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The effectiveness of TouchMath technique in teaching problem solving skills to students with intellectual disability

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Abstract

The purpose of this study is to determine the effectiveness of the TouchMath technique in teaching problem-solving skills to students with intellectual disability. In addition, the generalization effect of the instruction delivered through this technique to different settings and materials and the maintenance effect of the instruction after 10 and 20 days were investigated. This study adopted multiple probe across participants which is one of the single case research approaches. The dependent variable of the study is the level of students with intellectual disability in solving problems involving the additions, whereas the independent variable is the instruction delivered through the TouchMath technique. The research was conducted with three students aged between 11 and 12 who were diagnosed with intellectual disability. The collected data were analysed through visual analysis. The results revealed that the TouchMath technique was effective in teaching problem solving skills to the participating students. Moreover, it was found that students were able to maintain these skills 10 and 20 days after the end of the instruction as well as they could generalise this skill to other instructional settings and materials.

Keywords: Special education, intellectual disability, TouchMath technique, problem-solving skill, math instruction.

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1. Introduction

The main purpose of mathematics education is to support both the academic and daily lives of all students, including students with intellectual disability. In a study in the literature, some judgments were made in support of this statement. In the study, it was expressed that mathematics education is an important indicator of academic success at school as well as supporting students in their after-school lives (Duncan et al., 2007). In addition, it is stated in the literature that students who learn mathematics skills are successful in their academic and professional lives (Butterworth, 2005). With direct benefits to students regarding education and employment, mathematics is a core subject that everyone should learn (Algozzine et al., 1987; Beck et al., 2016; Duncan et al., 2007; Maccini et al., 1999; Xin et al., 2005). For this reason, mathematics education should be delivered to all students, including students whose performance is above or below the class average, in a way that it will develop their mathematics proficiency. Equally important, having basic mathematical skills (e.g., four operations skills and problem-solving skills) directly affects students' mathematical success in later years (Sarama & Clements, 2009). Therefore, students should be provided with the opportunity to have the same mathematics proficiency so that they can access the required knowledge and skills in their after-school life (Jimenez & Stanger, 2017).

When the primary and secondary school mathematics curricula are examined, it is seen that the main purpose of these programs is to provide all students with mathematics proficiency. In this program, there are four learning areas in primary school as numbers and operations, geometry, measurement and data processing. In secondary school, it is seen that there are five learning areas including numbers and operations, algebra, geometry and measurement, data processing and probability. In these learning areas, there are 36 learning objectives in the first grade, 50 in the second grade, 72 in the third grade, 71 in the fourth grade, 56 in the fifth grade, 59 in the sixth grade, 48 in the seventh grade and 52 in the eighth grade. When these learning areas and objectives are examined, it is striking that problem-solving skills are included in almost every grade level and learning area and it has become more critical in today's curricula.

Problem solving skill is the cornerstone of mathematics (Ali et al., 2010; Caballero et al., 2011; Karatas & Baki, 2013). This skill is a complex process that involves cognitive processes and consists of two main phases: problem representation and problem execution (Mayer, 1998; Polya, 1986). The first phase focuses on the presentation of the components in the problems. Problems can be represented by physical objects, semi-tangible objects, mental images, or a combination of all these (Janvier, 1987). Problem representation facilitates the understanding of the information given in the problem and offers alternative ways to solve the problem (Silver, 1987). Therefore, problem representation includes verbal, physical and graphical representations of abstract numerical information showing the relationship between the components of the problem (Mayer, 1985; Montague & Applegate, 1993; Van Garderen & Montague, 2003). As for the second phase, problem execution includes finding the solution paths of the problem, discussing these paths and checking for accuracy.

Gaining problem-solving skills is critical to both the academic and daily life of students. Acquiring basic mathematical concepts and skills like problem-solving is an integral part of daily life and is necessary for independent living. Examples of this situation are shopping, creating a budget, using calendars for planning purposes, calculating prices, calculating distances, measuring temperatures and telling the time (Saunders et al., 2018). It is of critical importance for students with special needs to become proficient in these concepts and skills as it can offer them better opportunities throughout their lives to be able to live independently, socialise and be employed. However, many students with special needs generally experience various difficulties in acquiring basic mathematical skills (e.g., counting and creating number sets) and problem-solving skills (Browder et al., 2012).

