Using Game-Based Learning in Place Value Teaching in Primary School: A Mixed-Method Study

Ebru Ergül [i]
Selcuk University

Mustafa Dogan [ii]
Selcuk University

Abstract

This article seeks to determine how game-based mathematics teaching affects students' success when compared with conventional instruction for the place value concept in primary school. The study was carried out with a convergent/parallel mixed-method research design. The study group consisted of 51 second-grade primary school students and their teacher. All research data were collected over a period of four weeks. In the quantitative part of the research, a quasi-experimental design with pretest and posttest control groups was carried out. Quantitative data were obtained with an achievement test specifically prepared for the research. All quantitative data were statistically analyzed using t-test. The qualitative part of the data involved audio and video recordings of students' interactions, teacher's diaries, and semi-structured interview forms collected from 26 second-grade primary school students in the experimental group. Quantitative data were analyzed using content analysis. The results showed that the game-based learning method was more effective than the conventional method. Students better understood the place value concept with gamification. Moreover, they increased their interest and motivation toward mathematics courses. Despite all these findings and the fact that many students declared that they had fun in the process, some students still preferred more traditional methods of teaching. This study was carried out on a new mathematical concept on which the effect of game-based teaching had not been tested before. The highlight of this study is the effectiveness of game-based mathematics teaching on the place value concept.

Keywords: Game-Based Learning, Students' Success in Mathematics, The Teaching of Place Value

----

[i] **Ebru Ergül,** Research Assist, Departmnet of the Basic Education, Selcuk University, ORCID: 0000-0002-0298-7035

Correspondence: ebru.ergul@selcuk.edu.tr

[ii] **Mustafa Dogan,** Prof. Dr., Department of Mathematics Education Faculty of Education, Selcuk University, ORCID: 0000-0002-7380-9869

INTRODUCTION

One of the most important arithmetical concepts to be learned by children in the early elementary grades is that of place value. Typically, children show a rapid improvement regarding their place value understanding in second-grade mathematics (Landerl, 2013). The best way to learn place value is through the use of procedural and conceptual knowledge dimensions in tandem (Van de Walle et al., 2016). Students who are in the procedural information stage can understand two-digit numbers and their representations in writing and reading. In the conceptual information stage, students are able to regroup, decompose, and show different representations of numbers (MacDonald et al., 2018; Wilkinson, 2017). This concept is directly related to a number of subcategories within primary school mathematics (Wilson, 2016). Place value concept knowledge is requisite for students to understand numbers, make sense of numbers (Thompson, 2000), and understand all arithmetic algorithms in mathematics (Dietrich et al., 2016). A lack of place value understanding adversely affects the ability to succeed in other mathematical concepts and operations (Moeller et al., 2011). If students do not understand place value concepts, they cannot perform mathematical skills such as rounding off to the nearest tens and hundreds (Van de Walle et al., 2016), making arithmetic calculations, comparing multi-digit numbers (Dietrich et al., 2016), solving problems, understanding divisibility laws, prime numbers and exponential numbers (Sharma, 1993), making operations about decimals and fractions (Herzog et al., 2019), and preventing misconceptions in numerical calculations (Kamii & Joseph, 1988; Sarı & Olkun, 2019). Previous research suggests that the place value concept cannot be effectively understood by primary school students with the current instructional methods used in classrooms today (Dinç-Artut & Tarım, 2006; Herzog et al., 2019; Sarı & Olkun, 2019; Thouless, 2014).

The place value concept can be learnt by using different methods in contrast to current learning methods in classrooms today (Russo et al., 2021). One of these methods is game-based teaching. This method can be defined as integrating a game in a course (Taja-on, 2019). Educational games which include mathematical activities facilitate the teaching of concepts, thereby enriching mathematics programs (Ernest, 1986). In this manner, these games can ensure the transformation of abstract concepts into concrete concepts (Wilson, 2016). In other words, the abstract structure of mathematics can be made clearer and more concrete through the implementation of game-based activities (Song, 2002). The fact that the place value concept is also an abstract structure (Arslan et al., 2011; Dinç-Artut & Tarım, 2006) leads many to believe that place value can be learned via educational mathematics games. Moreover, students have the opportunity to enhance their knowledge in a rich learning environment through educational games (Campos & Moreira, 2016). Thus, game-based mathematics activities can create more meaningful learning environments for many subjects in mathematics (Bragg, 2012a; Cohrssen & Niklas, 2019; Çalışkan & Mandacı Şahin, 2019; Demir, 2016; Skillen et al., 2018; Song; 2002; Lee & Choi, 2020; Liang et al., 2019; White & McCoy, 2019), and they have previously been shown to increase students' motivation and interest as a source of inspiration in the mathematics learning process (Deng et al., 2020; Gürbüz, et al., 2014; Kiili et al., 2018; Kebritchi et al., 2010; Rondina & Roble, 2019; White & McCoy, 2019).

Bragg (2012a) stated that games increased students' mathematical learning performance and participation based on 2,100 observations of fifth- and sixth-grade students' mathematics classes. Cohrssen and Niklas (2019) found that mathematical games had a positive effect on preschool students. Çalışkan and Mandacı Şahin (2019) reported that mathematical games increased second-grade students' success, and that this process contributed significantly to the affective characteristics of the students' number estimation (sense) and ability to round off numbers. Demir (2016) suggested that games positively affected first-year students' cognitive and affective abilities. A study by Song (2002) reported that primary school students could easily comprehend fractions and operations using gamification. Skillen et al., (2018) stated that a linear number board game had a positive effect on the development of mathematical competencies in six-year-old children. The results showed that playing the game led to stable improvements, especially in mathematical competencies of the first and second level of the underlying development model. Lee and Choi's (2020) study presents results of a tablet-based math game intervention to enhance early numeracy skills of children in Tanzania. Score gains in

the intervention group were substantially greater than those in the control group. White and McCoy (2019) explored game-based learning as fifth-grade mathematics students completed a brief unit on ordered pairs utilizing game-based lessons. The results revealed that student attitudes improved both toward the lessons and toward math in general. Liang et al. (2019) found that a mathematical game intervention improved the number sense level and growth rate of preschoolers in rural areas.

