-test,  $\bar{X} = 64.37$  for post-test and  $\bar{X} = 58.05$  for retention test. Students using technology-assisted learning material scored a pre-test score average

of  $\bar{X}$  =44.09, post-test score average of 66.48 and retention test score average of  $\bar{X}$  = 65.61. ANOVA and post-hoc analysis results, comparing the average scores of groups and differences between measurements are given below.

Table 13. ANOVA results of arithmetic performance test pre-test-final test-retention scores

Variance source	SS	df	SM	F	p*	η <sup>2</sup>
Between Subjects	60061.249	62				
Group (Concrete tool-tech-assisted-control group)	2937.591	2	1468.795	1.543	.222	.049
Error	57123.658	60	952.061			
Inter-Subjects	20414.62	126				
Measurement (pre-test – final-test - retention)	11353.552	2	5676.776	88.515	.000	.596
Group*Measurement	1365.011	4	341.253	5.321	.001	.151
Error	7696.057	120	64.134			
Total	424.509	2	212.255	11.726	.000	.281

\*p<.05

According to the ANOVA results of the score averages obtained from the arithmetic performance test, as shown in Table 13, group\*measurement factor has a joint effect on the dependent variable. According to this finding, the type of material used by students leads to a meaningful difference between the arithmetic performance test scores F(4, 120)=5.321,p<.05.

Table 14. Post-hoc results of arithmetic performance test scores

Group	Measurement	Control group			Concrete tool			Technology-assisted		
		Pre-test	Post-test	Retention	Pre-test	Post-test	Retention	Pre-test	Post-test	Retention
Control group	Pre-test	-	-9.62	-14.38	-4.26	-22.89	-16.58	-2.61	<b>-25.00*</b>	<b>-24.13*</b>
	Post-test		-	-4.76	5.36	-13.27	-6.96	7.01	-15.38	-14.51
	Retention			-	10.12	-8.51	-2.20	11.77	-10.62	-9.75
Concrete tool	Pre-test				-	-18.63	-12.32	1.65	-20.74	-19.87
	Post-test					-	6.32	20.28	-2.11	-1.24
	Retention						-	13.97	-8.43	-7.56
	Pre-test							-	<b>-22.39*</b>	-21.52

Technology-	Post-test	-	.87
assisted	Retention	-	-

\*p<.05

According to the Scheffe test results (Table 14), measurements did not yield any meaningful differences between groups. The analysis conducted indicated a meaningful difference between the pre-test ( $\bar{X}=44.09$ ) and post-test scores ( $\bar{X}=66.48$ ) of the students using technology-assisted a material. But in terms of arithmetic performance, there is no other meaningful difference between the measurements among the groups. According to this finding, there was an increase in the mathematics performance of students using a technology-assisted material, following the experiment. The fact that there is no difference between the final test and retention test scores of these students is an indication that the effect of the experiment is still ongoing.

#### 4. Discussion, Conclusions and Recommendations

This current research is examining the effect of concrete and technology-assisted learning tools on developing the place value conception, mathematics achievement and arithmetic performances of students. The findings acquired from this research can be distributed under three different main headlines; the effect of concrete and technology-assisted learning tools on developing the place value conception, on developing mathematics achievement and on developing arithmetic performance.

The effect of both concrete and technology-assisted learning tools on developing the place value perception of primary school 4th grade students is significantly high when compared with students who did not use any such learning tools. In other words, prepared with the purpose of developing place value concept, concrete (Dienes blocks, snap cubes) and technology-assisted (place value materials) learning tools were effective in developing the place value conception of students. The acquired findings are in line with the literature. Previous researches have shown that concrete tools (Broadbent, 2004; Kamii and Joseph, 1988; Moore, 1992; Schmidt, 1995; Valeras & Becker, 1997) and technology-assisted learning tools (Mutlu & Sarı, 2019) have positive effects on developing the place value perception of students. For instance, “decimals-based game” designed by Broadbent (2004) proved that the use of concrete materials helps students to develop their level of understanding the structure of counting system. Similarly, a study conducted by Mutlu and Sarı (2019) on 3rd grade students reported that computer-assisted educational materials develop the place value understanding of students. Computer-assisted education did not have any meaningful effect on the affective variables of students, such as anxiety and attitude.

