The Effects of Computer Assisted Instruction Materials on Approximate Number Skills of Students with Dyscalculia

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ABSTRACT
The aim of this study is to examine the effects of computer assisted instruction materials on approximate number skills of students with mathematics learning difficulties. The study was carried out with pretest-posttest quasi experimental method with a single subject. The participants of the study consist of a girl and two boys who attend 3rd grade at elementary school. The contents of the computer-aided instruction materials which have been designed consist of counting skills, place value concepts and addition subjects which are related to mathematics lesson's learning outcomes of 1st and 2nd grades of primary school. With the materials prepared, participants were given 75 lessons of individual instruction during five weeks, each weekdays and approximately 20-30 minutes a day. Dyscalculia screening tool and Panamath program were used as data collection tools. Panamath program calculates test response time, the percentage of accuracy and weber fraction data of participants. In the dot counting and comparison symbolic tests of DST, response time tests and number of correct answers of the participants were calculated, while mean absolute error were calculated in the mental number line tests. The findings of the study indicate that the approximate skills of the participants have developed and there has been significant increase in their speed of answering.

INTRODUCTION
Mathematics is a complex course which includes different domains like arithmetic, arithmetic problem solving, statistics, geometry, algebra, probability, and calculus. This condition means that variety of basic abilities related to sense of quantity, symbolic decoding, memory, visual-spatial capacity, and logics must be mobilized. Students who have difficulties with any of these abilities or in their coordination can experience mathematics learning disability (MLD) (Karagiannakis, Baccaglini-Frank, & Papadatos, 2014).

MLD / Dyscalculia is a term widely used to describe deficits in math skills associated with arithmetic and arithmetic problem solving (Karagiannakis et al., 2014). Such expressions like arithmetic learning disability/ difficulties, calculation disorientation, deficits in mathematics-arithmetic and specific learning disorder in arithmetic are different names used for the difficulties encountered in mathematics. However, MLD can be preferred due to the existence of difficulty and different causes of difficulty (Gersten, Jordan, & Flojo, 2005). In this study dyscalculia and MLD expression were used in place of each other. While Piazza and et all (2010) define MLD as deficits in possessing inabilities for the acquisition of mathematical knowledge and skills, von Aster & Shalev (2007) cite that developmental dyscalculia is a specific learning disability which affects the normal acquisition of mathematical skills and genetic, neurobiological, and epidemiological evidence related to dyscalculia like the other specific learning disabilities indicate that dyscalculia is a brain-based disorder. Kauffman and colleagues (2013) described primary mathematics learning difficulties as heterogeneous disorder resulting from individual deficits at behavioural, cognitive, neuropsychological and neuronal levels.

The Causes of Mathematical Learning Difficulties
Although the reasons for MLD are still not known very well and the discussions are still continuing (Käser et al., 2013; Michaelson, 2007; Olkun, Altun, Cangöz, Gelbal, & Sucuoğlu, 2012), there are some hypotheses put forward and grouped under two titles. One of these hypotheses is the domain-specific deficitd and the other one is domain-general deficitd (Berch & Mazzocco, 2007; Henik, Rubinsten, & Ashkenazi, 2011; Passolunghi & Lanfranchi, 2012; Vanbinst, Ghesquiere, & De Smedt, 2014).

In domain-specific deficit hypothesis, it is asserted that problems occurring in numerical abilities given to the human beings at birth which are also called number sense by Dehaene (2011), number module by Butterworth (2000) and core knowledge of number by Spelke and Kinzler (2007) cause MLD. It is argued that this core knowledge of number consists of two sub-systems (Carey, 2001; Feigenson, Dehaene, & Spelke, 2004). One of these two sub-systems is approximate number system (ANS) which subserves the estimation of the number of items in a set and the other one is exact number system(Izard, Pica, Spelke, & Dehaene, 2008; Olkun et al., 2012) or object tracking system (OTS) (Karagiannakis et al., 2014) which helps to determine the precise number of numerosities.

Approximate number skill is a skill used to estimate numerical quantities greater than four or when two numerosities are compared, it is used to identify which one is greater or smaller. It was determined that infants could perceive numerosities three hours after they were born (Izard, Sann, Spelke, & Streri, 2009). Moreover, the findings revealed that the differences in unlearned approximate number sense were related to the differences in mathematics achievement (Halberda, Mazzocco, & Feigenson, 2008), and numerical discrimination of individuals with MLD is much more problematic than their peers (Piazza et al., 2010).

Weber fraction is used as a measure for the determination of approximate number system. Weber fraction is a ratio which developed from the performance of two quantities that will be discriminated (Dehaene, 2003; Holden, Francisco, Zhang, Baric, & Tommerdahl, 2011). Figure 1 presents examples of different Weber fraction values. Numerical discrimination / numerical acuity is defined as an ability to discriminate between larger or smaller quantities when comparing them. It was determined that numerical discrimination/numerical acuity developed with increasing age, education and environmental factors (Halberda & Feigenson, 2008). It was reported that before their first birthday, infants' numerical discrimination/numerical acuity developed from the ratio of 1:2 to 2:3 ratio (Lipton & Spelke, 2003). It was found that infants at the age of 3-4 could discriminate numerosities by the ratio of 3/4 (Lipton & Spelke, 2003) and this ratio decreased to a value such as 7/8 in their 20s (Piazza et al., 2010).

Exact number system/object tracking system, one of the components of core knowledge of numbers, enables subitizing which is defined as the ability to 'see' a small amount of objects (maximum 4 objects) and know how many there are without counting, counting, and mental calculation. Kaufmann and colleagues (1949; as cited in (Desoete, Roeyers, & De Clercq, 2004) was defined the ability of subitizing as rapid (40-100 ms/item), accurate, and reliable judgments of numbers performed for small number of items. Clements (1999) states that there are two kinds of subitizing: perceptual and conceptual. Perceptual subitizing is close to the original definition of subitizing and one can state how many without counting or using mathematical operations. For example, Clements (1999) cites that a child without any learned mathematical knowledge can subitize "3 items" perceptually. Similarly, Clements states that conceptual subitizing has an advanced-organizing role in counting. For example, Clements argues that people recognize the eight-dot domino without counting it because they see it as a composite of parts and as a whole. They see the eight-dot domino as composed of two groups of four and as one eight.

Young children use perceptual subitizig to build their initial ideas of counting and cardinality (Celements, 1999). From this aspect, it can be stated that perceptual subitizing is thought to be the basis for conceptual subitizing. Thus, Olkun and Özdem (2015) found that conceptual subitizing implementations increased calculation performance of students with low math performance. In addition to this, it was stated that individuals with MLD were slower in subitizing tasks and showed deficits in subitizing, in comparison to their peers(Landerl, Bevan, & Butterworth, 2004).

The findings obtained on cognitive functions which affect mathematics performance like intelligence, language skills, working memory, executive functions, attentional control, semantic memory, and data processing speed revealed domain-general cognitive deficit hypothesis (Andersson & Östergren, 2012; Östergren, 2013). This hypothesis argues that the vulnerabilities in one or more cognitive functions given above cause mathematical learning disability.

Despite many studies conducted about the hypotheses put forward for the reasons for MLD, very few things are still known about which domains of mathematical cognition affect each other, which ones function together or alone and how these domains affect learning (Fuchs et al., 2010).

Computer-assisted instruction of students with MLD
With the developments in technology and research carried out in special education, the researchers who want to make contribution to the learning abilities of students with MLD went through the effort of using technology within the framework of mathematics curriculum. (Amiripour, Bijan-zadeh, Pezeshki, and Najafi, 2010). Maccini, Gagnon and Hughes (2002) state that technology-based interventions hold great promise for the educational development and growth of students with MLD and today technology has become a very important tool with lots of potentials helping students with MLD than ever before. Virtual environment provides an

opportunity for students to connect their opinions, emotions, and actions and also makes contributions to students' motivation for learning and cognitive development (de Castro, Bissaco, Panccioni, Rodrigues, & Domingues, 2014).

The research studies carried out on the improvement of elementary school mathematics point out that computer-based training of number sense (processing magnitudes or locating numbers on the number line) and training of domain-general cognitive abilities (working memory) can promote mathematics achievement (Kuhn & Holling, 2014).

Many studies carried about students with MLD reveal that instructional games and activities and computer-assisted instruction promote these students' math performance and develop positive attitudes towards mathematics (de Castro et al., 2014; Desoete & Praet, 2013; Räsänen, Salminen, Wilson, Aunio, & Dehaene, 2009; Wilson, Revkin, Cohen, Cohen, & Dehaene, 2006).