One of the most common types of disability among students with special needs is intellectual disability. As noted in the definition, students with intellectual disabilities experience limitations in various fields. As such, students with intellectual disabilities have some difficulties in learning, maintaining and generalising mathematical concepts and skills such as problem-solving. These students may have low mathematics performance due to some characteristics such as cognitive disability, limitations in motor skills, attention deficits, memory deficits and poor reading habits (Gürsel, 2017).

In addition to the limitations caused by their intellectual disability, these students may experience difficulties in learning mathematics concepts and skills due to ineffective instruction. Ineffective instruction can sometimes be related to instructional materials and materials and other times it can be caused by methods, techniques and strategies. Therefore, to teach mathematics concepts and skills to students with intellectual disabilities, teachers should make use of evidence-based methods and instructional materials and materials that have been proven to be effective.

Over the past 15 years, the field of special education has invested great effort and energy in establishing and disseminating evidence-based practices. The motivation behind these studies is to determine 'what works for whom under what conditions' and whether the effects differ according to any of these factors (Spooner et al., 2019). It is critical to use evidence-based practices that are known to be effective for students who need a longer time to achieve the targeted goals (Spooner et al., 2011). Delivering instruction with practices that are known to be effective has many benefits for students and teachers. Teaching with practices that have not been proven to be effective can create an exhausting process for both the student and the teacher. It may cause loss of time and effort, as well as cause students to think 'I cannot do this' and teachers may think 'I cannot teach'. Therefore, it is better to start teaching with evidence-based approaches.

Used in teaching mathematics in the field of special education and recognized among the evidence-based practices today, TouchMath is a technique whose effectiveness has been researched in many different disability categories, especially intellectual disability and learning disability. The TouchMath technique was developed by Janet Bullock, a primary school teacher, in 1975 (Alaaudein & Sahwan, 2014). As shown in Figure 1, according to this technique, there are touch points on the numbers 1–9 with fixed positions towards the direction of their drawing. While the numbers 1–5 have as many dots as their own values, there are circles around some dots on the number 6 and later. These circles mean that that dot will be counted twice (Cihak & Foust, 2008; Waters & Boon, 2011; Wisniewski & Smith, 2002). Before teaching mathematics through the TouchMath technique, the dots on the numbers should be taught to students (Simon & Hanrahan, 2004). After teaching the locations of the dots, the teaching of the target skill can begin.

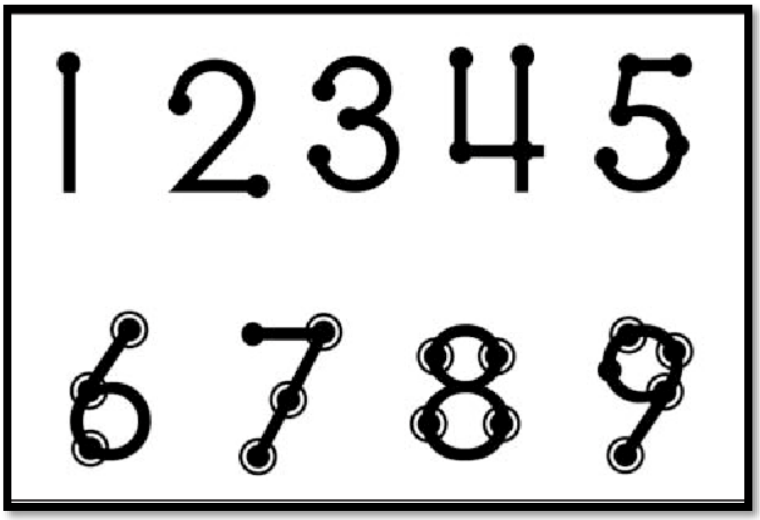

Figure 1

The Locations of The Dots on the Numbers According to the Touchmath Technique (Avant & Heller, 2011)

The TouchMath technique moves from the concrete to the abstract. In this respect, it corresponds to Bruner's theory of mental development. Touching the dots on the numbers serves for the concrete stage, seeing the numbers and the dots is on the visual stage and writing the numbers is for the abstract stage (Aydemir, 2017). This makes it easier to learn abstract mathematics. Another advantage of TouchMath is that students count the dots instead of finger counting while performing operations. By replacing finger counting, it prevents students with special needs from being noticed by their friends (Scott, 1993).