Concrete and technology-assisted learning tools helped students to develop their place value conception much higher than the control group students, because concrete learning

materials are objects that are used to make abstract mathematical concepts more concrete and they simplify the understanding process of these concepts (Moyer, 2001). Furthermore, technology-assisted learning tools are dynamic, interactive, flexible, manageable and easy to receive feedback (Petit, 2013; Sarama & Clements, 2016) and therefore they provide important opportunities for creating an effective learning-teaching process. Both concrete and technology-assisted tools play important roles in helping students to produce meaningful ideas (Clements, 1999). Concrete and technology-assisted are highly important as they are helping abstract mathematical ideas to be expressed tangibly, making mathematics meaningful for students, and also because they contribute to creating an environment where students can feel the things they are learning (Bulut, Çömlekoğlu, Özkaya-Seçil, Yıldırım & Tuncay-Yıldız, 2006).

One of the important findings of this research was that the comparison of the effect of both concrete and technology-assisted learning tools on developing the place value conception of students did not yield any meaningful difference. In other words, concrete and technology-assisted learning tools had a similar effect on developing the place value concept. A review of the literature did not yield a clear preference between computer and concrete manipulatives in mathematics education (Burns & Hamm, 2011). Some researches emphasize the effect of concrete tools (Clements, 1999; Petit, 2013; Konaş, 2016; Larbi & Mavis, 2016; Sarama & Clements, 2016) while others favor technology-assisted learning tools (Li & Ma, 2010; Turgut & Dogan-Temur, 2017) to have a better effect on mathematics achievement. From this perspective, this current research has shed some valuable light onto this uncertainty as it has revealed the same level of effect by concrete and technology-assisted learning tools on the place value conception of primary school 4th grade students. Concrete and technology-assisted learning tools are particularly useful in comprehensive and well-planned education environments. Environments designed with both concrete and technology-assisted concrete tools provide students with meanings that they can use to build, enhance and bind their mathematical ideas (Clements & McMillen, 1996; Sarama & Clements, 2016).

Another finding of the study is related to revealing the effect of concrete and technology-assisted learning materials, designed to develop the place value conception, on the mathematics achievement and arithmetic performance of primary school 4th grade students. The learning environment with concrete learning tools, used by the trial groups was more effective on the mathematics achievement of students when compared to the mathematics achievement of control group students. Likewise, the environment using technology-assisted learning tools had a meaningful effect on the mathematics achievement of students when compared to the environment not using such tools. And the use of concrete and technology-assisted learning tools yielded a similar effect on mathematics achievement. In other words, the effect of both concrete and technology-assisted learning tools on developing mathematics achievement of students is at a similar level.

With regards to the effect of concrete and technology-assisted learning environments, designed to develop the place value conception of students, on the arithmetic performances of 4th grade students, the arithmetic performance developing effect on trial groups in technology-assisted learning environment was higher when compared to the control group students and those in a learning environment using concrete tools. The possible reasons for the greater development of arithmetic performance in technology-assisted learning environment could be the content of the educational design, such as various counting strategies (taking a reference at 5 and 10) and grouping/solution strategies.

The reflection of the developed place value conception on both mathematics achievement and arithmetic performance is in line with the findings in literature. Failure to get a grasp of decimal system and place value concept creates difficulties in learning several other related concepts (Sarı & Olkun, 2019), because place value concept is highly important when learning to count (Boulton-Lewis, 1993), four operations, and the technique of operations (Dinç-Artut & Tarım, 2006). At the same time, there are several studies which point out to the critical importance of understanding PV concept in solving a mathematical problem (Fuson et al., 1997). The critical importance of place value in learning to count and performing four operations (Chan et al., 2014), place value performance estimating mathematics performance at a high level (Moeller et al., 2011; Sarı & Olkun, 2019) are important in the mathematics achievement of students. Understanding the concept of place value (PV) is a basic numerical ability and forms the basis of future numerical development. Therefore, place value conception of students acts as a pre-conditional skill for the further mathematics achievement of students (McGuire & Kinzie, 2013; Nataraj & Thomas, 2007). In other words, a flexible understanding of place value plays an important role in learning and understanding mathematics (Ladel & Kortenkamp, 2016).