Deng et al. (2020) examined the perceptions and experiences of a teacher and students in a Shanghai public primary school when digital games were used in a second-grade math class. Digital gameplay, when used once daily over a six-day period was found to enhance student engagement and interest in learning in many students. Gürbüz et al. (2014) investigated probability teaching with gamification in primary schools. The research results showed that game-based instruction methods facilitated the understanding of mathematical concepts and increased students' motivation towards mathematics lessons. Additionally, game-based learning reduced mathematics anxiety based on students' verbal expressions. These results show similarities with a study by Kebritchi et al. (2010). Students better understood mathematical concepts, had greater success in their mathematics classes, and focused better on mathematics courses. The main aim of the study by Kiili et al. (2018) was to investigate the educational potential of a game-based math game competition to engage students in learning rational numbers. The results indicated that students benefited significantly from participating in the competition and that playing behavior could be used to assess students' rational number knowledge. Moreover, students were engaged in the competition and the results revealed that intrinsically motivating factors such as enjoyment and perceived learning gains predicted students' willingness to participate in math game competitions again. Rondina and Roble (2019) conducted a study to investigate the effect of game-based design activities on students' achievement scores in algebra. The results of study showed that the mathematics game-based design activities demonstrated a positive influence on students' learning gains in algebra. They stated that offline and online game-based activities in mathematics are a promising approach to be explored by teachers to ignite students' interest and motivation in learning mathematics.

Regarding the gamification of mathematics lessons, extensive research has shown that games are effective in helping students better understand mathematical concepts. It would seem likely that understanding of the concept of place value will be achieved more effectively by students through the use of gamification. However, we saw that there are a limited number of studies on the teaching of place value concepts with gamification. Broadbent (2004) investigated what kinds of strategies to use to understand the base ten number system in her study with primary school students. Students used game-based activities with bundles of sticks. The results show that games contribute to students' understanding of concepts and that students can develop different strategies in the process. However, more research is still required. This study looks to build on previous research at the primary school level and determine the effects of mathematical game processes on the learning of a new mathematical concept (place value) in primary school. Specifically, the following questions will be addressed:

1. Is there a statistically significant difference between the experimental and control groups according to their pretest and posttest mathematics scores?

2. How are students affected by game-based mathematics teaching in terms of affective, cognitive or meta-cognitive, psycho-social, and psycho-motor domains?

METHODOLOGY

Model

A convergent/parallel mixed-method research design, which is the basic design of the mixed methods, was used. Mixed-methods research is an approach that involves collecting, analyzing, and intentionally integrating qualitative and quantitative data in a study. With the growing interest in mixed-methods research across countries and disciplines, researchers have used mixed-methods research to better understand complex research problems (Toraman, 2021). Both quantitative (pretest-

posttest) and qualitative data (teacher diaries, interviews, video, and audio recordings) collection tools were used in this study. The datasets were analyzed, interpreted and reported.

Study Group

The study group consisted of 51 second-grade students and their teacher. The participants in the research were chosen through convenience sampling from a primary school in Istanbul where one of the researchers is a teacher. Students were accepted as volunteers for the study. The students were aged seven-eight years old and were randomly assigned into two groups, consisting of 26 students (15 girls and 11 boys) in the experimental and 25 students (12 girls and 13 boys) in the control group. Their teacher was a 33-year-old female who had been working for eleven years in a state primary school.

Data Collection Tools

The quantitative data were obtained from two different achievement tests/scales used to answer the first question of the study. The qualitative data were collected to answer the second question of the research by using semi-structured interview forms, teacher's diaries, video recordings and audio recordings.

Achievement tests were used to collect quantitative data. The tests contain five open-ended questions to measure this learning outcome: "*Students are able to name the digits of numbers less than 100 in models, and demonstrate the place values of the digits*" (Ministry of National Education [MoNE], 2018). Two different achievement tests with parallel questions were used for this attainment. The pretest was used to determine the readiness level of the place value concept. The posttest was used to determine the effect of the applied instruction methods for mathematics teaching on the development of the place value concept. Questions were presented as in the example below:

Fill in the blanks

6 3   Name of the Place Value   The Place Value

Figure 1 The First Question of the Pretest

Semi-structured interview forms were used to collect the qualitative data. The participants responded to the semi-structure interview questions. The first question was "When you compare the game-based learning process and the conventional learning process, in which way would you prefer to learn mathematics?" ("Why?"-probe question). The second question was "How did the game-based teaching process affect your learning or reinforcement of the place value concept?" ("Can you explain your answer?"). The third question was "How did you feel during the game-based instruction process?" ("Can you explain your feelings?"). A total of twenty-six second-grade primary school students participated in the interview process and were recorded via audio.

Teacher's diaries were also used as a part of the qualitative data. One researcher attended the experimental process as a participant-observer. These observations were used to determine the possible effects of the gamification process on academic success and affective skills. All observations were written weekly.

Audio and video recordings were also used to confirm the statements made in the student interviews and teacher observations. Audio and video recordings were used for the description of the game-based mathematics teaching processes. At the end of the process, four forty-minute sessions were recorded.

Games Used in this Research

Four mathematical games were selected for this study based on literature reviews and experts' opinions. "Who Wants to Win a Smiley Face?" was an adaptation of a competition program. "What Number Do the Cards Show?" was an adaptation of an activity in a mathematics textbook (Van de Walle et al., 2016). "Surprise Boxes" and "My Names of the Place Value" were anonymous games selected from a collection in the education informatics network (EIN). The selected games in this study were piloted with 60 students. No difficulties were encountered during the piloting process. The games were used during class hours. These games are intended to teach this learning outcome: "S*tudents are able to name the digits of numbers less than 100 in models, and demonstrate the place values of the digits*" (MoNE, 2018).

Implementations

The research data were collected in the fall semester of the 2018-2019 academic year. Prior to the implementation process, parents, teachers, and students were informed about the experimental processes. Subsequently, the pretests were applied. The experimental study was carried out with the 26 students in the experimental group, who were exposed to game-based mathematical activities (games), whereas conventional instruction and activities (course book activities and paper-and-pencil exercises) took place in the control group (four weeks). Both the teacher's observations and video and audio recordings were collected over the four-week period. After the experimental processes, the posttests were applied to both groups. After the posttest, one of the researchers interviewed the students in the experimental group at the end of every school day. Each student was interviewed for about 10 minutes. These meetings took about one week. During the meetings, the students were asked the three questions in the semi-structured interview form, and their opinions about the gamification teaching process were recorded.