There exist several studies conducted through the TouchMath technique in the literature (Avant & Heller, 2011; Calik & Kargin, 2010; Cihak & Foust, 2008; Fletcher et al., 2010; Green, 2009; Newman, 1994; Rudolph, 2008; Simon & Hanrahan, 2004; Terzioğlu & Yıkmış, 2018; Valesco, 2009; Wisniewski & Smith, 2002; Yıkmış, 2016). When these studies are examined, it is seen that the effectiveness of this technique in teaching four operation skills, especially addition and subtraction, has been examined. However, there is no study in which the TouchMath technique was used in teaching problem-solving skills. Considering the importance of learning problem-solving skills in both school and daily life of students, the authors of the research wondered whether this technique would be effective in teaching this skill. Considering this, the purpose of this study is to examine the effectiveness of the TouchMath technique in teaching problem-solving skills to students with intellectual disability. The following research questions guided this study:

1. Is the TouchMath technique effective in helping students with intellectual disabilities acquire problem-solving skills?
2. After being instructed through the TouchMath technique, do students with intellectual disabilities maintain their performance in problem-solving skills after 10 and 20 days?
3. After being instructed through the TouchMath technique, can students with intellectual disabilities generalise their performance in problem-solving skills to different settings and materials?

2. Methodology

2.1. Participants

The participants for this study were recruited from a primary school in the city center of Bolu. In order for participants to learn the target skill; (1) the ability to understand the verbal instructions, (2) the ability to maintain their attention on a specific activity for at least 15 minutes, (3) the ability to read a paragraph composed of three sentences fluently and without mistakes, (4) the ability to do basic additions and (5) the ability to show the dots on the numbers were set as the selection criteria. To recruit participants, a primary school was visited and the special education teachers in this school were consulted. Students who can be suitable to teach the target skills were determined and they were observed in their classes. During the observation students were observed in terms of ability to follow the instructions and ability to maintain attention for at least 15 minutes. To evaluate their reading skills, short stories were given to students and comprehension questions were asked. To determine whether they can do the additions or not, a worksheet that includes 10 basic addition exercises was used. Students were expected to give correct answers to at least 90% of these questions. The participants were selected because of these procedures. The selected students went through teaching of the places of the points on the numbers according to the TouchMath technique. Additionally, before starting the intervention, written consents of the parents and students were received. The characteristics of these students can be seen in the next paragraphs by their codenames.

Sinan. Sinan is a 12-year-old male student who has been diagnosed with mild intellectual disability. He was identified as having a mild intellectual disability by the state clinic. Sinan'assessment indicated a mild intellectual disability, but a specific IQ score was not provided. He attends the special education class of his school. In addition, he attends a Special Education and Rehabilitation Center twice a week. He can read paragraphs that contain at least four sentences without mistakes and fluently. However, due to the type of his disability, he has difficulties in learning mathematical concepts and skills. Although he can do the basic addition, he cannot solve the word problems that include addition.

Ayşe. Ayşe is a 10-year-old female student with mild intellectual disability. Ayşe was identified as having a mild intellectual disability by the state clinic. Ayşe's assessment indicated a mild intellectual disability, but a specific IQ score was not provided. She attends the special education class of her school. In addition, 2 hours a week, she receives support from the Special Education and Rehabilitation Center. She can fluently read paragraphs that include at least three sentences and is able to maintain her attention for at least 15 minutes. However, because of the type of her disability, she has limitations in terms of learning mathematical concepts and skills. She can do the basic addition; however, she cannot solve word problems that include addition.