Another finding of the research is related to the retention test scores. The fact that there is no meaningful difference between the retention test, held three weeks after the trial, and post-test average scores is an indication that practices with both concrete and technology-assisted learning tools make the PV-related acquirments of students permanent. From this perspective, it is possible to say that computer-assisted education is important for ensuring retention of learned knowledge. Computer-assisted education is seen as a tool that helps knowledge to become permanent (Kula & Erdem, 2005). Findings related to the retention of learned knowledge have similarities with the findings in literature. Knowledge gained in learning environments with computer assisted education software are observed to be more permanent than those gained in environments without such tools (Mutlu & Sarı, 2019).

This research also includes a number of limitations. First of all, both concrete and technology-assisted learning tools have been applied to students with relatively weaker place value conception. In his sense, their effect is unknown on students with ordinary and higher level of achievement. Furthermore, arithmetic performance achievement has

developed more in environments using a technology-assisted learning tool. This is something that requires support through future studies. It is also deemed important to expand the samples of the study so that not only the effect of concrete tools and technology-assisted materials on dependent variables is reviewed but the interaction between dependent variables is also analyzed.

### Acknowledgements

This research was funded with support from Nevsehir Hacı Bektas Veli University [grant number BAP18S22].

### References

- Andreasen, J. B. (2006). *Classroom mathematical practices in a preservice elementary mathematics education course using an instructional sequence related to place value and operations*. University of Central Florida Orlando, Florida.
- Baroody, A. J. (1990). How and when should place-value concepts and skills be taught? *Journal for Research in Mathematics Education*, 21(4), 281–286.
- Boulton-Lewis, G. M. (1993). An analysis of the relation between sequence counting and knowledge of place value in the early years of school. *Mathematics Education Research Journal*, 5(2), 94–106.
- Broadbent, A. (2004). Understanding Place-Value: A Case Study of the Base Ten Game. *Australian Primary Mathematics Classroom*, 9(4), 45-46.
- Bulut, S., Çömlekođlu, G., Seçil, S.Ö., Yıldırım H. & Yıldız, B.T. (2002). Matematik öğretiminde somut materyallerin kullanılması [Using manipulatives in Teaching Mathematics]. V. *Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi*, Ankara.
- Burns, B. A., & Hamm, E. M. (2011). A comparison of concrete and virtual manipulative use in third and fourth-grade mathematics. *School Science and Mathematic*. 111(6), 256–261.
- Büyüköztürk, Ş. (2010). *Sosyal bilimler için veri analizi el kitabı [The handbook of data analysis for social sciences]* (11 ed.). Ankara: Pegem Akademi.
- Büyüköztürk, Ş. (2014). *Deneysel desenler [Experimental designs]* (4 ed.). Ankara: Pegem Akademi.
- Büyüköztürk, Ş., Çakmak, E.K., Akgün, Ö.E., Karadeniz, Ş., & Demirel, F. (2009). *Bilimsel araştırma yöntemleri [Scientific research methods]* (4 ed.). Ankara: Pegem Akademi.
- Byrge, L., Smith, L. B., & Mix, K. S. (2014). Beginnings of Place Value: How Preschoolers Write Three- Digit Numbers. *Child development*, 85(2), 437-443.
- Can, A. (2014). *SPSS ile bilimsel araştırma sürecinde nicel veri analizi [Quantitative data analysis in scientific research process with SPSS]* (3 ed.). Ankara: Pegem Akademi.
- Carbonneau, K. J., Marley, S. C., & Selig, J. P. (2013). A meta-analysis of the efficacy of teaching mathematics with concrete manipulatives. *Journal of Educational Psychology*, 105(2), 380.
- Chan, W. W. L., Au, T. K., & Tang, J. (2014). Strategic counting: A novel assessment of place-value understanding. *Learning and Instruction*, 29, 78-94. doi: <http://dx.doi.org/10.1016/j.learninstruc.2013.09.001>