This study seeks answers to the problem "what are the effects of computer-assisted instruction materials on approximate number skills of primary school 3rd grade students with dyscalculia?"

METHOD

Research Design

One group pre-test post-test research design was selected to measure the effect of CAI stated in the problem statement of this study on the achievement of students with MLD. Single subject research model is a quasi-experimental research design which interprets the findings related to one or a few subjects (McLaughlin and Mertens, 2004; Büyüköztürk, Çakmak, Akgün, Karadeniz, & Demirel, 2012). Because the subjects are not chosen via randomly, single subject studies are accepted as quasi-experimental.

Participants

The study group of the research consists of 3 students with MLD, 1 female and 2 males, going to two different elementary schools in Muş in 2015-2016 education year. The participants were chosen via multiple filtering design. In this model, teacher views, dyscalculia pre-assessment test, dyscalculia screening tool, student diagnostic form, and intelligence test were used as a filter.

M1. He is nine years and nine months old and he looks calm and quiet. However, when he comes together with his friends, he can be considered as one of the naughtiest children in school. He likes talking about his friends and events in his neighbourhood very much. He has got one sister and two brothers. He lives with his parents and siblings in a rented house. There are two rooms in the house and their house is heated with a stove. His father works a minimum wage job and his mother is a housewife. M1 did not receive pre-school education. He continued his education in the same school and considering attendance, he did not play truant (total one month or more than a month) for a long time according to the school records. The data obtained from the interviews and observations carried out with him and his family reveal that M1 is normal in every aspect regarding health. M1 does not have any problems with hearing and seeing and he did not have an illness which would affect him for a long time.

F1. F1 is nine years and five months old. She looks older than her peers and she is social and friendly. She lives in their own house with her parents and two sisters aged 12 and 14. Their house is heated with a stove and she does not have a room of her own. Her father is a chef in a restaurant and her mother is a housewife. F1 did not receive pre-school education and when she was in the second grade, she changed her school and went to another school located in the same city. Considering attendance, she did not play truant (total one month or more than a month) for a long time. F1 does not have any problems with hearing and seeing. Moreover, she did not have any diseases that affected her for a long time. The data obtained from the interviews and observations carried out with her and her family reveal that she is normal in every aspect regarding health.

M2. He is nine years and two months old. He can be identified as someone who keeps aloof from his friends and he is reserved. He loves spending time with his tablet. He reflects his interest in computers and computer games in his daily life talks. M2 is the youngest of his three siblings and he is the only son of his family. His father is a high school graduate and his mother is a primary school graduate. His father works as a construction foreman and his mother is a housewife. M2 lives with his parents and three sisters aged 14, 18, and 19 in their own house. M2 shares his room with his elder sister. The family state that they do not have financial difficulties. Because M2 is the youngest and the only son in the family, he is the family's favourite. His father states that when compared to their other children, they take care of him more and his elder sisters constantly help him with his lessons so that he can be successful. His father stated that although his son was successful in reading and writing, he was not successful in mathematics and added that he could not understand why he was unsuccessful in mathematics. The school records document that M2 did not receive pre-school education and he did not play truant when participating in his lessons (total one month and more than a month). However, M2 was exposed to teacher change during his three year education. M2 does not have any problems with hearing and seeing and also he did not have any diseases that affected him for a long time. The data obtained from the interviews and observations carried out with him and his family reveal that he is normal in every aspect considering health.

Data Collection Tools

Panamath. As seen in Figure 1, Panamath program (Halberda, Mazzocco and Feigenson, 2008) involves tasks comparing whether there are more blue dots or yellow dots in flash. With these tasks students' response time for approximate number system is measured over the variables of accuracy of their basic gut sense for numbers and Weber fraction. The number of tasks assigned change according to the determined time and the difficulty level of tasks change considering the age. Throughout the research, it was determined that the total time for Panamath test was 5 minutes. An individual's average scores obtained in this test is compared to the group average scores (below10% and above 90%) obtained from their peers.

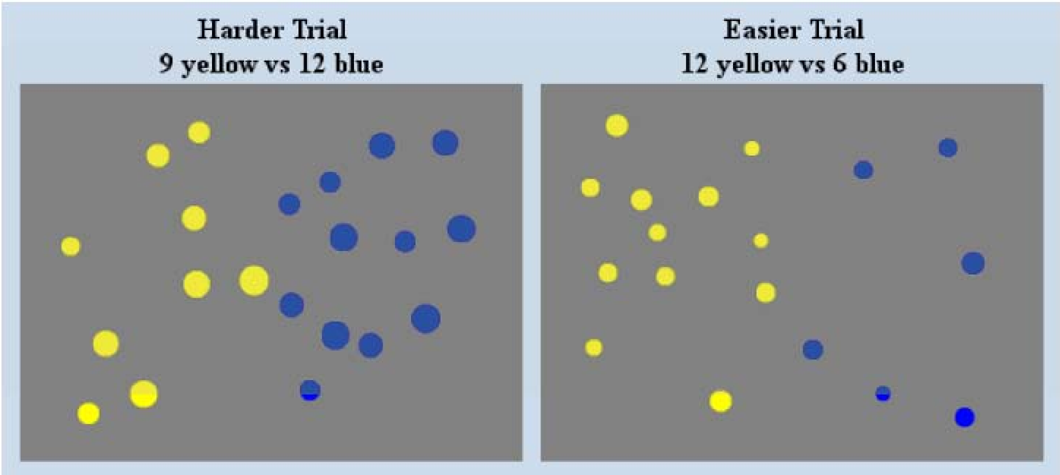

Figure 1. Panamath item examples (Halberda, Mazzocco and Feigenson, 2008)

Dyscalculia screening tool (DST). Mental Number Line Test, one of the sub-tests of DST developed within a research project funded by Scientific and Technological Research council of Turkey (TUBITAK No: 111K54 by Olkun and colleagues (2012) was used. The mean absolute error for the data obtained from the mental number line estimation was calculated. The absolute value was taken for the response given by the individuals for each item and the difference for the accurate response belonging to that item.

For the reliability analysis of Mental Number Line Estimation, the data were collected from total 261 3rd grade elementary school students (130 males and 131 females) chosen randomly from the five elementary schools located in Muş. The elementary school teachers were asked whether there was an inclusive student among the students chosen. In case there were inclusive students, they were excluded from the group; however, their test results were not used. The cronbach alpha values of the tests given in Table 1 were ,72 - ,85 - ,87, respectively.

Table 1:DST Tests' Reliability Measurements

	Madde Sayısı	**Cronbach Alpha**
MNL-1	9	,72
MNL-2	24	,85
MNL-3	25	,87

The content and functions of Mental Number Line (MNL), one of the sub-tests of DST were given below.

Mental Number Line: In this test the individuals are asked to indicate the position of numbers on number lines between the range of 0-10, 0-100, and 0-1000 approximately and the number lines are on the tablets and a line which could be manipulated appears on the number line when clicked. The position of total 58 numbers, 9 numbers within the range of 0-10, 24 numbers within the range of 0-100, and 25 numbers within the range of 1-1000 are estimated.

Data Analysis

The data were collected via Panamath, DST, and achievement tests. Panamath generates two output files after the test: a pdf file for the user and an excel file. The “Summary” section of the XLS file where the data were summarized contains response time data calculated for an individual, percent accuracy, and Weber fractions. DST does not present final data as is generated by Panamath. Thus, personal information stored on the tablets was organized in an XLS file by the researcher. Mean absolute error was calculated in Mental Number Line tests.

Implementation Process

Dyscalculia Pre-Assessment Test used for identifying the participants was also administered to assess the participants’ mathematics levels. When the students’ forms were examined, it was found that these students had problems with adding two one digit numbers and answering questions about place value concepts like ones and tens. Because of that, the materials were developed considering the 1st and 2nd grade mathematics course learning outcomes. In computer assisted instruction materials, first counting skills, concept of place value, and addition was taught respectively at 1st grade level and then at the 2nd grade level counting skills, concept of place value, and addition were taught. The implementation was carried out in a primary school located in a city in the east of Turkey. The study lasted five weeks, five days a week and between 20 and 30 minutes on average and the computer assisted instruction was given individually. The Materials was completed with a three-month study. Before the implementation started, materials were evaluated by the experts and testing study was conducted. The content was composed by the researchers and expert support was received for its design.

