ACTA DIDACTICA NAPOCENSIA

Volume 13, Number 2, 2020 - DOI: 10.24193/adn.13.2.6

DEVELOPING ELEMENTARY SCHOOL STUDENTS' MENTAL COMPUTATION SKILLS THROUGH DIDACTIC GAMES

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Abstract: Our research focuses on developing elementary students' mental computation skills with the help of card games. Choosing this area of study was motivated by our personal experiences, namely, that mathematics programmes of study do not lay emphasis on this aspect; there are too few hours dedicated to developing this skill, and several mental computation strategies are not presented in the classroom. As a result, students struggle with mental computation, a basic skill needed in our day-to-day life, and a relevant basis for further mathematical knowledge, computation competence, and higher order thinking skills.

In order to develop this skill, we have transformed well-known card games into didactic games, which encourage development almost unnoticeably, given the fact that children love to play, they need play. We have devised five new, appealing tools, with different levels of difficulty, suitable for developing mental computation skills in an attractive way.

This paper presents an experiment involving second grade (8-9 years old) students. Two experimental groups were involved. The aim was to investigate whether mental computation is more efficient when using the traditional method or when using card games. We hypothesized that using card games might prove helpful in developing mental computation skills.

Key words: mental computation, strategies, skills, didactic games, basic mathematical operations, number sense, mental mathematics

1. Introduction

Our research focuses on developing mental math skills. The choice of topic was motivated by our personal and work-related experiences, namely, that developing mental math is not given enough importance in education. During our lesson observations we have rarely witnessed classes which lay emphasis on developing mental math skills. We have not witnessed one single class which would focus on developing mental computation skills. These types of problems were generally used at the beginning of the class, in the warm- up part, while the main part of the lesson focused on other issues. We have found that elementary school students cannot set oral operations apart from written ones. They solve both types in the same way, with the slight difference that when they do mental math they picture the operations. One of the main reasons for this might be the fact that they do not learn mental math strategies and students do not have enough practice to figure out the strategies on their own. In cases when strategies are presented, there is a lack of practice. As a result, written operations are stored better in the long-term memory than mental math strategies.

We consider that mental computation is a foundation for mathematical concepts and operations children encounter in their learning of mathematics. If children learn oral operations, they will have a better understanding of number system relationships (Hope, 1986; Schall, 1973), they will know their way around numbers and their logical thinking will develop (Reys, 1985).

Received April 2020.

Cite as: Debrenti, E. & László, B. (2020) Developing Elementary School Students' Mental Computation Skills through Didactic Games. *Acta Didactica Napocensia,* 13(2), 80-92, https://doi.org/10.24193/adn.13.2.6

If they use and practice mental computation in every lesson, they will develop a practical skill, which they can later use in many areas of life (Gusty, 2005). If children are familiar with oral operations, they will more easily understand the relationships in written operations (Sauble, 1955). Supposing that more emphasis is put on oral operations in mathematics education, and children practice it in every lesson, this practice has to be varied lest it becomes boring and children use their motivation (Roșu, 2006).

Taking all these aspects into consideration the main aim of our research is to develop mental math skills. It is our firm conviction that using play facilitates skills development.

In our research, we have developed mental math skills with the help of card-games in a playful way so that children would not find it boring but rather enjoyable.

2. Theoretical background

In the last stage of elementary school education, elements of the formal operational stage surface simultaneously with elements of the concrete operational stage. For this reason, in elementary mathematical education it is advisable to do concrete activities, and operations with concrete objects first, and more abstract logical operations later (Roșu, 2006).

Consolidation and fixation of concepts can be attained through revision, application and use in various contexts (Ambrus, Munkácsy, Szeredi, Vásárhelyi & Wintsche, 2013).

In mathematics students have to formulate new concepts on their own and they can do this only by relying on previously acquired mathematical concepts. Consequently, teaching mathematics, in elementary school in particular, depends to a large degree on the teaching methods used (Skemp, 1971). Following this line of thought, learning motivation and play as a teaching method will be discussed later in this paper. The next section presents the theoretical problems concerning performing arithmetic operations relevant to our study.