- Clements, D. H., & McMillen, S. (1996). Rethinking concrete manipulatives. *Teaching Children Educational Studies in Mathematics*, 47, 175-197.
- Clements, D.H. (1999). “Concrete” manipulatives, concrete ideas. *Contemporary Issues in Early Childhood*, 1 (1): 45-60.
- Cooper, L. L., & Tomayko, M. C. (2011). Understanding place value. *Teaching Children Mathematics*, 17(9), 558-567.
- Cuffel, T. A. (2009). *Linking place value concepts with computational practices in third grade*. University of Central Florida Orlando, Florida.
- De Vos, T. (1992). “Tempo-test rekenen (Number fact retrieval test).” Nijmegen: Berkhout.
- Demetriou, L. (2016). The use of virtual and concrete manipulatives in kindergarten school. *CERME 9 - Ninth Congress of the European Society for Research in Mathematics Education*, Charles University in Prague, Faculty of Education; ERME, Feb 2015, Prague, Czech Republic. pp.1911-1917. hal- 01288463
- Department for Education and Skills. (2001). *Guidance to Support Pupils with Dyslexia and Dyscalculia: The Daily Mathematics Lesson*. Department for Education and Skills.
- Dietrich, J. F., Huber, S., Dackermann, T., Moeller, K., & Fischer, U. (2016). Place-value understanding in number line estimation predicts future arithmetic performance. *British Journal of Developmental Psychology*, 34(4), 502-517. doi: **10.1111/bjdp.12146**
- Diñç Artut, P., & Tarım, K. (2006). İlköğretim öğrencilerinin basamak değer kavramını anlama düzeyleri [Elementary students’ comprehension of place value concept]. *Eğitimde Kuram ve Uygulama*, 2(1), 26–36.
- Durmus, S., & Karakirik, E. (2006). *Virtual Manipulatives in Mathematics Education: A Theoretical Framework*. Turkish Online Journal of Educational Technology-TOJET, 5(1), 117-123.
- Fidan, E. (2013). *İlkokul öğrencileri için matematik dersi sayılar öğrenme alanında başarı testi geliştirilmesi [Development of achievement tests in the number domain of mathematics course for elementary school students]*. (Unpublished master's thesis), Ankara Üniversitesi, Eğitim Bilimleri Enstitüsü.
- Fuson, K. C., Wearne, D., Hiebert, J., Murray, H. G., Human, P. G., Olivier, A. I., vd. (1997). Children’s conceptual structures for multidigit numbers and methods of multidigit addition and subtraction. *Journal of Research in Mathematics Education*, 28,130-162.
- Geary, D. C. (2004). Mathematics and learning disabilities. *Journal of learning disabilities*, 37(1), 4-15.
- Griffin, S., Case, R., & Siegler, R. S. (1994). *Rightstart: Providing the central conceptual prerequisites for first formal learning of arithmetic to students at risk for school failure*. In K. McGilly (Ed.), *Classroom lessons: Integrating cognitive theory and classroom practice* (pp. 25-49). Cambridge, MA: MIT Press.
- Heppner, P. P., Kivlighan, D. M. J. & Wampold, B. E. (1999). *Research design in counseling (2 ed.)*. Belmont, CA: Wadsworth.
- Kablan, Z., Baran, T., Işık, Ç., Kal, F. M., & Hazer, Ö. (2013). PowerPoint öğretim materyalleri ile somut öğretim materyallerin öğrenme etkililiği açısından karşılaştırılması [Comparison of powerpoint and concrete teaching materials in terms of learning efficiency]. *Eğitim ve Bilim*, 38(170), 206-222.
- Kamii, C., & Joseph, L. (1988). Teaching Place Value and Double-Column Addition. *Arithmetic Teacher*, 35(6), 48-52.