The program consisted of three sections: material home page, (home page) and the related content page or pages. After pushing the enter key, students will see the menu bar. The menu page includes the following subjects: Under the main heading “Mathematics Begins with Counting” designed for counting skills are “Hundred Cards, Which one has got more? And Going for Hundred”, under the main heading “Numbers Increase Digit by Digit” developed for teaching digit concept are “ Make it tens!, Numbers with Cubes”, and considering the addition, under the main heading “Let’s Get Together and Increase” is “ How many? What is the carried value? All the activities in the materials were dubbed. Moreover, with starting of the material, background music specially prepared plays. Home page and menu page screen shot belonging to the materials are given below:

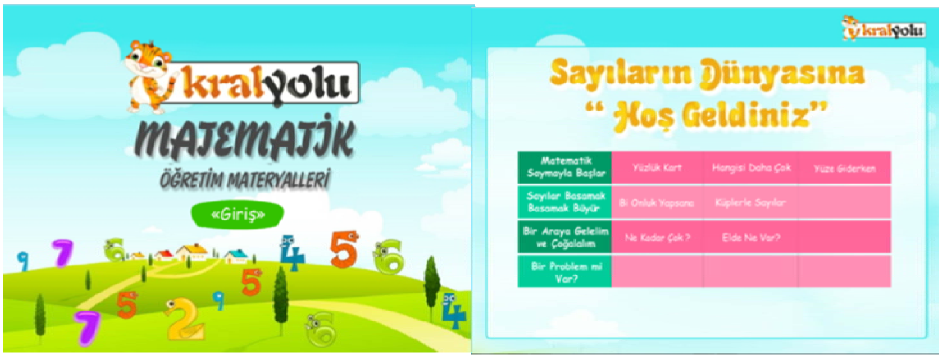

Figure 2. Course materials’ home page and menu page screen shot

The implementation was carried out in six sessions. The first three sessions were about 1st grade mathematics course objectives and the last three sessions included 2nd grade mathematics course objectives. The sessions were explained in detail below.

***1st* Session.** In this sessions the following 1st grade mathematics course objectives “The student identifies the number of items in a group which has less than 10 items and writes out the number in words (letters)/ using figures “and “The student matches the items one-to-one included in two groups less than 10 and compares the number of items in the groups” were considered and a four-day training was held with the materials designed. While developing the material,” such neuroscientific findings as triple coding, approximate number skill, exact number skill, distance effect, distance/ size effect, and working memory were benefited from. In the session, key concepts like “more, less, and matching” were included. In the material “Which one has got more?” developed for counting skills, firstly, points in different colours are counted. Then, the number of the points is written out in words (letters) and using figures and the answers are controlled. If the answer is wrong, the window opens and the statement “Wrong answer, please try again” occurs vocally. When the student answers the question correctly, he moves on to the next window and he is asked to count the points in another colour. After this step, he is asked which points in different colours are many or few. The points occur on the screen for two seconds and then disappear. The question is answered by clicking on the colourful buttons appearing on the screen consecutively. There are total 12 activities in the material which involve the process explained. In the first six activities, the question “Which one has got more?” is asked and in the last six activities the question “which one has fewer” is asked. The screen shot of the material called “Which one has got more?” is presented below.

Figure 3. “The screen shot of the material called “Which one has got more?

2nd Session. In this sessions the following 1st grade mathematics course objectives “the student shows a group of quantity of items between 10 and 20 by separating them into ones and tens, he writes out the number in figures and reads it which corresponds to these items” were considered and a four-day training was given with the materials designed. While preparing the material,” such neuroscientific findings as triple coding, approximate number skill, and working memory were used. In the sessions such key concepts as “ones, tens, units digit, tens digit were included. In the course material “Make it Tens” developed for place value, students are asked to write out the number of the different items between 10 and 20 in letters and figures. When the student answers it correctly, a new window opens and the student is asked to drag the items into the ones and tens boxes and leave them there. When this process finishes, the student pushes the continue button and another section in which he can enter the number of the ones and tens. When the student enters it correctly or wrongly, an animated window opens and gives explanation about the process. There are total 10 activities which are independent of each other. The screen shot of the material called “Make it Tens” was given below.

Figure 4. “The screen shot of the material called “Make it Tens”

3rd Session. In this session considering the 1st grade mathematics course objectives “the student finds the sum of two natural numbers whose sum is 10, writes it as a mathematical statement and shows it with a model” and “the student finds the sum of two natural numbers whose sum is between 10 and 20, writes it as a mathematical statement and shows it with a model”, a four-day training was given with the materials designed. While preparing the material,” such neuroscientific findings as triple coding, number disorientation, and working memory were used. A candy making machine was designed in the material called “How many?” intended for addition. When the candy making machine is clicked, the machine sways back and forth with a sound typical of machines and makes candies for the first bowl in designated numbers. While the candies fall into the bowl, the number of the candies appears in letters and figures just below the bowl. After this operation, the machine moves on to the second bowl automatically and when it is clicked, it produces candies and disappears. In addition to this, the student is asked how many candies the candy making machine has made. The student enters the result in letters and figures. If the answer is true or false, a new window opens and the next activity continues. The screen shot of the material called “How many?” was given below.

Figure 5. “The screen shot of the material called “How many?”

4th Session. This session was designed considering the 2nd grade mathematics course objectives “the student compares two natural numbers less than 100 and determines the relationship between them”, “the student lines up three numbers less than 100 from smaller to bigger or bigger to smaller “, “the student lines up four numbers less than 100 from smaller to bigger or bigger to smaller” and a four-day training was given with these teaching materials developed according to these objectives. While preparing the material, such neuroscientific findings as triple coding, approximate number skill, number disorientation, and working memory were utilized. In the session, key concepts like “bigger, smaller, the biggest, the smallest were included. The teaching material called “Going for Hundred” consisting of two parts was developed for counting skills at the 2nd grade level. In the “Line up the Numbers” section, the students are asked to line up the numbers containing 10 items. In “Smaller? Bigger?” section, the students are asked to line up two numbers in four items, three numbers in four items, and four numbers in the remaining four items from smaller to bigger or bigger to smaller. When the check answer buttons are pressed, the numbers are seen in-line on a ruler. It draws attention that on each check answer page there are smaller and bigger symbols and ranking of numbers on the number line. The screen shot of the material called “Going for Hundred” was given below.

Figure 6. “The screen shot of the material called “Going for Hundred”

5th Session. In this session, a four-day training was offered with the teaching material which was developed considering the 2nd grade mathematics course objectives “the student separates a quantity with less than 100 items into a set of ones and tens and writes and reads the number which correspond to them” and “ he names the digits of the natural numbers less than 100 and identifies the digit value of the numbers”. While developing the material, such neuroscientific findings as triple coding and working memory were utilized. The key concepts such as “tens, ones, tens digit, units digit” were used. The student pushes the generate number button and the numbers smaller than a hundred appears on the screen randomly with the material “Numbers with Cubes” designed to teach place value concepts. The student is asked to use the units and tens digits of the number and ones and tens blocks. For the ones block he clicks the ones button and if enough numbers are exceeded, it is deleted with an eraser and the operation can be repeated. The same thing can be done with tens blocks. As the buttons are clicked, the numbers appear on the screen both as in letters and figures and they are also dubbed. The screen shot of the material called “Numbers with Cubes” was given below.

Figure 7. The screen shot of the material called "Numbers with Cubes"

6th session. In this session, a five-day training was given for the teaching material developed according to the primary school 2nd grade mathematics course objectives "the student does the addition of natural numbers without carrying (regrouping)" and including regrouping whose sums are 100 and he explains what regrouping means in addition with models". While developing the material, such neuroscientific findings as triple coding and working memory were utilized. The key concepts like addend, sum, and regrouping (carrying or borrowing)" were included. As shown in Figure 7 prepared for teaching of addition at the 2nd grade level, there are two generate number buttons in this material. The numbers are generated randomly. First of all, because addition without regrouping will be performed, suitable numbers are generated with generate number buttons. Considering the figures of the number in the units digit and tens digit, the student is asked to click the (+) and (-) buttons in each section and add ones and tens blocks. The operation is performed firstly with blocks. But, if addition with regrouping is performed, regrouping button is also used. The sum is written and "check the answer" button is clicked. The screen shot of the material called "What is the carried value" was given below.