Şeyma. Şeyma is an 11-year-old female student who has been diagnosed with mild intellectual disability. Şeyma was identified as having a mild intellectual disability by the state clinic. Şeyma's assessment indicated a mild intellectual disability, but a specific IQ score was not provided. She attends the special education class of the primary school she is enrolled. In addition, she attends a Special Education and Rehabilitation Center twice a week. She can fluently and correctly read paragraphs composed of at least three sentences and she can also maintain her attention on an activity for at least 15 minutes. On the other hand, the type of her disability makes it difficult for her to learn mathematical concepts and skills. She can also do basic addition, nevertheless, she cannot solve word problems that include addition.

2.2. Setting

The subjects of the study attend the same school. Therefore, the setting is the same for each subject. Sessions were held in an empty classroom at the school. This class is approximately 20 square meters in size. In the classroom there was a table, two chairs, a bookshelf and a blackboard. A table and two chairs in the classroom were used throughout the research. Sessions were conducted with each student individually and took place 3 days a week. During the sessions, attention was paid to keep the environment quiet so that the student's attention would not be disturbed.

2.3. Practitioner

The intervention process of the study was conducted by a person other than the authors. The practitioner holds an MA in the field of special education and was a PhD student in the same department. The reasons why this practitioner was chosen were she wrote an MA thesis on teaching problem-solving skills and had many academic publications in which she investigated the effectiveness of the TouchMath technique. The first author of this study explained the steps of the experimental procedure with all the details to the practitioner and a teacher training session was conducted in several sessions. These teacher training sessions included detailed information on what the practitioner needs to do at the baseline level, intervention, maintenance and generalization sessions. Moreover, the data collection process was explained to the practitioner, the data collection materials were introduced and how this process should be conducted was explained using examples. During the training of the practitioner, the ethical principles specified in the literature were followed (Yıkmış, 2022; Yikmiş & Akbiyik, 2022). After these trainings, the practitioner performed the experimental process and collected the data.

2.4. Materials

Each session of the study included 10 problems. During the baseline, maintenance and generalization sessions worksheets with 10-word problems on addition, pencils and erasers were used. As for the intervention sessions, teaching activities were conducted with picture cards which were based on the TouchMath technique. The first author of the study prepared guidelines for the properties of the TouchMath picture cards, the types of problems and pictures to be included in these cards, as well as the size and thickness of the cards. Expert opinions were received on these guidelines and the final decision on the TouchMath picture cards was made in line with the expert opinions. The visualisation of the problems on cards was done by two university students who attend art teaching departments of a state university. After the images were prepared, they were covered with transparent plastic foil to make them more enduring, reusable, as well as to be able to write the solutions of the problems on them. These cards were prepared as 14.8 × 21 cm. In addition to these materials, a video camera and a data entry form were used to record the experimental procedures. A visualised TouchMath card can be seen in Figure 2. The word problem was written on the card shown in Figure 2 and it was used in teaching. The word problem written on the card in Figure 2 was 'There were 4 cows in a farm. 2 more cows were bought for the farm. How many cows are there now?'.