Data Analysis

The data of the study were analyzed with a colleague who is an academician. The achievement tests were evaluated by using a rubric developed by the researchers. The first theme involved writing place value names. For this section, 5 points were given for each correct answer. The highest score that a student could achieve from this section was 10 points. The second theme consisted of writing place values as numerals. The second section was scored in the same way as the first section. The total achievement scores of the students were calculated. The data (total achievement scores) distributions were tested. It was determined that the data were normally distributed statistically. Therefore, all quantitative data were statistically analyzed using parametric tests. For the first question, a t-test analysis was conducted to determine the cognitive effects of game-based mathematics teaching. Cohen's d (2013) was calculated for the effect size.

The semi-structured interview forms and teacher's diaries were analyzed using content analysis. Firstly, data obtained from the audio recordings of the semi-structured interview forms were transcribed by the researchers. Secondly, the teacher's diaries and written expressions collected from the semi-structured interview forms were read repeatedly to extract detailed information. Thirdly, the data were separately coded and combined into themes by both researchers. Fourthly, the themes were compared from the point of view of their similarities and differences. Similar codes were subsumed under the themes. The codes and themes were discussed and checked by the researchers. Consequently, ten codes and six themes were generated from the teacher's diaries. Since only one case was observed for two themes in the teacher's diaries, no code was created. The relationships of the created themes and codes are summarized in Figure 2.

Figure 2 Relationships of Themes and Codes in Teacher's Diaries
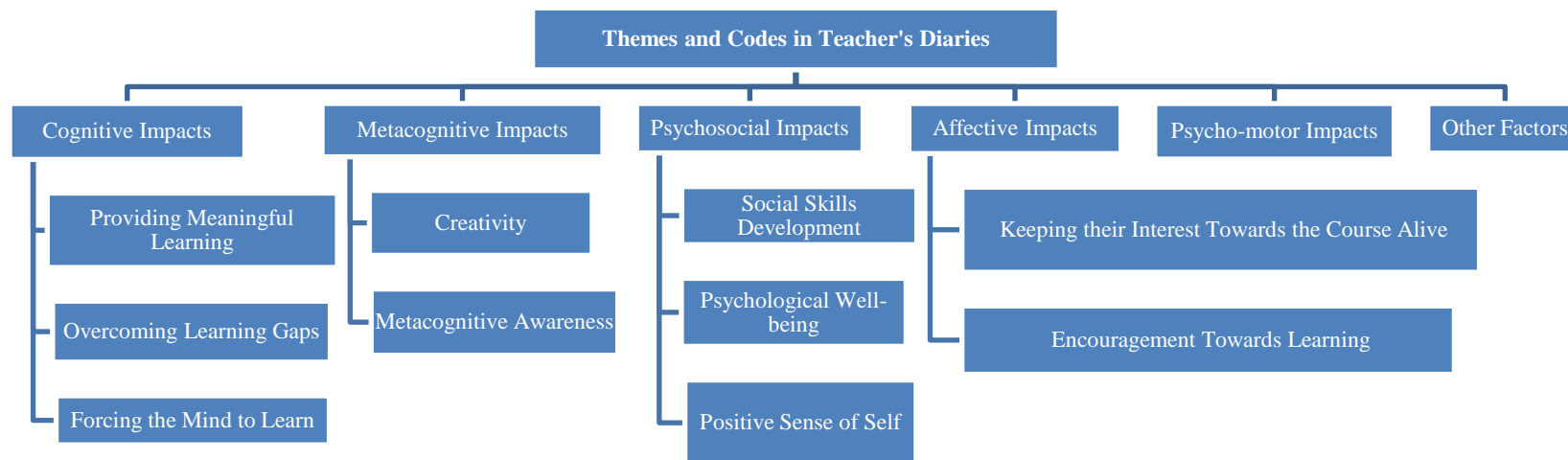
Twenty codes and eight themes were created from the semi-structured interview forms. The relationships of the created themes and codes are presented in Figure 3.