Figure 8. The screen shot of the material called "What is the carried value"

FINDINGS

The findings obtained in this section via DST, Panamath software, and achievement tests were included considering the sub-problems of the study. The findings belonging to the participants were interpreted within the context of each problem.

Findings Related to the Approximate Number Sense of Students with MLD

In this section within the context of the sub-problem "What are the effects of computer assisted instruction materials on approximate number representations (sense) of students with MLD?", the findings obtained from the Mental Number Line Estimation, one of the sub-tests of Panamath and DST, were included. The test results of F1, M1 and M2 were given, respectively.

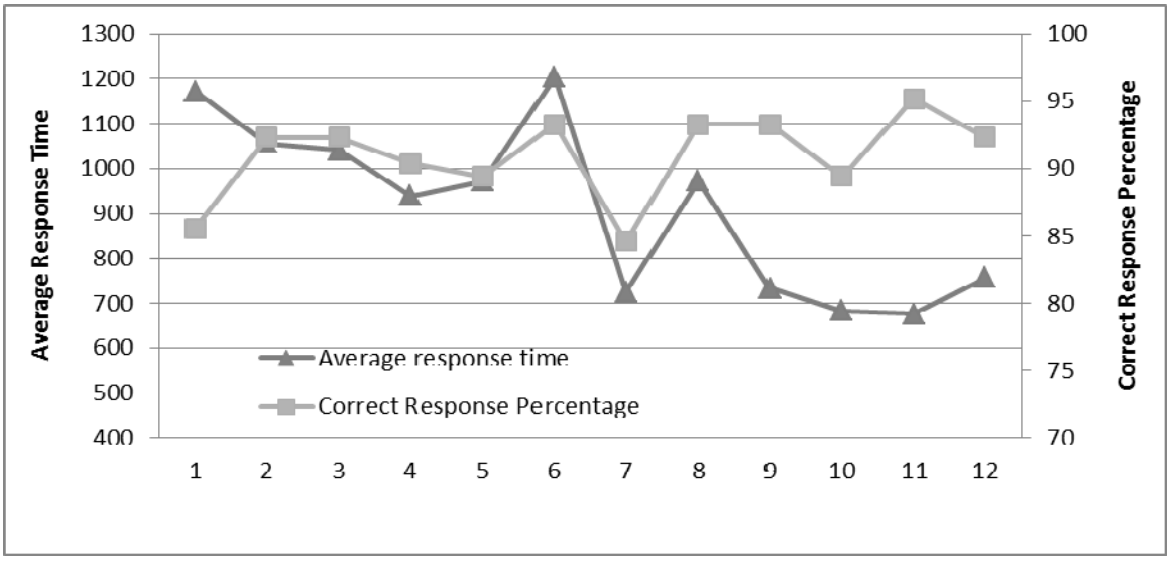

Figure 9. The data belonging to F1's response time and percent accuracy in Panamath test

When Figure 9 is analysed, the data belonging to K1's mean correct response time and percent accuracy obtained from 12 tests in the Panamath software are viewed. F1's lowest percent accuracy is 85 % with the 7^{th} test and the highest percent accuracy is 95% with the 11^{th} test. F1's mean accuracy is 91%. When test results are examined, it can be stated that percent accuracy has gradually increased.

F1's highest test with mean correct response time for each item is the 2^{nd} test (1203ms) but the 11^{th} test has the lowest mean response time as 677ms. F1's mean response time for 12 tests is 991 ms. When considered correlating it with the correct responses, it is viewed that there was a decrease with F1's response time. Considering the Panamath data, while the mean response time for below 10% of nine-year old children is 1630 ms, above 90% of students' mean response time is 1004. According to the Panamath data, F1's mean response time is below that of 90% of the group's mean response time.

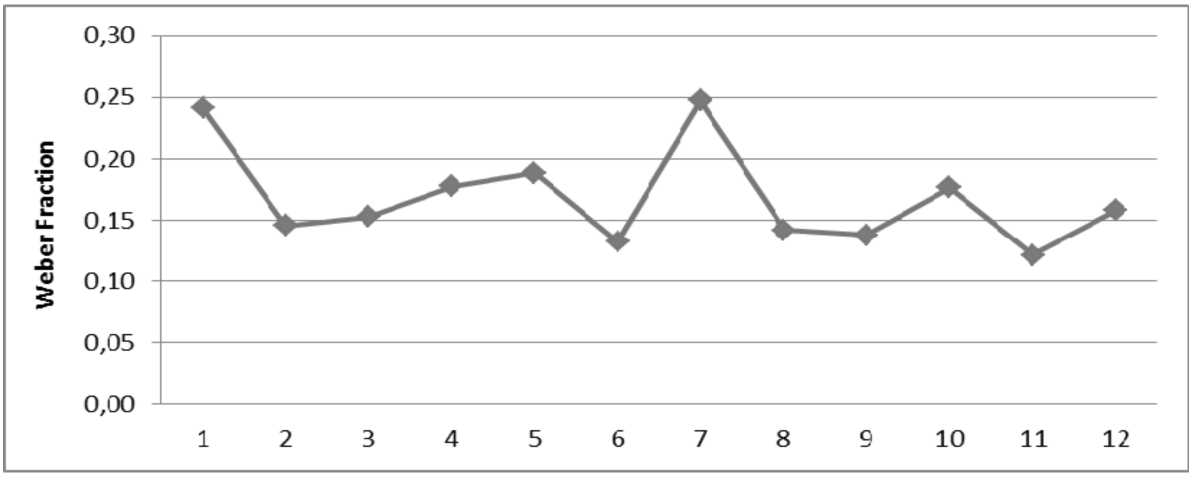

Figure 10. F1's data of Panamath test Weber fraction

When Figure 10 is analyzed, 12 Weber fractions belonging to F1 in the Panamath software is are presented. F1 got the highest Weber fraction value (0.25) in the 7^{th} test and the lowest Weber fraction value (0,12) in the 11^{th} test. F1's mean Weber fraction is 0,17 in 12 tests. It can be stated that when F1's tests were compared, the values for the Weber fraction generally decreased,thus the acuity of number sense increased and the training had a positive effect on F1. The values F1 got regarding the Weber fraction can be compared to the 9-year-old children's mean scores. While the mean Weber fraction for the group below 10% is 0,48, the mean Weber fraction for the group above 90% is 0,18. It was determined that F1's mean Weber fraction was below that of the group above 90%.

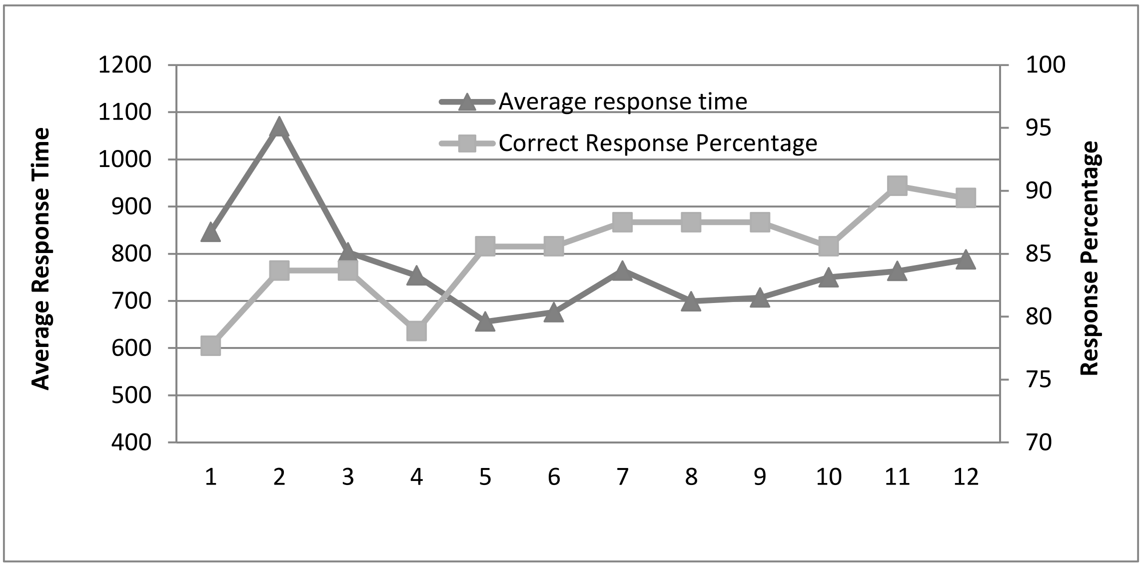

Figure 11. The data belonging to M1's response time and percent accuracy in Panamath test

When Figure 11 is examined, the data belonging to M1's response time percentages and percent accuracy obtained from 12 tests in the Panamath software are viewed. M1's lowest percent accuracy is 78 % with the 1st test and the highest percent accuracy is 90% obtained from the 11th test. It can be stated that percent accuracy has increased gradually. M1's mean accuracy for the 12 tests is 85%.