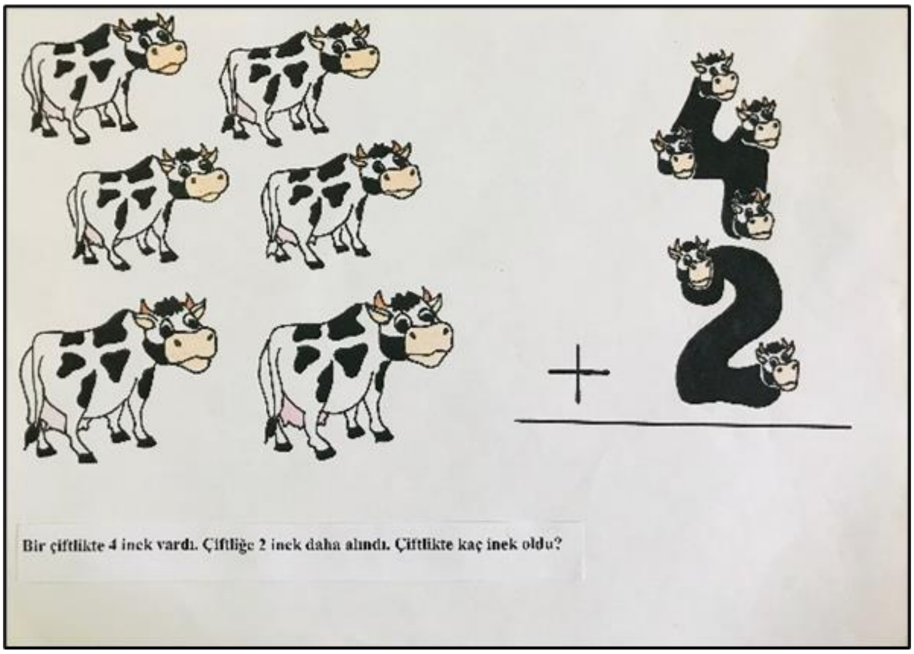

Figure 2

A Sample Problem Card

2.5. Dependent and independent variable

The dependent variable of the study is the level of addition problem-solving skills of students with intellectual disability. On the other hand, the independent variable is the teaching conducted with TouchMath technique. Students were expected to acquire the skill of solving addition word problems. These additions were limited with the operations whose results were maximum 10. In addition, target problems consist of problems with unknown results. In the intervention sessions of the study problem-solving skills were taught using TouchMath technique and after the teaching practice the student's performances were determined in the maintenance sessions. The analysis of the skills regarding the dependent variable is as follows: (1) The student reads the problem, (2) spots and tells what is given in the problems, (3) shows the operation on the problem card, (4) says the above number, (5) says the number below, (6) says the result by counting the dots on the numbers forward, (7) writes the result of the problem under the operation line, (8) crosschecks the result of the problem by counting the images on the cards.

2.6. Experimental design

This study adopted multiple probe across participants which is one of the single case research approaches that was adopted to determine the effect of the TouchMath technique on problem-solving skills. The baseline sessions were started simultaneously for each participant. Baseline sessions were conducted for at least three sessions until obtaining stable data. After getting stable data from the first participant (i.e., Sinan), intervention sessions with the TouchMath technique were started for this student. After Sinan met the mastery criterion (i.e., three sessions of 80% or higher), the second student's (i.e., Ayşe) intervention phase started. Similarly, after Ayşe met the mastery criterion, the intervention phase for Şeyma, who is the last student, started.

2.7. Procedure

This study consists of four phases baseline, intervention, maintenance and generalization sessions. Before starting the experimental procedure, the participants of the study were trained regarding the places of the dots on the numbers according to the TouchMath technique. These training programs are maintained until students learn the places of the dots. The training sessions were conducted through TouchMath poster and cards. After the training sessions students were given worksheets that include numbers without dots. They were asked to draw/color the dots on the numbers. The training was maintained until students correctly drew the locations of dots on all of the numbers. After students learned the places of the dots, the experimental procedures started with baseline sessions.

2.7.1. Baseline

Each student was asked to solve the 10 problems on the worksheets. The practitioner carried out the process one-on-one with each student. She sat next to students and put the worksheet on the desk. She instructed me to students as 'Solve these problems'. The correct, incorrect and neutral answers of students were recorded on the data entry form. At this stage, the practitioner did not provide any clues to students and asked them to complete the worksheets independently. The baseline sessions lasted minimum three sessions for each participant.