- Kontas, H. (2016). The Effect of Manipulatives on Mathematics Achievement and Attitudes of Secondary School Students. *Journal of Education and Learning*, 5(3), 10-20.
- Kula, A., & Erdem, M. (2005). Öğretimsel bilgisayar oyunlarının temel aritmetik işlem becerilerinin gelişmesine etkisi [The effect of educational computer games on the development of basic arithmetical operation skills]. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, 29, 127-136.
- Ladel, S., & Kortenkamp, U. (2016). *Development of a Flexible Understanding of Place Value*. In T. Meaney, O. Helenius, M. L. Johansson, T. Lange, & A. Wernberg (Eds.), *Mathematics Education in the Early Years: Results from the POEM2 Conference, 2014* (pp. 289-307). Cham: Springer International Publishing.
- Larbi, E., & Mavis, O. (2016). The Use of Manipulatives in Mathematics Education. *Journal of Education and Practice*, 7(36), 53-61.
- Lee, Y. (2005). Develop students' spatial ability with physical and virtual manipulatives. (Thesis). University of Hong Kong, Pokfulam, Hong Kong SAR. Retrieved from [http://dx.doi.org/10.5353/th\\_b3567780](http://dx.doi.org/10.5353/th_b3567780)
- Li, Q., & Ma, X. (2010). A Meta-analysis of the effects of computer technology on school students' mathematics learning. *Educational Psychology Review*, 22(3), 215–243. <https://doi.org/10.1007/s10648-010-9125-8>
- McGuire, P., & Kinzie, M. B. (2013). Analysis of Place Value Instruction and Development in Pre-Kindergarten Mathematics. *Early Childhood Education Journal*, 41(5), 355-364. doi: [10.1007/s10643-013-0580-y](https://doi.org/10.1007/s10643-013-0580-y)
- Moore, B. S. (1992). A comparison of two approaches to place-value instruction in first-grade classrooms. (Master's Thesis), San Jose State University, California.
- Moyer, P. S. (2001). Are we having fun yet? How teachers use manipulatives to teach mathematics. *Educational Studies in Mathematics*, 47, 175-197.
- Mutlu, Y. & Sarı, M.H. (2019). İlkokul öğrencilerinin basamak değeri kavrayışlarının geliştirilmesi. *Kastamonu Education Journal*, 27(2), 657-667. doi:10.24106/kefdergi.2645
- Nataraj, M. S., & Thomas, M. O. (2007). Developing the concept of place value. *Mathematics: Essential Research, Essential Practice*, 523-532.
- Olkun, S. (2003). Comparing computer versus concrete manipulatives in learning 2d geometry. *Journal of Computers in Mathematics and Science Teaching*, 22(1), 43-56.
- Olkun, S., Can, D., & Yeşilpınar, M. (2013). Hesaplama performansı testi: geçerlilik ve güvenilirlik çalışması [Calculation performance test: validity and reliability study]. *XII. Ulusal Sınıf Öğretmenliği Eğitimi Sempozyumu*. Aydın: Adnan Menderes Üniversitesi, 89-92.
- Olkun, S. & Toluk-Uçar, Z. (2018). *İlköğretimde etkinlik temelli matematik öğretimi [Activity based mathematics teaching in primary education]*. Nevşehir: Genç Kalemler Yayıncılık.
- Olkun, S., & Sarı, M.H. (2016). Geometric aspect of number line estimations. *13th International Congress on Mathematical Education*, July 24-31, Hamburg, Germany.
- Olkun, S., Altun, A., Cangöz, B., Gelbal, S., & Sucuođlu, B. (2012). Developing tasks for screening dyscalculia tendencies. Paper presented at the E-Leader, Berlin
- Petit, M. (2013). Comparing Concrete to Virtual Manipulatives in Mathematics Education. *Science Lib*, 5, 130911.
- Reimer, K., & Moyer, P. S. (2005). Third-graders learn about fractions using virtual manipulatives: A classroom study. *Journal of Computers in Mathematics and Science Teaching*, 24(1), 5-25.