2. 1. Operations on natural numbers

Performing operations contributes to a deeper understanding of the concept of numbers (Olosz & Olosz, 2000). Basic operations can be performed by two algorithms. Based on this, we will distinguish between written and oral operations. In order to perform written operations correctly, students have to be confident in mental computation. Therefore, it is important to devote time to teaching mental computation (Herendiné, 2013). Mental math is not an innate ability, but a skill that has to be acquired. Mental math can be improved similarly to the way people improve their memory and logical thinking (Tuzson, 2016).

"The basis of transportation is walking, while the basis of counting is mental math" (Ambrus et al, 2013, 112.). Taking this into account it is essential that children are first acquainted with oral operations, which provide a basis for written operations.

Hall (1954) defines mental arithmetic as:

1) Arithmetic problems which arise

a) in an oral manner

b) in written form, or

c) "in the head" of the person who needs to solve the problem;

2) Problems in which pencil and paper and other mechanical devices, such as calculators are not used to record the intermediate steps between the statement of the problem and its answer;

3) Problems in which pencil and paper are used, and problems in which they are not used, to record the answer;

4) Problems in which quick estimations are made, which either may or may not be verified by a written response (p. 353).

Everyday life demands a practical need for mental calculation skills for children and adults. As cited in Gusty (2005), Sauble (1955) states: They need to realize that the better they understand numbers, the more skill they possess in the operations of arithmetic, and the oftener they put these understandings and skills to productive use, the more adequately they will be able to meet the steadily increasing quantitative demands of daily living (p. 33).

Mathematics is a discipline in which children have to take an active part in cognition and mental processes. Students are different; some acquire new knowledge easily, others have to first revise already acquired knowledge in order to understand new information, yet others need help in order to process new information. For understanding to actually take place, it is essential for students to gain concrete experiences (Cser, 1972).

2. 2. Teaching oral addition

When calculating we can use a variety of aids, such as paper, pencil, electronic calculator or some type of mechanical calculator, for example the soroban. Mental math is done without the help of tools, nonetheless students can use learning aids. These can include realia, such as beans, disks, counting rods or finger-counting. These learning aids facilitate developing mental math skills. When children can do mental computing with confidence, they no longer need these aids.

The strategies below might also prove helpful in oral addition:

$36 + 53 = (30 + 6) + (50 + 3) = (30 + 50) + (6 + 3) = 80 + 9 = 89.$

$28 + 17 = 28 + (10 + 7) = (28 + 10) + 7 = 38 + 7 = 38 + (2 + 5) = (38 + 2) + 5 = 40 + 5 = 45$

$28 + 17 = (20 + 8) + (10 + 7) = (20 + 10) + (8 + 7) = 30 + 15= 40 + 5 = 45$

$19 + 28 = (19+1) + (28+2) – (1 + 2) = 20 + 30 – 3 = 47$

$23 + 72 = (23 – 3) + (72 – 2) + (3 + 2) = 20 + 70 + 5 = 95$

$96 + 48 = (96 + 4) + (48 – 4) = 100 + 44 = 144$

$24+27 = 2x24 + (27 – 24) = 48 + 3 = 51$

The analogies presented above also apply for large numbers, such as 1000s, and 10000s (Herendiné, 2013).

Written addition builds on oral addition. Mental computing develops children’s memory and attention, and teaches creativity and independence. (Olosz & Olosz, 2000).

2. 3. Teaching oral subtraction

Similarly to oral addition, in the first stage of oral subtraction it is essential that the operation relies on physical activities with concrete materials.

The strategies below might also prove helpful in oral subtraction (Benjamin & Shermer, 2009):

$13 – 5 = 13 – 3 – 2 = 10 – 2 = 8$

$7 – 3 = 4, 17 – 3 = 14, 27 – 3 = 24$

$36 – 14 = 36 – 10 – 4 = 26 – 4 = 22$

$36 – 19 = 36 – 10 – 9 = 26 – 9 = 25$

$86 – 29 =86 – 30 + 1 = 66 + 1 = 67$

$63 – 46 = 63 – 50 + 4 = 13 + 4 = 17.$

The analogies presented above can also be applied when subtracting three-digit or four-digit numbers, simplifying the operation (Herendiné, 2013).