E1's highest test with mean response time for each item in the Panamath test is the 2nd test (1203ms) but the 5th test has the lowest mean response time as 677ms. M1's mean response time for 12 tests is 773 ms. When considered correlating it with the correct responses, it is viewed that there was a decrease with M1's response time. Regarding the Panamath data, while the mean response time for below 10% of nine-year old children is 1630 ms, above 90% of students' mean response time is 1004. The Panamath data reveals that M1's mean response time is lower than that of above 90% of the group's mean response time.

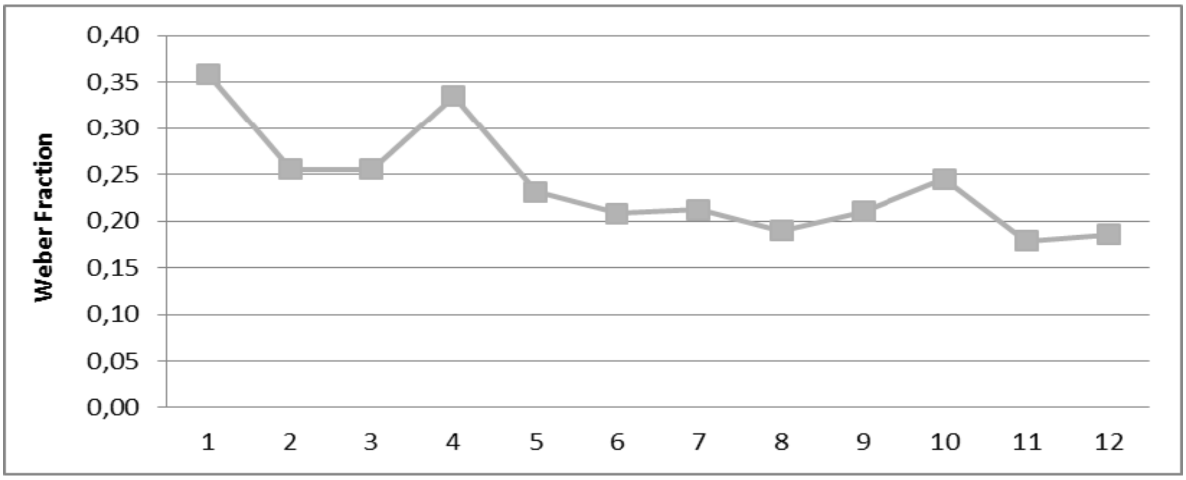

Figure 12. M1's data belonging to Panamath test Weber fraction

Figure 12 presents the values of 12 tests for Weber fraction obtained from the Panamath software and belonging to M1. M1 got the highest Weber fraction value (0.36) in the 1st test and the lowest Weber fraction value (0,18) in the 11th test. E1's mean Weber fraction is 0,24 in 12 tests. It can be stated that when M1's tests were compared, the values for the Weber fraction generally decreased thus the acuity of number sense increased and the training had a positive effect on M1. The values M1 got regarding the Weber fraction can be compared to the 9-year-old children's mean scores in the Panamath software application. While the mean Weber fraction for the group below 10% is 0,48, the mean Weber fraction for the group above 90% is 0,18 in the Panamath software. It was determined that M1's mean Weber fraction was below that of the group above 10% and close to the mean Weber fraction of the group above 90%.

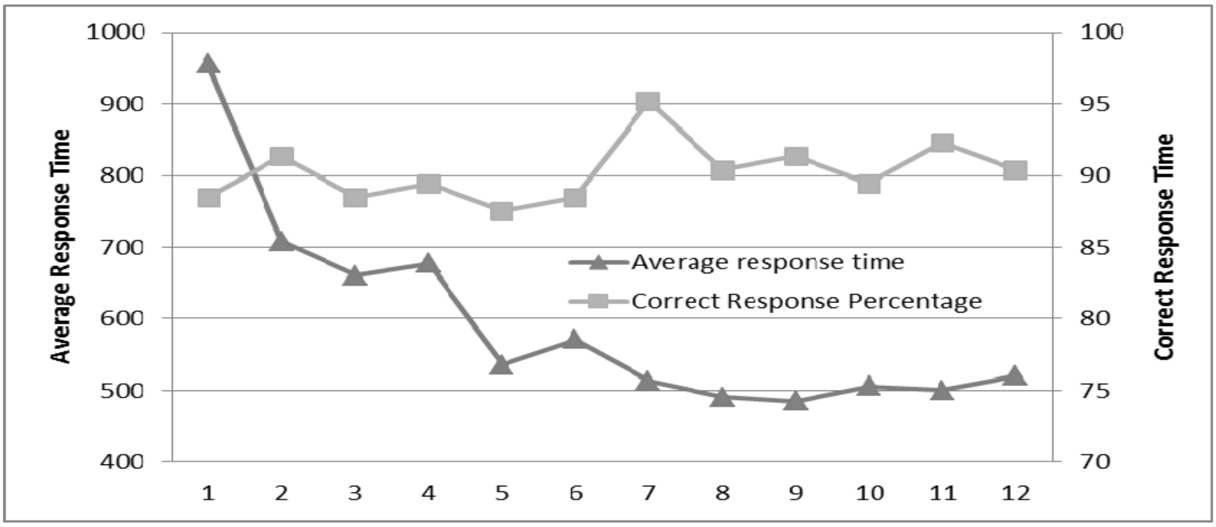

Figure 13. The data belonging to M2's response time and percent accuracy in Panamath test

When Figure 15 is examined, the data belonging to M2's response time percentages and percent accuracy obtained from 12 tests in the Panamath software are considered. M2's lowest percent accuracy is 88 % with the 1st,3rd, 5th and 6th tests and the highest percent accuracy is 95% in the 7th test. It can be stated that percent accuracy has increased in general. M2's mean accuracy for the 12 tests is 90%.

M2's highest test with mean response time for each item in the Panamath test is the 1st test (956) but the 5th test has the lowest mean response time as 485 ms. M2's mean response time for 12 tests is 594 ms. When considered correlating it with the correct responses, it is viewed that M2's response time decreased. Regarding the Panamath data, while the mean response time for below 10% of nine-year old children is 1630 ms, above 90% of students' mean response time is 1004. In comparison to the Panamath data, it is found that M2's mean response time is much lower than that of above 90% of the group's mean response time.

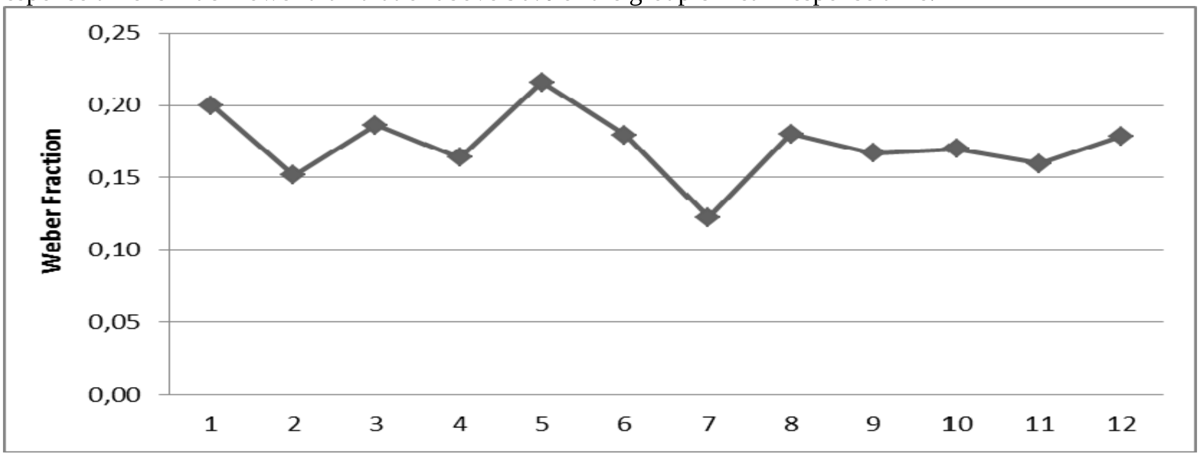

Figure 14. M2's data belonging to Panamath test Weber fraction

Considering Figure 14, 12 test values for Weber fraction obtained from the Panamath software and belonging to M2 are presented. M2 got the highest Weber fraction value (0.22) in the 5th test and the lowest Weber fraction value (0,12) in the 7th test. M2's mean Weber fraction is 0,17 in 12 tests. It can be stated that when M2's tests were compared, the values for the Weber fraction constantly decreased, thus the acuity of number sense increased and the training had a positive effect on M2. The values M2 got regarding the Weber fraction can be compared to the 9-year-old children's mean scores in the Panamath software. While the mean Weber fraction for the group below 10% is 0,48, the mean Weber fraction for the group above 90% is 0,18 in the Panamath software. It was determined that M2's mean Weber fraction was below that of the group above 90%.