Figure 3 Relationships of Themes and Codes in Semi-Structured Interview Forms
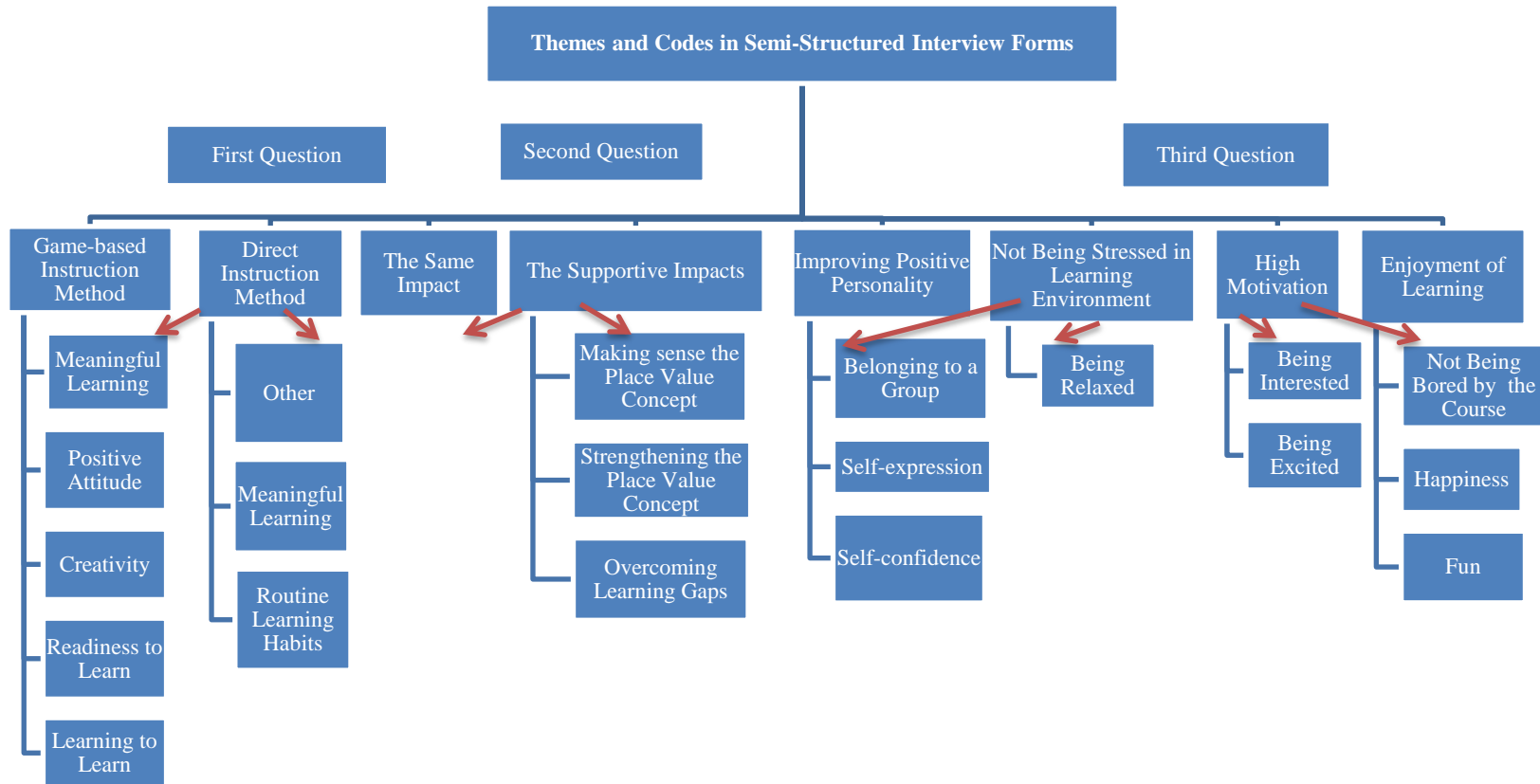
The created codes and themes are presented with frequency values. For the students' direct statements, students were given a code, such as S1 (first student), S2 (second student), etc. The researchers used the codes GO-1 (first game observations), GO-2 (second game observations), etc. to report the teacher's diaries. The audio and video recordings were used for consistency between the teacher's diaries and students' opinions. Both researchers' observations about the audio and video recordings have been reported. Students' interactions are presented to illustrate the basis of the determinations.

Validity and Reliability

Three different second-grade mathematics textbooks approved by the Ministry of National Education [MoNE] were used to create the achievement tests. At the end of the investigation process, ten open-ended questions were prepared. The ten questions were checked by the experts: two primary school teachers, one Turkish language teacher, and one academician in mathematics education. Thus, compliance with measurement and evaluation criteria and content validity were ensured. A pilot study of the achievement test questions was conducted with 48 second-grade students. The results of the pilot study showed that the questions were clearly understood by the students. Finally, the 10 questions were divided into two tests, each with five questions. Pearson correlation coefficients were calculated for interrater reliability of the achievement tests (R=0.941). This value is accepted as a high correlation between raters. Since the achievement tests were equivalent to each other, the reliability coefficient of the parallel tests was conducted (p=0.729). A high correlation value indicates that the tests are reliable (Büyüköztürk et al., 2018). The three questions in the semi-structured interview forms were evaluated by the experts: two primary school teachers, one Turkish language teacher, and one academician in mathematics education. As a result of this evaluation, positive opinions were expressed by the experts about the semi-structured interview forms. A pilot study was carried out on the comprehensibility of the questions with ten second-grade student volunteers. Again, the students clearly understood the questions in the pilot study. In order to increase the reliability of the code and theme determination processes, the degree of consensus between the coders was calculated based on the Miles and Huberman (1994) formula [$\Delta = C \div (C + \partial) \times 100$]. For this research, the degree of consensus between the encoders was calculated as 83%. Miles and Huberman (1994) accepted this value as important for consistency.

RESULTS

Quantitative Data Results

Statistical analysis for the first question of the research, that is "Is there a statistically significant difference between the experimental and control groups according to their pretest and posttest mathematics scores?" is presented in this section.

Comparison of Pretest and Posttest Scores for Experimental and Control Groups

Independent samples t-test analysis was conducted to determine the pre-knowledge of the students about the place value concept. The related results are given in Table 1.

Table 1 Pretest Results oft the Experimental Group and the Control Group

Group	N	M	SD	t	df	p
Experimental group	26	62.50	15.50	0.23	48	0.81
Control group	25	61.44	16.77			

p>.05

Table 1 shows that the participants' average performances in both groups were almost identical on the pretest. The independent samples t-test also showed that there was no statistically large difference between the students' average results in the control group (M=61.44; SD=16.77) and experimental group (M=62.50; SD=15.50; t=.234; df=48; p>.05), indicating that the participants' understanding of the notion of place value was about the same before the intervention.

Independent samples t-test analysis was also used to compare the posttest scores of participants. The results are presented in Table 2.

Table 2 Posttest Results of the Experimental Group and the Control Group

Group	N	F	M	SD	t	df	p	Effect size (Cohen's d)
Experimental group	26	0.43	80.46	14.77	2.69	49	.010*	0.75
Control group	25		69.16	15.23				

*p<.05

Table 2 indicates that the participants in the experimental group (M=80.46; SD=14.77) performed better than the participants in the control group (M=69.16; SD=15.23) on the posttest. An independent samples test for equal variance assumption using Levene's test (F=.43; t=2.69; p>.05) also showed that there was a statistically significant difference between the participants' average results in the control and experimental groups (t=2.69; df=49; p<.05). Moreover, an effect size of 0.75 using standardized Cohen's d indicates a large effect based on Cohen's criteria. This effect size indicates that the mean of the participants in experimental group is 0.75 standard deviations higher than the mean of the participants in the control group. These results suggest that game-based teaching methods have a noteworthy effect on mathematics achievement in teaching the place value concept.