2. 4. Teaching oral multiplication

In second grade the concept of multiplication is introduced as repeated addition and for a better understanding it is presented through practical problems. Patterns are pointed out in the multiplication tables. For example, every second element of the 5 times table can be found in the 10 times table as well. We teach the 2 times, 4 times and 8 times table in a similar way, followed by the 3 times, 6 times and 9 times table, and finally the 7 times table (Herendiné, 2013). There are several methods for teaching the oral multiplication of larger numbers. The one presented below can be used for the multiplication of numbers between 10 and 19:

„E.g. 18×17=? The steps are:

1) We add the last digit of the second number to the first number: 18+7=25

2) The result is multiplied by 10: 25×10=250

3) Now multiply the last two digits of the original numbers: 8×7=56

4) Add up the results of the last two multiplications: 250+56= 306)" (Tuzson, 2016, 281.)

Given that 2nd grade children do not use written multiplication, and they do not multiply larger numbers, we will not devote time here to the written method.

2. 5. Motivation in the mathematics classroom. Didactic games

Motivating students in the mathematics classroom is essential. Teachers ought to try to make the most of students' intrinsic motivation. Building on intrinsic motivation can make the subject more enjoyable. In case intrinsic motivation is not put to good use, the subject might become a burden, and most students would immediately abandon all future plans regarding mathematics (Hadnagy, 2013). Children have to actively take part in the learning process; while teachers should play the role of facilitator, organizer and provide guidance. Teachers should not serve as a source of knowledge; children should build on previously acquired knowledge and experiences. It is therefore important that external motivation is replaced by internal motivation, and children can experience the joy of discovery in mathematics (Bálint, 2015).

In order to preserve a motivating atmosphere in the classroom, it is essential that students have a sense of accomplishment. Avoiding monotony is crucial. This can be achieved through varied problems which present life-like situations and are appropriate for the students' age category (Takács, 1997).

"More serious" goals can also be achieved through games. They can be used to practice certain skills or design approaches and strategies. Teachers should make sure that the games used in the classroom have a structure and a goal (Bíró, 2011). Children express their inner world and desires, and cope with problems through play. Games help in developing self-expression and communication skills. Through games children learn to adapt and cooperate with others. During play children are capable of longer periods of attention. Playing is a source of joy, which reduces or entirely eliminates anxiety in children (Kántorné, 2010).

In order for a game to be efficient children need to have a certain amount of knowledge in the area the game focuses on. Didactic games are one of the most highly efficient methods in elementary education. They can be applied conjointly with other methods, in any discipline, in any type of classroom, and in any part of the lesson (Roșu, 2006).

In the mathematics classroom, games can raise interest, break monotony, and facilitate a better understanding of concepts. Games can be conducted as a joint activity involving the whole class, or they can provide an opportunity for differentiated instruction, for the teacher to deal with children in smaller groups or individually. Games have a motivating effect, which improves children's focus, consequently, learning or practising through play is not wasted time in the classroom. Children acquire new knowledge easier through play and memorize information better. If teachers use appropriate games at an appropriate time, they make learning easier and more efficient. Children find games entertaining, therefore playing games in the classroom is a fun way to learn and develop skills. In order for children not to think of mathematics as a difficult-to-understand discipline, it is essential to use illustration, play and interesting course books when teaching mathematics (Kántorné, 2010). Games are not always the most time-saving methods of teaching; there are games which are more time-consuming. In order to meet the objectives, play has to be frequent and varied (Auth, 2012).

A problem or exercise is considered a didactic game if it meets the following criteria:

- it has methodological aims;
- it performs a methodological task;
- it uses rules that children are familiar with;
- it contains playful elements;
- it has an appealing content (Roșu, 2006).

The beneficial effects of mathematical didactic games are:

- they develop different cognitive operations and the quality of these
- they develop a sense of initiative and independent work, but also team spirit
- they shape imagination, creativity, and observation skills
- they improve attention, discipline and continuity during the activity
- they develop fast and accurate work
- they ensure a more pleasant, approachable and faster acquisition of knowledge that students at this age might otherwise find dull (Roșu, 2006, 90).