- Sarama, J., & Clements, D. H. (2016). *Physical and Virtual Manipulatives: What Is “Concrete”?*. In International perspectives on teaching and learning mathematics with virtual manipulatives(pp. 71-93). Springer, Cham.
- Sarı, M.H., & Olkun, S. (2019). Relationship between place value understanding, arithmetic performance and mathematics achievement in general. *İlköğretim Online*, 18(2), 953-958, [Online]:<http://ilkogretim-online.org.tr>
- Sarı, M.H., Aydođdu, Ş., & Aydođdu-Özaydın, Y. (2019). İlkokul 4.sınıfta basamak değeri kavramını geliştirmeye yönelik eğitsel alıştırma yazılımının geliştirilmesi. *III. International Congress on Science and Education*, 21-24 March, Afyonkarahisar, Türkiye.
- Schmidt, M. E. (1995). Mathematics intervention: Second grade place value concepts. *Education*, 116(2), 229.
- Shalev, R. S. (2004). “Developmental dyscalculia.” *Journal of Child Neurology*, 19(10), 765-771.
- Shalev, R. S., Manor, O., Kerem, B., Ayali, M., Badichi, N., Friedlander, Y., & Gross-Tsur, V. (2001). Developmental dyscalculia is a familial learning disability. *Journal of learning disabilities*, 34(1), 59-65.
- Sharma, M. C. (2015). *A window into dyscalculia and other mathematics difficulties*. The Routledge international handbook of dyscalculia and mathematical learning difficulties, 277.
- Suh, J., & Moyer-Packenham, P. (2007). Developing students’ representational fluency using virtual and physical algebra balances. *Journal of Computers in Mathematics and Science Teaching*, 26(2), 155-173.
- Thomas, N. (2004). *The Development of Structure in the Number System*. International Group for the Psychology of Mathematics Education.
- Thompson, I. (2000). Teaching Place Value in the UK: Time for a reappraisal? *Educational Review*, 52(3), 291-298. doi: **10.1080/713664046**
- Thouless, H. (2014). Whole-number place-value understanding of students with learning disabilities (Doctoral dissertation).
- Tosun, M. (2011). *İlköğretim öğrencilerinin basamak değeri kavramına ilişkin becerilerinin incelenmesi [The investigation of primary school students' skill in place value]*. (Unpublished master's thesis), Çukurova Üniversitesi, Sosyal Bilimler Enstitüsü.
- Turgut, S., & Dogan-Temur, Ö. (2017). The effect of game-assisted mathematics education on academic achievement in Turkey: A meta-analysis study. *International Electronic Journal of Elementary Education*, 10(2), 195–206.
- Valeras, M., & Becker, J. (1997). Children's developing understanding of place value: Semiotic aspects. *Cognition and Instruction*, 15(2), 265-286.
- Whyte, J. C., & Bull, R. (2008). “Number games, magnitude representation, and basic number skills in preschoolers.” *Developmental Psychology*, 44, 588–596.
- Wilson, A. J., Revkin, S. K., Cohen, D., Cohen, L., & Dehaene, S. (2006). “An open trial assessment of “The Number Race”, an adaptive computer game for remediation of dyscalculia.” *Behavioral and Brain Functions*, 2(20).
- Yaman, H., & Şahin, T. (2014). Somut ve sanal manipülatif destekli geometri öğretiminin 5. sınıf öğrencilerinin geometrik yapıları inşa etme ve çizmedeki başarılarına etkisi [Concrete and virtual manipulative-assisted teaching of geometry's impact on the success of building and drawing geometric structures of 5th grade students]. *Abant İzzet Baysal Üniversitesi Eğitim Fakültesi Dergisi*, 202-220.