Qualitative Data Findings

In this section are content analyses for the question of "How are students affected by game-based mathematics teaching in terms of affective, cognitive or meta-cognitive, psycho-social, and psycho-motor domains?"

Findings of Semi-Structured Interviews

Interviews were conducted after the posttests were implemented with the 26 students in the experimental group who participated in the game processes. In these interviews, the students were first asked, "When you compare the game-based learning process and the conventional learning, in which way would you prefer to learn mathematics?" ("Why?"-probe question). For the first question, a number of the students' responses were under the theme of the "game-based instruction method" (f=19). According to students' answers in this theme, the codes generated by the researchers were "meaningful learning" (f=13), "learning to learn" (f=1), "readiness to learn" (f=3), "creativity" (f=1), and "positive attitude" (f=1). The others' answers were under the theme of the "conventional instruction method" (f=7). The subthemes of this theme were defined as "routine learning habits" (f=3), "meaningful learning" (f=3) and "other" (f=1). Some students' answers to the first question are as follows:

S1: "I like to learn with games. I felt more comfortable."

S5: "Teaching with games. Playing and learning using games is more effective than learning by doing homework."

S6: "Conventional instruction, because I understand the lessons better when I can write the numbers down using a pencil and paper."

S15: "Conventional instruction. Playing games all the time is tiresome."

S16: "I prefer to learn through games because I can find my own way of learning. When I play mathematical games, I can produce my own solving strategy for problem scenarios."

S17: "Teaching with games, because it made mathematics a fun subject to learn."

S20: "Conventional instruction, because that's how we are taught in our other lessons."

S22: "I like to learn through games, because I want to play my own mathematical games."

The second question of the interview was "How did the game-based teaching process affect your learning or reinforcement of the place value concept?" ("Can you explain your answer?"-probe question). The answers to this question were listed under the themes "the supportive impacts" (f=25) and "the same impact" (f=1). The codes of the first theme were created under the following titles: "making sense of the place value concept" (f=12), "strengthening the place value concept" (f=1) and "overcoming learning gaps" (f=12). A separate code was not created for the second theme: "the same impact" (f=1). The responses of some students to the question are as follows:

S2: "There was no difference. I can learn both ways."

S3: "It had a positive effect. It made it easier to learn the place value concept."

S4: "Positive. It helped me to consolidate this concept."

S10: "It had a beneficial effect. I think I understand it better."

S16: "There was a beneficial effect. I was confused before, but not now."

S24: "Positive. I no longer make mistakes."

S26: "It had a wonderful effect. I had some difficulty in understanding place value. Now, I am okay. I can determine place value better and more accurately."

The last question of the interview form was "How did you feel during the game-based instruction process?" ("Can you explain your feelings?"-probe question). Students answers were collected under the themes of: "enjoyment of learning" (f=17), "high motivation" (f=4,), "not being stressed in the learning environment" (f=2) and "improving positive personality" (f=3). The first theme was coded as: "fun" (f=9), "happiness" (f=7), and "not being bored by the course" (f=1). The second theme included the codes of: "being excited" (f=3) and "being interested" (f=1). The third theme consisted of the following code: "being relaxed" (f=2). The last theme comprised the codes of: "self-confidence" (f=1), "self-expression" (f=1) and "belonging to a group" (f=1). Statements of some students are as follows:

S4: "The games excited me."

S5: "I was happy. The lessons are good like this."

S7: "I had fun."

S8: "It was nice to achieve something with my friends."

S14: "I felt more relaxed in class. I could state my ideas and they were correct."

S15: "I found it fun. I was not bored during the lessons."

S17: "I was interested in learning mathematics by playing games."

S21: "I was excited and curious. I always wanted to know who would win. Some games ended with a pretty close score."

S24: "It was useful."

Findings of Teacher's Diaries

The teacher's weekly observations notes were collected under six themes. One of these themes was the "cognitive impacts". Some of the codes that were effective in the emergence of this theme are as follows: "providing meaningful learning" (f=3), "overcoming learning gaps" (f=3) and "forcing the mind to learn" (f=3). Some of the teacher's notes regarding these themes are as follows:

"They learned the place value concept better through the use of the game's concrete materials. Therefore, some things that they did not previously understand became clearer." (GO-1)

"They exhibited all their mental and physical capacity to succeed... This was an essential opportunity for them to think creatively and enabled them to structure their knowledge through their own experiences in this process. They were also able to easily transfer this situation to new statements... Their learning was more meaningful. Their mistakes gradually decreased... They discovered how to direct their own learning and to have a greater say in their learning."(GO-2)

"As they gained experience in the games, they were able to transfer their knowledge more quickly and effectively to the learning environment."(GO-3)

The "metacognitive impacts" were also observed in the students. For this theme, the "creativity" (f=4) and "metacognitive awareness" (f=3) codes were generated. Some examples of explanatory statements can be given as follows:

"They created alternative ideas... When they did not win, they came together and discussed what they could do to win." (GO-1)

"I saw them trying different strategies when something went wrong." (GO-2)

"The third game involved a process based on student ideas from start to finish. They wrote this game's questions, which were then used in the games we played in the classroom. This significantly improved their productivity... They could make highly effective situation analyses."(GO-3)

"I observed that my students could use their decision-making, game-making, self-control, and self-management skills." (GO-4)

The "psycho-social impacts" theme was created for verbal expressions that indicate some social and psychological impact. For this theme, the codes "social skills development" (f=3), "psychological well-being" (f=6) and "positive sense of self" (f=4) were created. Some quotes are as follows:

"They realized that performing cooperatively with each other was effective... Everyone was happy to contribute in order to achieve... My students had fun at the end of this process." (GO-1)

"They supported each other throughout the game process. This affected the group dynamic positively... They learned to help each other." (GO-2)

"Learning the correct answers from their colleagues strengthened the communication and learning chain between them... Even if they gave incorrect answers to the questions in the game, the idea of making a mistake impacted on their desire to work together and to learn."(GO-3)

"It also aided their self-confidence. They were happy to take on individual responsibility on behalf of their groups. They voiced their opinions without hesitation. The third game involved an activity process based on student ideas from start to finish. The fact that they wrote the game's questions became a part of the game design. This only increased their self-confidence." (GO4)