Board games and logical games can also teach conflict management. Apart from developing skills, games also transmit values, such as empathy, cooperation, politeness, patience, orderliness, success orientation and smartness. The aim of didactic games is to provide a safe and cheerful atmosphere for learning, suitable for children (K. Nagy, 2007).

Play has a significant role in teaching, especially in elementary education. Though practice is very important in the mathematics classroom, it is more appropriate if practice and play overlap. If children think of work as play, they do it more willingly and show more interest in it (Varga, 1969).

A card game is a type of board game, involving more players who use playing cards in order to play the game. Card games can be used in the mathematics classroom in various ways (Kántorné, 2010).

2. 6. Studies on pupils' mental computation skills

As cited in Gusty (2005), Reys states that the development of mental calculation skills stimulates higher-level mathematical thinking skills (Reys, 1985). Hazekamp (1986) discussed some of the benefits of teaching children mental calculation strategies. He claimed that the use of mental calculation strategies could provide children with the ability to recognize and work with numbers that are multiples of powers of ten. Also, students gain mental flexibility that allows them to think of numbers in many ways and forms (Beishuizen, 1997). Hope (1986) and Schall (1973) stress the importance of mental calculation in that mental strategies help students to better understand the number system and number relationships. These authors assert that mental calculation strategies can help children become independent of techniques that were learned via memorization. Having acquired such techniques, mental strategies give children more options for solving problems and they are not locked into mentally attempting to use standard written algorithms for a problem that could easily and efficiently be solved with the appropriate mental technique.

Academically, the benefits of mental calculation skills extend beyond the mathematics classroom and weakness in this area can profoundly influence material comprehension in other subjects (Gusty, 2005).

Mental computation helps children understand how numbers work, how to make decisions about procedures, and how to create different strategies to solve math problems. Although researchers agree on the importance of mental computation skills, they debate how to help students develop these skills.

It is very important to teach children techniques in mental calculation. Certainly, there is an academic need. Mental methods will help children in the math classroom and other classrooms as well. The development of these skills will serve as a springboard for more complex arithmetic procedures they will encounter in their adolescent years. Mental methods of calculation require that math principles are clearly understood and acquisition of these methods offer children an additional bank of means to find the exact answers or estimations to problem solving tasks. Moreover, there is a practical everyday need for the ability to calculate mentally and this need exists long into an individuals' twilight years. (Gusty, 2005)

Varol & Farran (2007) conducted a study exploring the existing literature in order to identify key points that are related to students' use of different mental calculation strategies in a variety of settings and their conceptual understanding of those strategies.

Pourdavood, McCarthy & McCafferty (2015) studied the relationship between children's mental mathematics and mathematical reasoning. It is important that children receive many opportunities to develop the skills and strategies associated with mental computations. Having number sense is necessary to understanding mathematical concepts, yet it is frequently lacking in many of today's elementary schools. Mental computation strategies help children develop higher order thinking, reasoning, critiquing, and making sense of number and number operations. Mental mathematics will not only serve students well in school but outside of the classroom as well. Students who master the strategies of mental mathematics will find that the strategy helps them in many situations. Not all students will develop rapid mental mathematics to the same degree. Because of the students' different mathematical backgrounds and their different learning styles, some students may find their strength in mathematics through other avenues, such as visual or graphic representations when solving problems. No matter what strategies a student uses, mental mathematics has a clear place in school mathematics.

A card game is a type of board game, involving more players who use playing cards in order to play the game. Card games can be used in the mathematics classroom in various ways (Kántorné, 2010). Hedrén (1999) conducted a research among 2nd grade pupils in Sweden. In this study the pupils were not taught the traditional algorithms for the four arithmetic operations. Instead they were encouraged to find their own methods. The pupils used mental computation as far as possible and took notes to help them when the computations were too complicated for the them to keep the results in mind.

Baranyai, Egri, Molnár & Zsoldos- Marchiș (2019) studied developing preservice primary school teachers' mental computation competency by games and found that didactic games had a significantly higher effect on developing mental calculation skills then other types of games (board-games and mobile games).

3. Methodology

3. 1. Research questions, hypothesis

In our research we tried to find the answer to the following questions: are card games suitable for developing metal math skills? Do they facilitate or hinder development compared to traditional practice?