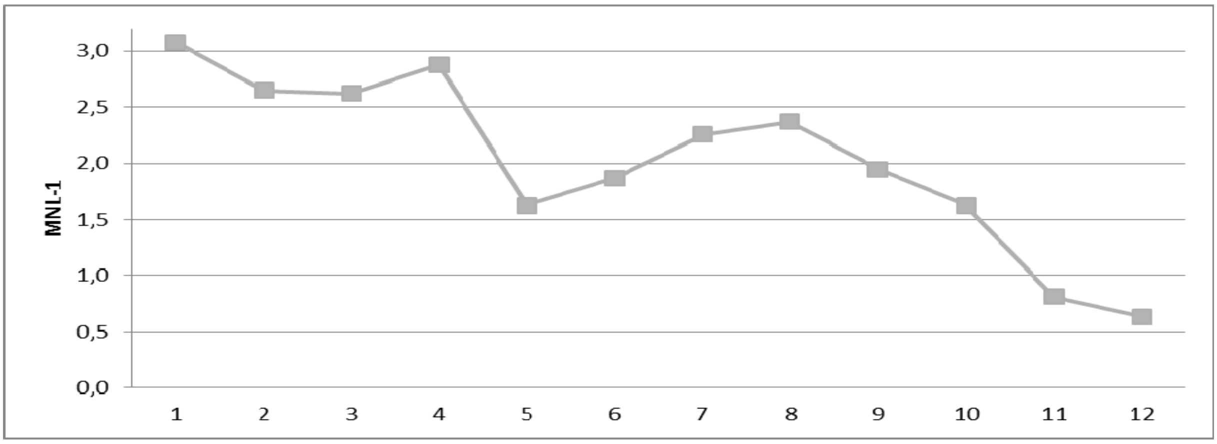

Figure 15. F1's data for mental number line estimation (0-10)

Figure 15 presents F1's mean inaccurate estimates in MNL-1 test, one of the sub-tests of DST and including the task of locating the position of numbers on number line between the ranges of 0-10. While F1 made the most inaccurate estimates with 3.1 in the 1st test, she made the fewest inaccurate estimates with 0,6 in the 12th test. The average for mean inaccurate estimates of F1 in 12 tests is 2,3. F1's MNL-1 test results reveal that the computer-assisted instruction increased F1's performance in estimating the position of number on the number line between the ranges of 0-10.

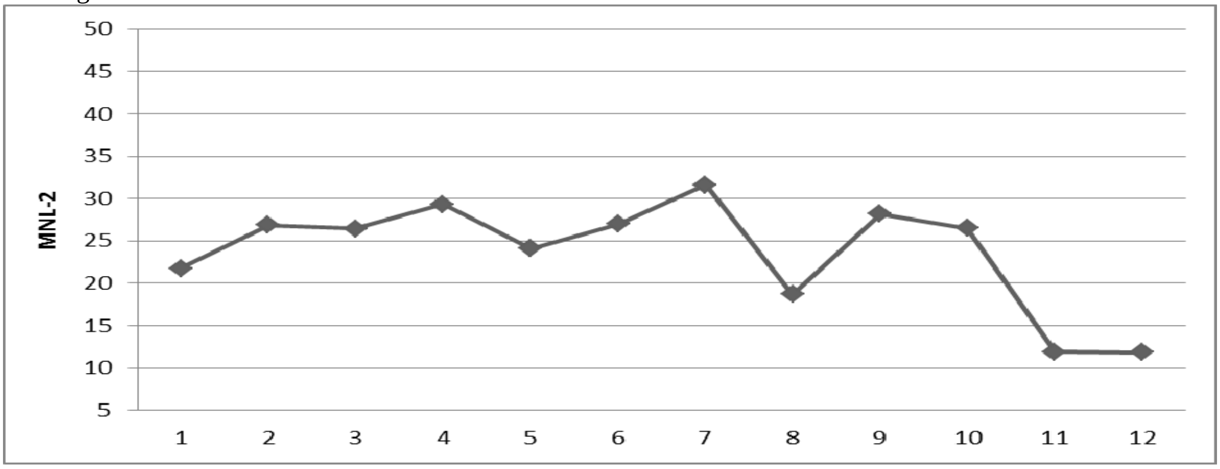

Figure 16. F1's data for mental number line estimation (0-100)

In Figure 16, F1's mean inaccurate estimates in MNL-2 test, one of the sub-tests of DST and including the task of indicating the position of numbers on the number line between the ranges of 0-100 are given. While F1 made the most inaccurate estimates with 31.6 in the 7th test, she made the fewest inaccurate estimates with 11.9 in the 11th and 12th tests. The average for mean inaccurate estimates of F1 in 12 tests is 23.68. F1's MNL-2 test results reveal that the computer-assisted instruction increased F1's performance in estimating the position of number on the number line between the ranges of 0-100.

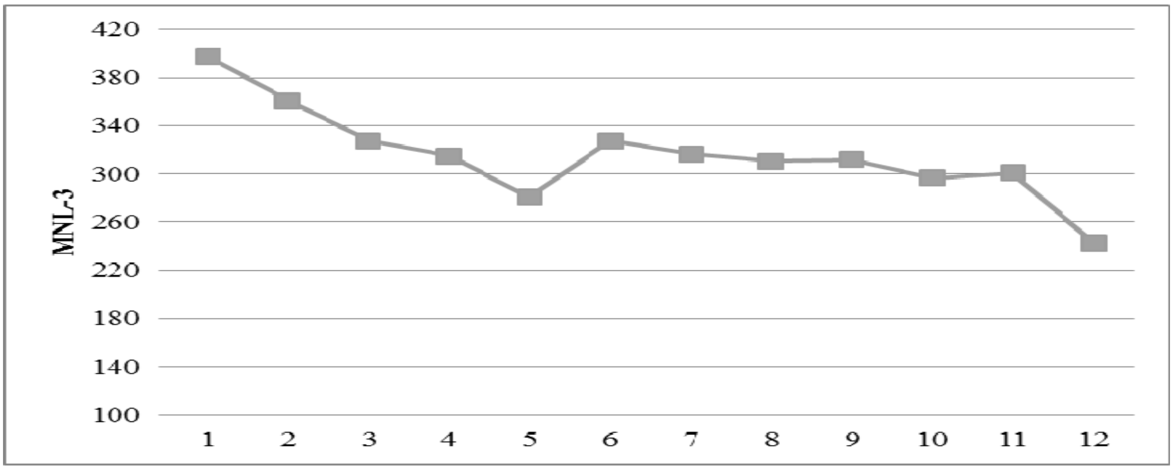

Figure 17. F1's data for mental number line estimation (0-1000)

Figure 17 presents F1's mean inaccurate estimates in MNL-3 test, one of the sub-tests of DST and including the task of indicating the position of numbers on the number line between the ranges of 0-1000.While F1 made the most inaccurate estimates with 398 in the 1st test, she made the fewest inaccurate estimates with 243 in the 12th test. The average for mean inaccurate estimates of F1 in 12 tests is 315. F1's MNL-2 test results reveal that the computer-assisted instruction increased F1's performance in estimating the position of number on the number line between the ranges of 0-1000.