The contents of the teacher's diaries were also gathered under the "affective impacts" theme, and the codes "keeping their interest towards the course alive" (f=2) and "encouragement towards learning" (f=3) were created. Some teacher notes were as follows:

"My first observation was that my students were more enthusiastic about playing mathematical games. The idea of learning some things via gamification excited them. They wanted to learn the game rules as soon as possible so they could learn how to play it. They listened to me with keen interest during the game introduction. The game process led to increasingly active participation and excitement."(GO-1)

"In the second game of this week, I saw that my students were significantly motivated in the maths classes. My students participated willingly in the second game. They supported each other with a lot of enthusiasm." (GO-2)

"Students who normally participated very little during the routine maths classes were now excited for their turn to come." (GO-3)

"The last game was not group-based, but because of gamification, it assigned tasks to students. Starting the game, setting up the game, managing the process, and checking the accuracy of the result were pretty much dependent on them. As always, their willingness to participate was excellent." (GO-4)

A small amount of physical strength was needed in some games. Thus, the "psycho-motor impacts" theme was created. There was only one situation. For this, a code was not created. Evidence of students actively using their physical strength is presented directly:

"They exhibited all their mental and physical capacity to succeed." (GO-2)

The last theme created was defined as "other factors". Because only one item was determined under this theme, a separate code was deemed unnecessary. The observed situation is the noise that students make during games such as cheers, applause, etc. Evidence is presented in the form of the teacher's direct statement:

"There was a great deal of noise in all the game processes. But this is natural as the children were very excited when playing the game. They could not control their enthusiasm." (GO-4)

Findings of Video and Audio Recordings

The video recordings for each game were inspected by the researchers for the consistency of student views and teacher observations. Points determined by both the researchers and teacher were reported as follows: Students' willingness to participate in the learning environment, high motivation towards mathematics lessons, the low state of anxiety and stress, interest in the lessons and having willingness to succeed in each game task, effective communication among students and collaborative teamwork, leadership, reasoning and self-control skills, presenting creative ideas, a willingness among students to correct their mistakes, reinforcing what has been learned, peer learning, a few noises, and an enjoyable atmosphere.

When the video and audio recordings were evaluated in terms of student opinions, the following were determined: Students had fun, they participated willingly and actively in the math

lessons, and there were excitement and enthusiastic demonstrations such as jumping, clapping, cheering, etc.

From the "Surprise Boxes" game, a dialogue between two students indicates the real positive effects of gamification on the students' learning processes:

"S1: I was confusing the place of tens and units of two-digit numbers. I was reading incorrectly. Did you think like me?"

"S2: I was confusing them too. I was writing units instead of tens."

"S1: It was not like that, but now I understand. In a two-digit number, the first digit represents tens and the second digit units. "

"S2: Yeah! It was. The first digit from the left shows how many tens groups. Those that cannot be in a group of ten remain as a unit. And, write the second digit number from the left."

DISCUSSION AND CONCLUSION

This study sought to determine how game-based mathematics teaching affects students' success when compared with conventional instruction methods when teaching the place value concept in primary school. The research was carried out using mixed methods. The study group consisted of 51 second-grade students and their teacher. For the first question of study, quantitative analysis results show a statistically difference between the pretest and posttest scores of the experimental and control groups students in favor of the experimental group (Table 2). The results indicate that the game-based learning method positively affected the students' ability to learn the place value concept when compared with the conventional instruction method. The results confirm similar conducted studies (Bragg, 2012a; Cohrssen & Niklas, 2019; Çalışkan & Mandacı Şahin, 2019; Demir, 2016; Skillen et al., 2018; Song; 2002; Lee & Choi, 2020; Liang et al., 2019; White & McCoy, 2019).

For the second question of the study, semi-structured interview forms, teacher's diaries and video and audio recordings were investigated. Firstly, when the results of the semi-structured interviews were examined, a majority of the students (19 people) preferred the game-based teaching method when learning mathematics. Most of the students who made this choice stated that they better understood mathematics through the games they played in the classroom. Almost all the students saw mathematical games as beneficial for understanding the place value concept. Students' comments show that the mathematical games reduced misconceptions about the place value concept and supported learning of the place value concept (S3, S10, S24 and S26). Mathematical games provided meaningful learning in this study. These results prove that abstract concepts (like the place value concept) turn into concrete concepts with games, as Song (2002) stated. Only one student in the experimental group stated that she could understand the concept of place value equally well using both methods (S2). The natural learning process of gamification may have kept students mentally active and made them more willing to learn. An active mind can generate more ideas. Therefore, the development of creativity may be supported (S22). In addition, the game processes allowed students to be responsible for their own learning. The games may have had a supportive effect on issues such as effective reasoning, self-regulation, and metacognitive awareness (S16). This finding was also reported by Bragg (2012). In other student answers from this study, students stated that they felt more ready to learn and enjoyed learning. Feeling ready to learn and creating a positive attitude can be attributed to the fact that the games provided students with a learning environment free of stress and anxiety (S1, S17). Students mostly expressed their feelings as: enjoyment (S7, S15), happiness (S5), a sense of curiosity (S4, S21), a positive attitude towards lessons (S17), and achieving something with the group or dealing with something useful (S8, S14, S24). These results corroborate earlier studies (Deng et al., 2020; Gürbüz, et al., 2014; Kiili et al., 2018; Kebritchi et al., 2010; Rondina & Roble, 2019; White & McCoy, 2019). There were, however, some students (a total of 7) that found the conventional instruction method more effective when learning mathematics. These students perhaps