We hypothesized the following:

H1: It is hypothesized that the group which uses card games to develop mental computation skills will show significant differences compared to the group which uses traditional methods to practice mental computation.

H2: It is hypothesized, that following the intervention, as a result of the ten playful lessons, children in the experimental group will be able to perform mental computation in a shorter time than children in the control group.

3. 2. Research participants

The research was carried out in the spring of 2018 at an elementary school in Oradea. Research subjects were 30 second grade (8-9 years old) pupils, divided into two experimental groups. All subjects were present when the research was carried out.

One of the classes, the experimental group, consisted of 15 pupils (7 boys and 8 girls). We used card games in 10 lessons to develop their mental computing skills. The other class, the control group, consisted of 15 pupils (6 boys and 9 girls) and they practiced mental math with the help of traditional methods.

Table 1 presents the sample distribution by group and sex:

Table 1. *Sample Distribution by Group and Sex*

Sample	**Girls**		**Boys**		**Total**
	Number	***Percentage***	***Number***	***Percentage***	***Number***
Experimental group	8	53.33%	7	46,66%	15
Control group	9	60%	6	40%	15

3. 3. Intervention

Our research is an experiment-driven development which follows the specific three-stage structure of a pedagogical research.

The intervention period lasted for two months and was structured into ten lessons. Five different card games, adapted to different levels of difficulty were used in the classroom. Children worked in random groups. The rules of the games were explained either to the whole group or to smaller groups. Each child had to try out each game at least once. We have selected games that were suitable for the age group and which children would find interesting. The rules were also designed in a way to be easily understood. Some of the games were already familiar to the children, some were new to them.

The card games were designed to develop mental math skills at different levels of difficulty:

- addition of two -digit numbers without regrouping;
- addition of two -digit numbers with regrouping;
- subtraction of two -digit numbers without regrouping;
- subtraction of two -digit numbers with regrouping;
- multiplication- and division tables;
- addition of three -digit numbers without regrouping;
- subtraction of thee-digit numbers without regrouping;

During the games, if children struggled with operations, help was offered in the form of mental math strategies, or revision of the steps of mental computing strategies they were already familiar with. We found that most children struggle with operations involving regrouping; consequently, we have presented several strategies to facilitate computing. Children were allowed to choose the strategy they found the easiest.

During the same period the control group also attended ten classes. Their skills were developed by their teacher, with the help of traditional methods.

3. 4. Evaluation

Following the intervention period, both the control and experimental groups were given a posttest, the structure of which was similar to the pretest. The results of the posttest were compared to the results of the pretest. We carried out statistical calculations and hypothesis testing.

In the assessment stage the control and the experimental groups were evaluated with the help of a worksheet (pretest) designed by us. This contained all four basic operations at different levels of difficulty according to the curriculum. Since we wanted to evaluate the level of oral operations, children were told before the test not to calculate the operations in writing. They were also told that in case mental computing posed a problem for them, they should rather leave the exercise unsolved. The time spent completing the worksheet was measured for each individual.

Cronbach's alpha – accurate testing: this measure of internal consistency tells us if the test is accurately measuring the variable of interest. According to our calculations the Cronbach's alpha value of the pretest is 0.87, which means that the test is reliable.

3. 5. Tools. Developmental games used

We have used five adapted card games (didactic games). These were based on the following well-known classic card games: Black Peter, Halli Galli, 6 nimmt!, Set (see fig. 1), and Rock-paper-scissors. In this study we detail only two of these games.

Rock-paper-scissors: Each player is dealt 5 cards. The cards contain numbers or operations. The players check their hand and choose one of the cards, which they place face down on the table. When each player has placed a card on the table, they simultaneously turn the cards face up. Before the game starts, the players decide which numbers value more: larger numbers, smaller numbers, even numbers, or odd numbers. If large numbers value more, the player who has the card with the largest number or operation resulting in the largest number wins the other players' cards and sets them aside face down on the table. These cards cannot be played. Similar rounds follow until all cards have been played. The winner is the person who has collected the most cards. When cards are turned face up, each player has to say out loud the number on the card or the result of the operation on the card. Players have to carefully monitor their peers to perform all operations correctly. The game ends when all cards have been played. Players count how many cards they have collected. The winner is the person who has collected the most cards.