2.7.2. Intervention

After obtaining stable results in the baseline sessions of the first student the teaching of the target skill began. In the intervention sessions, students with intellectual disability were subjected to the teaching of problem-solving skills through the TouchMath technique. Intervention sessions were held in three sessions per week and these sessions were one-on-one with the student. Before starting the teaching, the practitioner showed the problem cards and talked about them in order to attract students' attention to the lesson. After sharing the purposes and importance of the lesson with the student, intervention sessions started. Intervention sessions followed these steps (The steps of the intervention sessions were explained according to the 'There were 4 cows in a farm. 2 more cows were bought for the farm. How many cows are there now?' problem.): (1) the practitioner and the student sit side by side, (2) the practitioner puts the visualised TouchMath card that can be seen in Figure 1 in front of the student, (3) After giving students the instructions as 'Now, let's look at the card in front of us and read the problem'. The practitioner waited for the student to read the problem, (4) after the student read the problem, the practitioner asked for the baseline (4 cows) and change (2 cows) amount of the problem. The student's correct answers were reinforced saying 'Well done!'. When the student gives an incorrect answer or did not respond the practitioner told the starting point and the change in number herself, (5) these amounts were shown to students on the problem card, (6) the practitioner attracted the students' attention to the places of dots on the numbers, she pointed the number 4 which corresponded to 4 cows and the number 2 which corresponded to 2 cows, (7) the practitioner instructed the student as 'Let's count the dots on the number above' and expected the student to count the places of number, (8) when the student counted by touching the cow images on the dots (student counting as 1, 2, 3 and 4), the practitioner asked the student to count by adding the number of the dots below to the number of the dots above, (9) the student counted from 4 by touching the dots with cow images adding the number 2 which is placed below, (10) student wrote the result as 6 on the problem card, (11) the correct answer of the student was reinforced verbally, (12) after the end of the trials in the sessions the practitioner reinforced the student saying 'Today we studied problem-solving skill with dots with images, thank you for your participation'. and gave the reinforcer she had promised at the beginning of the session.

2.7.3. Maintenance

Maintenance sessions were conducted 10 and 20 days after the completion of the intervention session. In the maintenance sessions the practitioner and students worked on a one-on-one basis. The maintenance sessions were held like baseline sessions. During the maintenance sessions students were given a worksheet with 10 problems whose results were unknown. The student was expected to do these problems independently. The practitioner did not provide any clues in the maintenance sessions. The reactions of students towards the problems were recorded on the data entry form.

2.7.4. Generalization

Generalization sessions were held to determine whether the participants can generalise the target skill to different material or setting. Different materials were prepared to use during the generalization sessions. Different types of problems were included in this tool set. In addition, the generalization sessions were held in the student's classroom. A worksheet that includes 10 different problems was given to the student. The practitioner asked the student to solve these problems. The practitioner did not react to the correct or incorrect answers of the student. The student was expected to complete the worksheet independently. The student's reactions to the problems during the generalization sessions were noted on the entry form.

2.8. Data collection

The effectiveness data were collected through data entry forms during the baseline, intervention, maintenance and generalization sessions to evaluate the performances of the participants. The data entry form was developed and consulted to the field experts. These forms were prepared to record the correct or incorrect reactions of students. The student's responses to the problems were recorded on these forms. During the data collection there was a worksheet containing 10 problems in front of students and in front of the practitioner, there was a data entry form. After the student was instructed as 'Look at your paper and solve the problems'. each of the answers given by the student was recorded by the practitioner.

2.9. Data analysis

The effectiveness data of the study were analysed through graphical analysis. The collected data were converted into the form of a line graph using a specialised computer program. The elements such as the students' pseudonyms, the number of sessions and the percentage of correct responses were presented on the graph. During the analysis of effectiveness, the correct answer percentages of each student at the baseline level and their correct answer percentages in the evaluations done after the intervention sessions were compared. The correct reaction percentages of students in the baseline level were expected to increase gradually after the intervention started. Th data collected in the maintenance and generalization sessions were analysed similarly. After they gained the target skills students were expected to maintain after a while, with different materials and in different environments. The data gathered in these sessions were also included in the graph. Students' correct response percentages in the baseline level, maintenance and generalization sessions were compared and interpreted.