- Yuan, Y., Lee, C. Y., & Wang, C. H. (2010). A comparison study of polyominoes explorations in a physical and virtual manipulative environment. *Journal of Computer Assisted Learning*, 26(4), 307-316.
- Zamarian, L., Ischebeck, A., & Delazer, M. (2009). “Neuroscience of learning arithmetic--evidence from brain imaging studies.” *Neurosci Biobehav Rev*, 33(6), 909-925. doi: **10.1016/j.neubiorev.2009.03.005**

## Appendix A. Description of Materials Used in Research Process

In Trial 1 group, concrete tools have been used to perform activities oriented towards the place value concept. As concrete tools, Dienes blocks and Snapcube have been used, as shown in Figure 1. Concrete tools have been used by the students under the guidance of their teacher. Learning-teaching process has been ensured through activities based on grouping and resolution strategies forming the place value concept. Learning-teaching process of Trial 1 group has been shaped within the scope of 8-hour study plan and study pages.

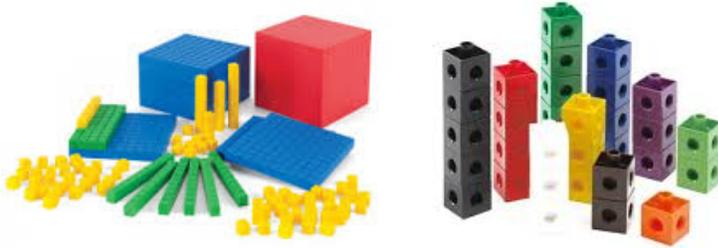


Figure 1. Concrete tools used in the study (Dienes blocs and Snap cubes)

In Trial 2 group, educational digital materials, related to place value concept have been used. Educational exercise software has been created by running analysis, design and development processes. During the analysis stage, place value acuirements, included in mathematic teaching program, have been reviewed. 9 different sections have been created in the application by taking these acuirements into consideration. Design of the sections have been prepared in relation to the grouping and resolution skills related to place value. Sections consist of the following stages: counting the multitudes given, grouping or solving the multitudes given, verbal expression of multitudes and symbolic expression of multitudes (See Figure 2, Figure 3 and Figure 4). Educational digital material developed for the place value concept has been practised with the students throughout the 8 class hours. Materials have been uploaded into computers in the schools of students and two students were available in each computer to try the application.



Figure 2. Application screens (Home page and Section menu)

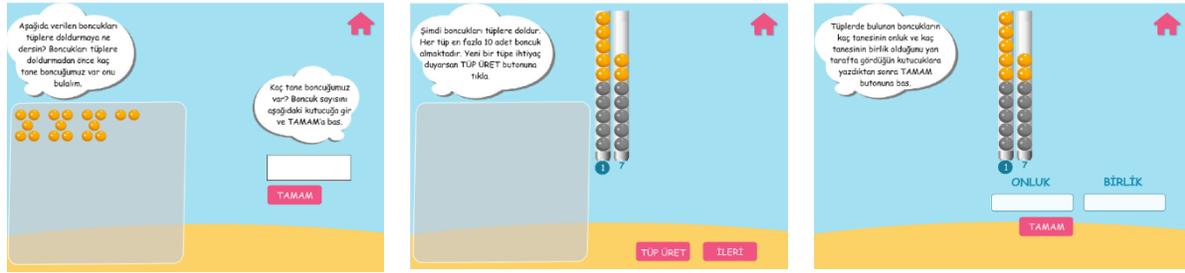


Figure 3. First section, placing the beads (Counting, Placing beads and Entering decimal and unit values)



Figure 4. Fourth section: number of eggs and expressing their place value (Giving a certain amount of eggs and Expressing the number of eggs in tens and units)

### Copyrights

Copyright for this article is retained by the author(s), with first publication rights granted to the Journal.

This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (CC BY-NC-ND) (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).