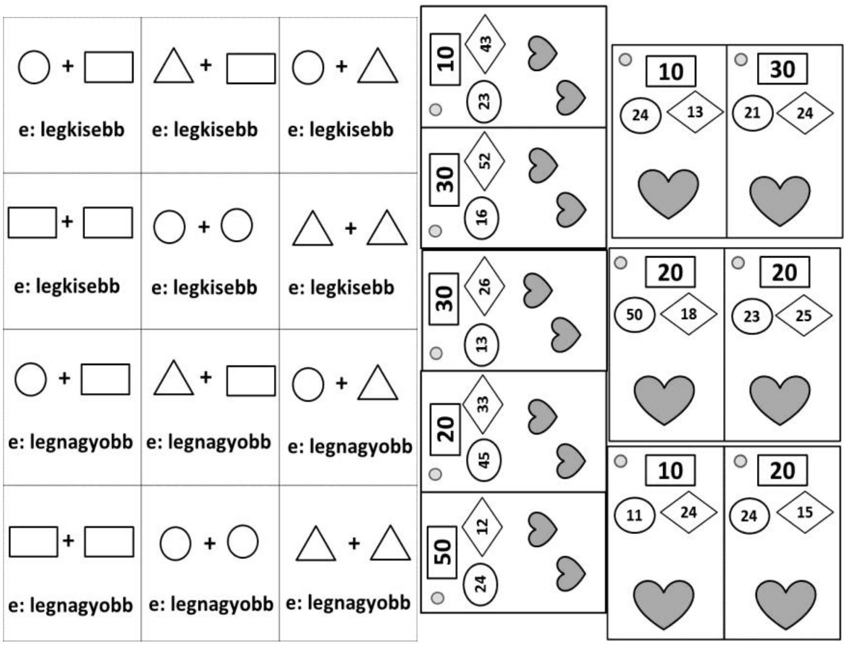

Figure 1. *Set card game (own design)*

Halli Galli: The game is played by a maximum of four players. The deck of cards is equally divided between the players and the players keep their decks face down on the table. An object is placed on the middle of the table. Each player deals the top card of their deck face up and places it onto the table. The numbers on the cards are added up. Before the game starts a rule card is placed on the middle of the table. This card determines when to grab hold of the object on the middle of the table. For example: the sum of the numbers on the cards is greater than 50. The person who grabs hold of the object is the winner of the round. If someone grabs the object in perfect timing, the cards dealt in the round have to be picked up by the player who was the last to deal their card in the given round. If someone grabs the object when the conditions are not met, they have to hand one card from their deck to each player. The round starts with the player who has picked up the cards in the previous round or has given cards to the others. The player who first runs out of cards wins the game.

4. Results and Discussion

In the pre-assessment stage both groups solved a worksheet in which they could score a maximum of 10 points. The results are presented in the table 2:

Table 2. *The Results of the Pretest for the Experimental and Control Group*

Group	Sample distribution by score				Average
	0- 4.4 insufficient	4.5- 6.4 sufficient	6.5-8.4 good	8.5-10 excellent	
Experimental group	1 (6.67%)	1 (6.67%)	3 (20%)	10 (66.67%)	8.27
Control group	0 (0%)	3 (20%)	6 (40%)	6 (40%)	8.00

Table 2 shows that in the experimental group there was 1 insufficient and 1 sufficient result, whereas in the control group there were no insufficient and 3 sufficient results. In the control group there were more good results, however in the experimental group there were more excellent results. There is no significant difference between the averages of the two groups.

The results of the final evaluation are presented in the table 3:

Table 3. *The Results of the Posttest for the Control and Experimental Group*

Group	Sample distribution by result				Average
	0-4.4 insufficient	4.5-6.4 sufficient	6.5-8.4 good	8.5-10 excellent	
Experimental group	0 (0%)	0 (0%)	3 (20%)	12(80%)	9.10
Control group	0 (0%)	2 (13.33%)	5 (33.33%)	8 (53.33%)	8.33

The Table 3 shows that there were no insufficient and sufficient results in the experimental group. Apart from 3 children who received a good result all the others received excellent results. There were no insufficient results in the control group, there were 2 sufficient, 5 good and 8 excellent results.