required the habitual learning processes that are dependent on an instructor at home or at school (S6; S15; S20). These individuals may have also had difficulties in quitting a well-established routine (S6; S20), or they may have been hesitant to take active responsibility for their learning as the games used in this study required of them (S15); in which case it is understandable that those students preferred the conventional instruction methods as a more suitable learning method for their own learning style. Secondly, similar to the semi-structured interview forms, the most prominent themes from the teacher's diaries were the cognitive, metacognitive, psycho-social and affective effects of the lessons. Cognitive and metacognitive effects were a superior performance in mental processes, overcoming learning losses, effective knowledge transfer, meaningful learning, a reduction in mistakes, the effective use of decision-making ability, creativity, etc. Psycho-social affects can be categorized as being excited, being self-confident, being responsible, having fun, having self-control, peer learning, having a positive attitude, collaborating, and communicating effectively. Affective effects can be presented as active participation, motivation, willingness to attend the lesson, etc. The cognitive and affective dimensions of the teacher's observations corroborate the fact that students had a high level of interest in the mathematics courses, had a positive attitude, and were cognitively active. These dimensions (active participation, a positive attitude, mathematical creativity, problem solving, self-regulation, and collaboration) are important in terms of achieving success in the mathematics curriculum (MoNE, 2018). The research results show that significant mathematical skills targeted in the curriculum can be gained through mathematical game processes. Psycho-motor and other impacts were not as obvious as the others. Only the noises in the theme of other impacts were also seen in the study by Gürbüz et al (2014). Thirdly, it emerged in some dialogues among students and common opinions of the researchers that through games, a lack of knowledge in the concept of place value can be solved, erroneous learning can be corrected, some basic information can be created, and high motivation for mathematics learning can be provided. According to Van de Walle et al. (2016), it is not enough to have a concrete mental substructure (having the level of mental development to understand mathematical concepts) in order to learn mathematics. Learning mathematics also requires students to take an interest in the lessons and develop a positive attitude towards the lessons. In this study, the mathematical games contributed both emotionally and mentally to the students' success in better understanding the place value concept.

When the quantitative and qualitative results of this research are integrated, the results show that game-based mathematics teaching is effective on learning the place value concept in terms of the affective, cognitive or meta-cognitive, psycho-social, psycho-motor domains. However, a small number of students did not prefer game-based learning in their mathematical learning process. Future research can investigate the reasons for their choice among students who prefer the conventional instruction method in a new qualitative study.

REFERENCES

Arslan, S., Yıldız, C., & Yavuz, İ. (2011). Analysis Of The Teaching Process Of Place Value Concept. *E-Journal Of New World Sciences Academy*, *6*(1), 491–507. Https://Dergipark.Org.Tr/En/Download/Article-File/185642

Bayırtepe, E., & Tüzün, H., (2007). The Effects Of Game-Based Learning Environments On Students' Achievement And Self-Efficacy In A Computer Course. *Hacettepe University Journal Of Education*, 33, 41-54. Https://Avesis.Hacettepe.Edu.Tr/Yayin/0133ca0e-5dbe-4170-A54c-5414556485ab/The-Effects-Of-Game-Based-Learning-Environments-Onstudents -Achievement-And-Self-Efficacy-In-A-Computer-Course

Bragg, L.A. (2012a). The Effect Of Mathematical Games On On-Task Behaviours In The Primary Classroom. *Mathematics Education Research Journal,* 24**,** 385–401. Https://Doi.Org/10.1007/S13394-012-0045-4

Broadbent, A. (2004). Understanding Place-Value. *Australian Primary Mathematics Classroom,* 9(4),45-46

Ds.A.Ebscohost.Com/Eds/Pdfviewer/Pdfviewer?Vid=0&Sid=17790f48-3285-4377-83b3-41276b1f457e%40sdc-V-Sessmgr03

Büyüköztürk, S., Çakmak-Kılıç E., Akgün O. E., Karadeniz S. & Demirel F. (2018). *Bilimsel Araştırma Yöntemleri* (24. Baskı). Pegem A.

Campos, H., & Moreira, R. (2016). Games As An Educational Resource In The Teaching And Learning Of Mathematics: An Educational Experiment In Portuguese Middle Schools. *International Journal Of Mathematical Education In Science And Technology*, *47*(3), 463–474. Https://Doi.Org/10.1080/0020739x.2015.1075614

Cohen, J. (2013). *Statistical Power Analysis For The Behavioral Sciences*. Academic Press.

Cohrssen, C., & Niklas, F. (2019). Using Mathematics Games In Preschool Settings To Support The Development Of Children's Numeracy Skills. *International Journal Of Early Years Education*, *27*(3), 322-339.

Çalışkan, M., & Mandacı-Şahin, S. (2019). Investigation Of The Effect Of Games And Activities On Rounding And Estimation Subject. *International Journal Of Eurasia Social Sciences, 10*(38), 1059-1080. Https://App.Trdizin.Gov.Tr/Publication/Paper/Detail/Txprek5uwxlnzz09

Demir, M. R. (2016). *Effect Of Teaching Mathematics Through Different Play Types On 1. Grade Students' Achievements And Retention Of Learning Levels* (Order No: 436706) [Doctoral Dissertation, Necmettin Erbakan University]. Yok National Theses Center.

Deng, L., Wu, S., Chen, Y., & Peng, Z. (2020). Digital Game-Based Learning In A Shanghai Primary-School Mathematics Class: A Case Study. *Journal Of Computer Assisted Learning*, *36*(5), 709-717.

Dietrich, J. F., Huber, S., Dackermann, T., Moeller, K., & Fischer, U. (2016). Place-Value Understanding In Number Line Estimation Predicts Future Arithmetic Performance. *The British Journal Of Developmental Psychology*, *34*(4), 502–517. Https://Doi.Org/10.1111/Bjdp.12146

Dinç-Artut, P., & Tarım, K. (2006). Elementary Students' Comprehension Of Place Value Concept. *Journal Of Theory And Practice In Education, 2*(1), 26–36. Https://Doi.Org/10.17984/Adyuebd.325364

Ernest, P. (1986). A Rationale For Their Use In The Teaching Of Mathematics In School. *Mahtematical Association*, *15*(1), 2–5. Https://Doi.Org/10.1016/S0022-3182(73)80003-2

Gürbüz, R., Erdem, E., & Uluat, B. (2014). Reflections From The Process Of Game-Based Teaching Of Probability. *Croatian Journal Of Education,16*(3), 109–131. Https://Doi.Org/10.15516/Cje.V16i0.536

Herzog, M., Ehlert, A., & Frits, A. (2019). Development Of A Sustainable Place Value Understanding. In A. Fritz, V. G. Haase, & P. Räsänen (Eds.) *International Handbook Of Mathematical Learning Difficulties* (Pp. 561-579). Springer Press. Https://Doi.Org/10.1007/978-3-319-97148-3

Kamii, C., & Joseph, L. (1988). Teaching Place Value And Double-Column Addition. *The Arithmetic Teacher*, *35*(6), 48–52. Http://Www.Jstor.Org/Stable/41193351

Kebritchi, M., Hirumi, A., & Bai, H. (2010). The Effects Of Modern Mathematics Computer Games On Mathematics Achievement And Class Motivation. *Computers And Education*, *55*(2), 427–443. Https://Doi.Org/10.1016/J.Compedu.2010.02.007.