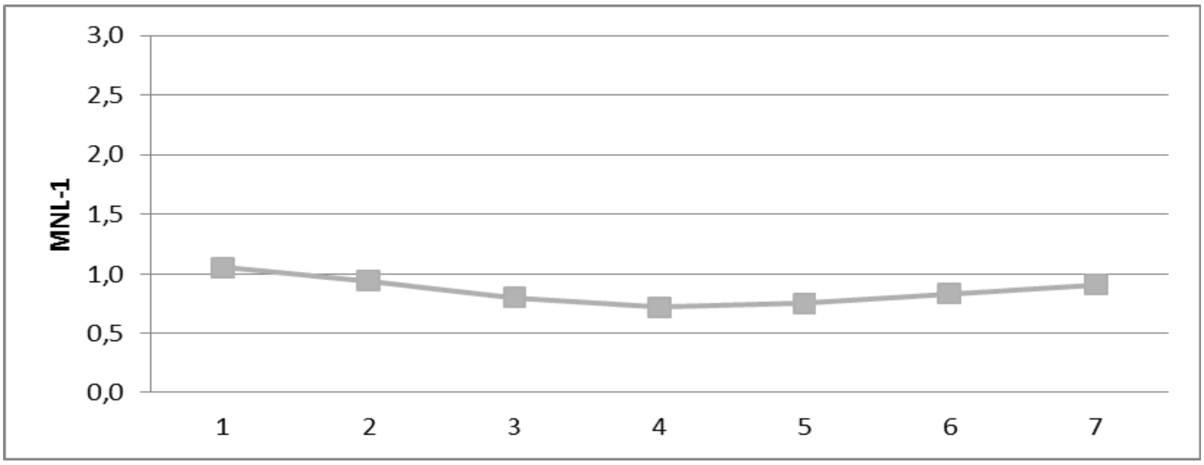

Figure 18. M1's data for mental number line estimation (0-10)

Figure 18 presents E1's mean inaccurate estimates in MNL –1 test, one of the sub-tests of DST and including the task of locating the position of numbers on number line between the ranges of 0-10. M1 made the most inaccurate estimates with 1.2 in the 11th and 9th tests but he made the fewest inaccurate estimates with 0,7 in the 4th and 11th tests. The average for mean inaccurate estimates of M1 in 12 tests is 0.9. It can be stated from M1's MNL-1 test results that the computer-assisted instruction promoted M1's performance in estimating the position of number on the number line between the ranges of 0-10.

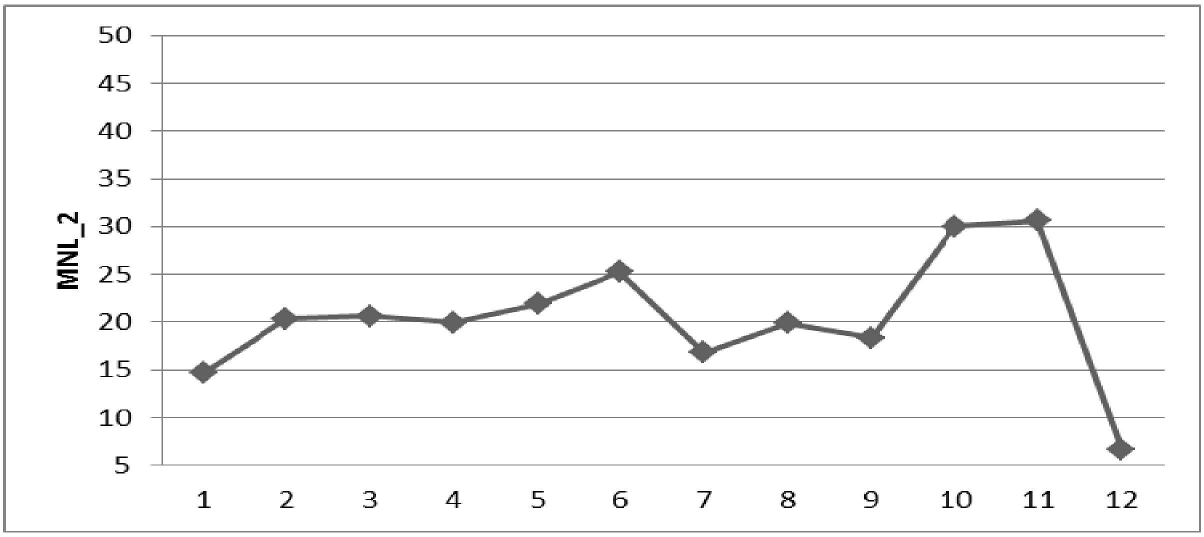

Figure 19. M1's data for mental number line estimation (0-100)

Figure 19 presents M1's mean inaccurate estimates in MNL –2 test, one of the sub-tests of DST and including the task of locating the position of numbers on number line between the ranges of 0-100. The highest mean inaccurate estimates M1 made were30.6 in the 11th test and the lowest mean inaccurate estimates he made were 6.7 in the 12th test. The average for mean inaccurate estimates of M1 in 12 tests is 20.4.

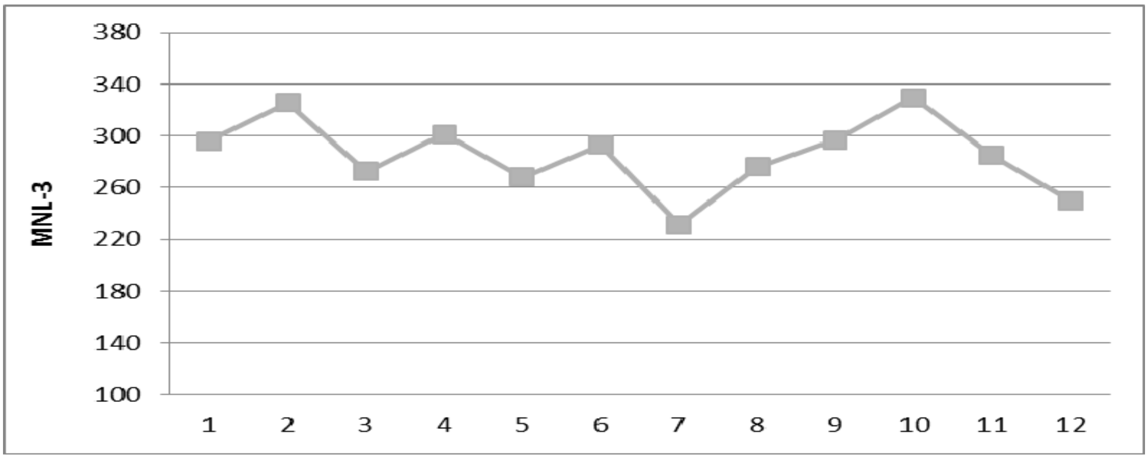

Figure 20. M1's data for mental number line estimation (0-1000)

Figure 20 presents E1's mean inaccurate estimates in MNL –3 test, one of the sub-tests of DST and including the task of locating the position of numbers on number line between the ranges of 0-1000. The highest mean inaccurate estimates M1 made were 330 in the 10th test and the lowest mean inaccurate estimates he made were 231 in the 7th test. The average for mean inaccurate estimates of M1 in 12 tests is 285.4.

It can be stated from M1's MNL-3 test results that the computer-assisted instruction increased M1's achievement in estimating the position of number on the number line between the ranges of 0-1000.

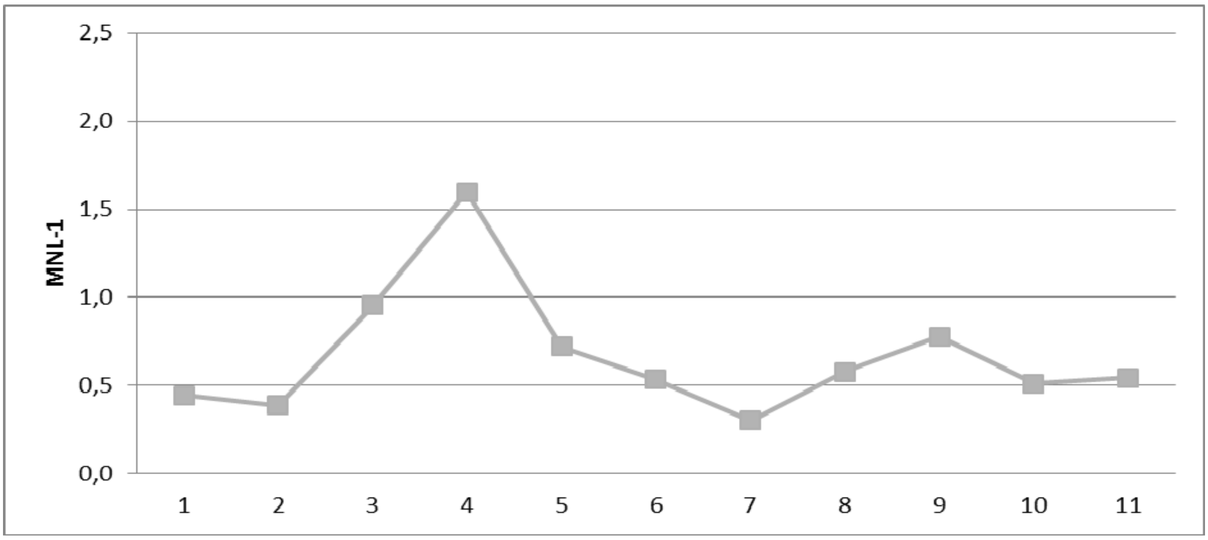

Figure 21. M2's data for mental number line estimation (0-10)