4. 1. Analysing hypothesis 1

Based on the data presented above, the diagram below illustrates the improvement in children's knowledge.

Figure 2 presents the average values of the pretest and posttest for the experimental and control group. We can see a more significant improvement in the experimental group as compared to the control group. An F-test was used to test the variances. The 3.46 test value shows that children in the experimental group achieved significantly better results (using the common significance level of 0.05) than children in the control group.

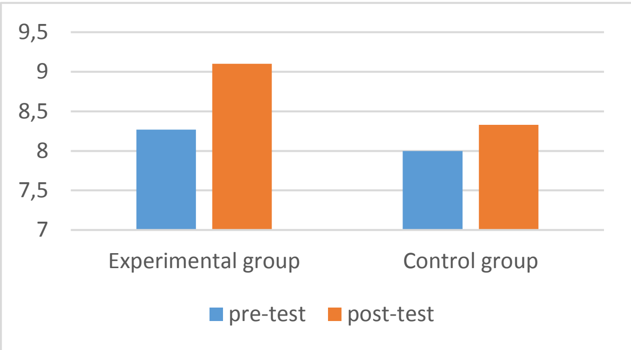

Figure 2. Development of children's knowledge in the experimental and control group

4. 2. Analysing hypothesis 2

The time children spent solving the test was measured in seconds both for the pretest and the posttest. An average was calculated. The time children spent on solving the tests is presented in the chart below:

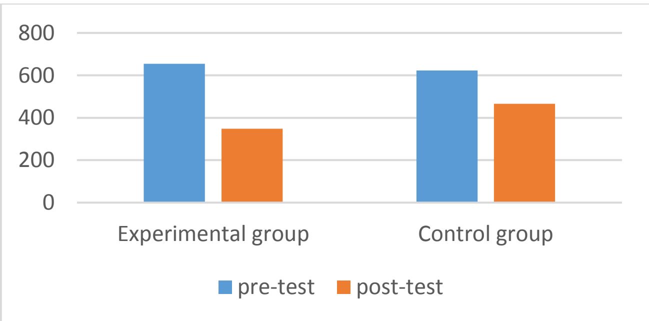

Figure 3. Time spent on solving the tests for the control and experimental group (in seconds)

Figure 3 shows that children in the experimental group required on average somewhat more time to solve the pretest than children in the control group. However, following the intervention period, the average time spent on solving the test has decreased to almost half the amount in the case of the experimental group. As regards the control group there was no significant change. The evident improvement in the results of the experimental group supports the second hypothesis, according to which, as a result of the ten playful lessons, children in the experimental group can perform mental computation in a shorter time than children in the control group.

An F-test was used to test the variances. The resulting value was not significant; consequently a t-test was also carried out. The 2.38 t-test value shows that children in the experimental group worked significantly faster (using the common significance level of 0.05) than children in the control group.

5. Conclusion

The aim of our pedagogical research was to help children do mental computation confidently, accurately, and faster. We also investigated whether didactic games (in the present study card games) are suitable for the development of mental computation skills.

The intervention was structured into ten lessons, while two additional lessons were dedicated to writing the pretest and posttest. The posttest and pretest had a similar structure. The intervention period, and posttests were followed by an evaluation stage; we also compared the time spent on solving the pretest to the time spent on solving the posttest.

The two hypotheses were confirmed. The first hypothesis stated that the group which uses card games for developing mental computation skills will show significant improvement compared to the group which uses traditional methods to practice mental computation.

The second hypothesis was also confirmed as there was a significant improvement in the time spent on solving the problems. As a result of the ten playful lessons, children in the experimental group can perform mental computation in a shorter time than children in the control group. This proves that card games, as didactic games, are a more efficient method for mental math skill development than traditional methods. The pedagogical research has proved conductive; there is scope to consider further studies carried out on 3rd and 4th graders to find out whether card games would be efficient with older pupils as well and to investigate whether age is a significant factor, considering that second graders, given their age-specific characteristics, need more play, which is not necessarily the case with older children. This experiment involved only 31 children; it would be worth working with a larger group to further test the efficiency and applicability of this method in the classroom.

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