Kiili, K., Ojansuu, K., Lindstedt, A., & Ninaus, M. (2018). Exploring The Educational Potential Of A Game-Based Math Competition. *International Journal Of Game-Based Learning (Ijgbl)*, *8*(2), 14-28.

Landerl, K. (2013). Development Of Numerical Processing In Children With Typical And Dyscalculic Arithmetic Skills – A Longitudinal Study. *Frontiers In Psychology, 4*, 459.

Lee, H. K., & Choi, A. (2020). Enhancing Early Numeracy Skills With A Tablet-Based Math Game Intervention: A Study In Tanzania. *Educational Technology Research And Development*, *68*(6), 3567-3585.

Liang, Y., Zhang, L., Long, Y., Deng, Q., & Liu, Y. (2019). Promoting Effects Of Rti-Based Mathematical Play Training On Number Sense Growth Among Low-Ses Preschool Children. *Early Education And Development*, *31*(3), 335-353. Https://Doi.Org/10.1080/10409289.2019.1664261

Macdonald, B. L., Westenskow, A., Moyer-Packenham, P. S., & Child, B. (2018). Components Of Place Value Understanding: Targeting Mathematical Difficulties When Providing Interventions. *School Science And Mathematics*, *118*(1–2), 17–29. Https://Doi.Org/10.1111/Ssm.12258

Miles, M., B., & Huberman, A. M. (1994). *Qualitative Data Analysis: An Expanded Sourcebook.* (2nd Ed.). Thousand Oaks, Ca: Sage.

Ministry Of National Education [Mone]. (2018). *Matematik Dersi Öğretim Programı* (Ilkokul Ve Ortaokul 1, 2, 3, 4, 5, 6, 7 Ve 8. Sınıflar)[Mathematics Course Curriculum (Primary And Elementary School 1, 2, 3, 4, 5, 6, 7 And 8 Grades)] Http://Mufredat.Meb.Gov.Tr/Dosyalar/201813017165445matematik%C4%B0k%2%C3%96 %C4%9eret%C4%B0m%20programi%202018v

Moeller, K., Pixner, S., Zuber, J., Kaufmann, L., & Nuerk, H. C. (2011). Early Place-Value Understanding As A Precursor For Later Arithmetic Performance-A Longitudinal Study On Numerical Development. *Research In Developmental Disabilities*, *32*(5), 1837–1851. Https://Doi.Org/10.1016/J.Ridd.2011.03.012

Rondina, J. Q., & Roble, D. B. (2019). Game-Based Design Mathematics Activities And Students' Learning Gains. *The Turkish Online Journal Of Design Art And Communication*, *9*(1), 1–7.Https://Doi.Org/10.7456/10901100/001

Russo, J., Bragg, L. A., & Russo, T. (2021). How Primary Teachers Use Games To Support Their Teaching Of Mathematics. *International Electronic Journal Of Elementary Education*, *13*(4), 407-419.

Sarı, M. H., & Olkun, S. (2019). The Relationship Between Place Value Understanding, Arithmetic Performance And Mathematics Achievement In General. *Elementary Education Online*, *18*(2), 951–958. Https://Doi.Org/10.17051/Ilkonline.2019.562086

Sharma, M. C. (1993). Place Value Concept: How Children Learn It And How To Teach It. *Math Notebook*,*10*(1&2),1–23.

Skillen, J., Berner, V. D., & Seitz-Stein, K. (2018). The Rule Counts! Acquisition Of Mathematical Competencies With A Number Board Game. *The Journal Of Educational Research*, *111*(5), 554-563.

Song, Z. (2002). *Designing Game-Based Interactive Mathematics Learning Environments For Children* [Master's Thesis, The University Of British Columbia]. Https://Open.Library.Ubc.Ca/Collections/Ubctheses/831/Items/1.0051167

Taja-On, E. P. (2019). Game-Aided Instruction: Enhancing Critical Thinking Through Logical-Mathematical Games. *Online Submission*, *1*(1), 1-15.

Thompson, I. (2000). Teaching Place Value In The Uk: Time For A Reappraisal?. *Educational Review*, *52*(3), 291-298.

Thouless, H. R. (2014). *Whole-Number Place-Value Understanding Of Students With Learning Disabilities* [Doctoral Dissertation, University Of Washington]. Https://Digital.Lib.Washington.Edu/Researchworks/Bitstream/Handle/1773/25492/Thouless _Washington_0250e_12853.Pdf?Sequence=1&Isallowed=Y

Toraman, S. (2021). Mixed Methods Research: A Brief History, Definitions, Perspectives, And Key Elements. *Qualitative Social Sciences, 3*(1), 1-29. Doi:10.47105/Nsb.847688

White, K., & Mccoy, L. P. (2019). Effects Of Game-Based Learning On Attitude And Achievement In Elementary Mathematics. *Networks: An Online Journal For Teacher Research*, *21*(1), 5.

Wilkinson, M. (2017). *An Investigation Of Place Value Understanding In Year 2 Children* (Order No: 109618) [Doctoral Dissertation, Queensland University Of Technology]. Https://Eprints.Qut.Edu.Au/109618/1/Margaret_Wilkinson_Thesis.Pdf

Wilson, K. (2016). Place The Value The Fun Way. *Collaborative Teacher Educaiton*. Https://Charlotteteachers.Org/Wp-Content/Uploads/2017/02/Kwilson-Unit.Pdf

Van De Walle, J. A., Karp, K. S., Ve Williams, J. M. B. (2016). *Elementary And Middle School Mathematics: Teaching Developmentally*. Pearson.