Figure 21 presents M2's mean inaccurate estimates in MNL –1 test, one of the sub-tests of DST and including the task of locating the position of numbers on number line between the ranges of 0-10. The highest mean inaccurate estimates M2 made were 1.6 in the 5th test and the lowest mean inaccurate estimates he made were 0.3 in the 1st and 8th tests. The average for mean inaccurate estimates of M2 in 12 tests is 0.64.

In addition to abnormal test results of M2, mean test scores demonstrate that there was not an increase in M2's performance.

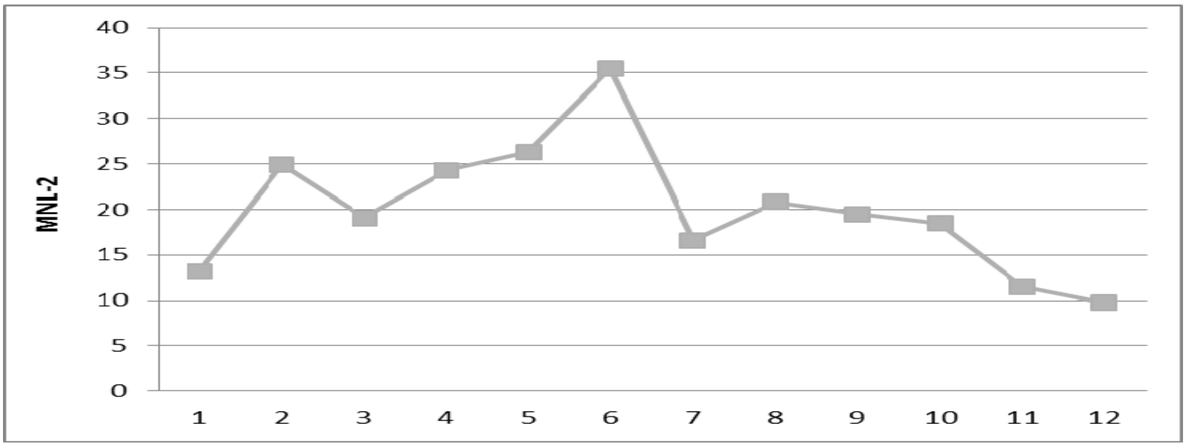

Figure 22. M2's data for mental number line estimation (0-100)

Figure 22 presents M2's mean inaccurate estimates in MNL –2 test, one of the sub-tests of DST and including the task of locating the position of numbers on number line between the ranges of 0-100. The highest mean inaccurate estimates M2 made were 35.3 in the 6th test and the lowest mean inaccurate estimates he made were 9.7 in the 12th test. The average for mean inaccurate estimates of M2 in 12 tests is 20.

It can be stated from M2's MNL-2 test results that the computer-assisted instruction increased M2's achievement in estimating the position of number on the number line between the ranges of 0-100.

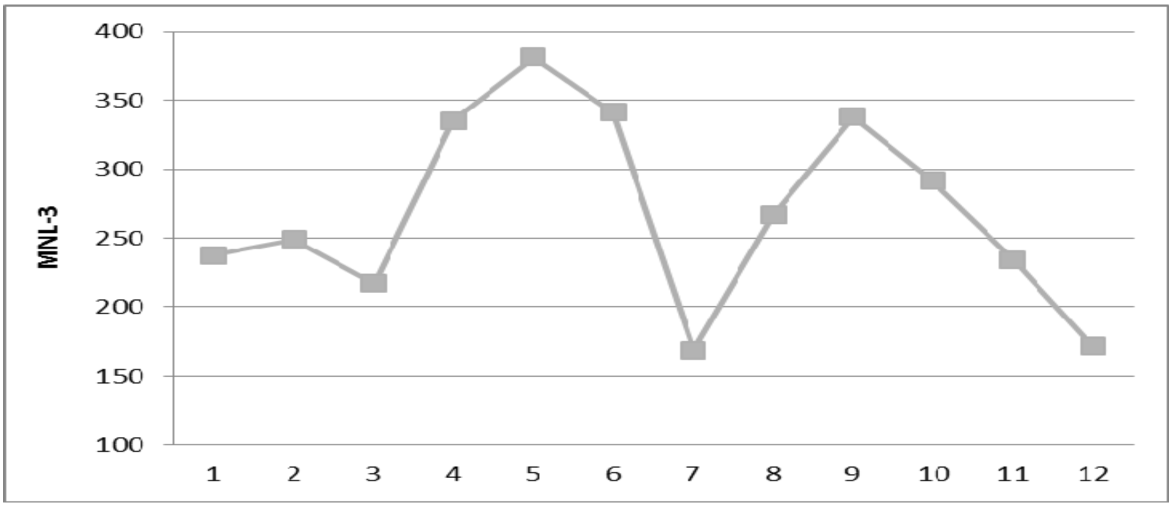

Figure 23. M2's data for mental number line estimation (0-1000)

Figure 23 presents M2's mean inaccurate estimates in MNL –3 test, one of the sub-tests of DST and including the task of locating the position of numbers on number line between the ranges of 0-1000. The highest mean inaccurate estimates M2 made were 381 in the 5th test and the lowest mean inaccurate estimates he made were 169 in the 7th test. The average for mean inaccurate estimates of M2 in 12 tests is 269.25.

It can be stated from M2's MNL-2 test results that the computer-assisted instruction increased M2's achievement in estimating the position of number on the number line between the ranges of 0-100. In addition to abnormal test results of M2, it is observed that M2 got scores below the beginner level in some tests.

CONCLUSION, DISCUSSION, AND SUGGESTIONS

This study examined the effect of computer assisted instruction materials on the number sense abilities of one female and two male students with MLD determined via using multiple filtering design. The study was carried out via single subject pre-test post-test, quasi-experimental research design.

The data about number sense acuity were gathered via Panamath test and Mental number Line (MNL) test, one of the sub-tests of DST. The Panamath data of the participants reveal that participants' Weber fraction values decreased and MNL test results exhibit that their mean absolute error decreased, therefore, their number sense acuity increased. Similarly, the findings related to exact number sense reveal that the speed of students with MLD increased in the dot counting and number comparison tests. This condition supports that computer assisted individualized instruction has a positive effect on students' number sense acuity.

Many studies reveal that approximate number system is not independent of educational and cultural inventions (Gordon, 2004; Halberda ve Feigenson, 2008; Nys, Ventura, Fernandes, Querido, & Leybaert, 2013). Thus, Obersteiner, Reiss, and Ufer (2013) in their study examined the effect of training intended for enhancing first grade students' basic number processing and arithmetic skills on their approximate mental number skills. It was reported in the study that performance of the students with MLD improved with tasks related to the exact or approximate number sense. The improved number sense acuity of students with MLD enables them to perform arithmetic operations much more easily (Kucian et al., 2011; Obersteiner et al., 2013).

It was determined that the differences in unlearned approximate number sense was associated with the differences in math achievement (Halberda et al., 2008) and the numerical acuity of individuals with MLD was further problematic in comparison to their peers (Piazza et al., 2010) . Within this context, considering the findings obtained about approximate number sense and the literature, it can be stated that the activities consisting of comparing non-symbolic mumerosities in math courses in pre-school and in the first years of schooling, estimating numbers on a number line, and the distance effect in number comparison (eg: is number 5 numerically close to 8 or 3?) have a considerable potential to increase the performance of students with MLD. Moreover, the reflections of activities developed for approximate number abilities can be examined in the long term and via more groups participating in training.

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