3. Findings

In this study, the effectiveness of the TouchMath technique in teaching problem-solving skills to students with intellectual disability was examined. In addition, the maintenance and generalization effects of the TouchMath technique were also investigated. The data collected during the experimental process of the study were indicated in Figure 3. In the figure, the horizontal axis shows the number of sessions while the vertical axis shows the correct response percentages of students. This figure was visually analysed to determine whether the technique was effective in teaching problem-solving skills. For an effective intervention, it was expected that the performance of students in the baseline phase would increase after the independent variable was applied in the intervention phase. The effectiveness, maintenance and generalization findings of the study are explained in detail under the following headings.

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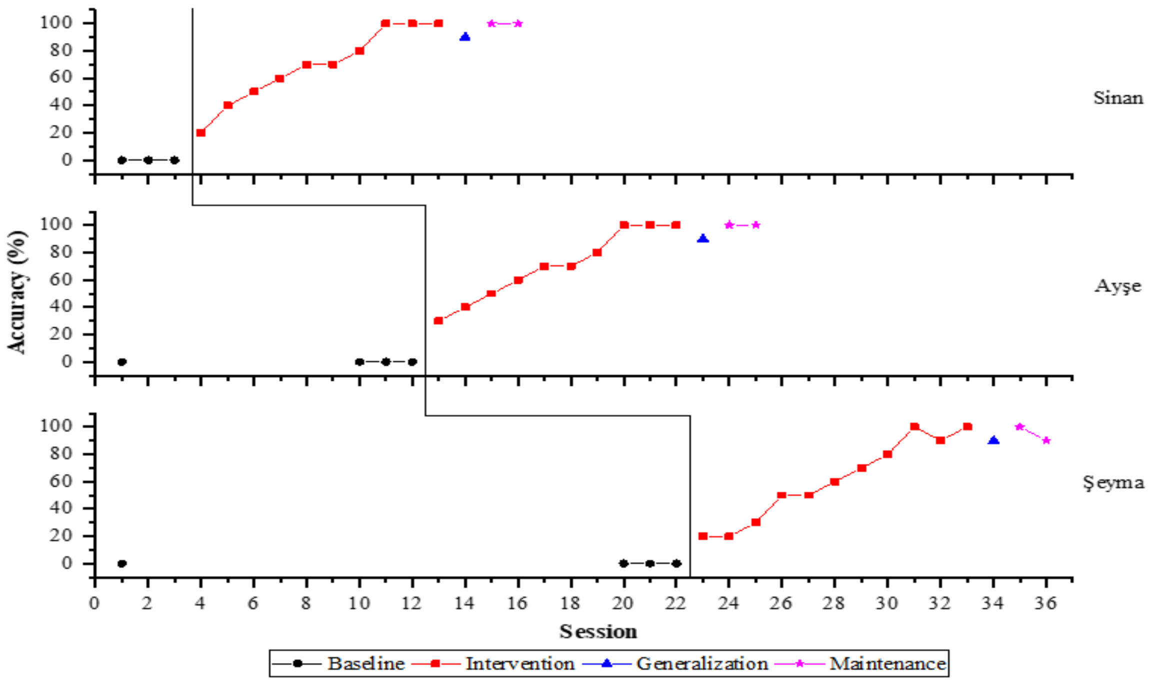

Figure 3

Students' Correct Response Percentages in the Baseline, Intervention, Maintenance and Generalization Sessions

3.1. Effectiveness findings

Sinan: When Figure 3 is examined, it is seen that Sinan gave correct responses at the level of 0%, 0% and 0%, respectively, in the baseline sessions. Based on this result, it is understood that this student did not answer any of the ten problems presented to him in the baseline sessions correctly. The intervention phase was started for Sinan when stable data were obtained from three consecutive sessions in the baseline phase. In the intervention phase, the TouchMath technique was used and teaching was carried out through the prepared picture cards. In the daily probe sessions held after the intervention sessions, Sinan gave the correct response as 20%, 40%, 50%, 60%, 70%, 70%, 80%, 100%, 100% and 100%, respectively. A total of 10 intervention sessions and 100 trials were carried out in the teaching of problem-solving skills to Sinan. Regarding this student, the target criterion (100%) was reached in the eighth intervention session. Teaching was continued until the target criterion was achieved in three consecutive sessions. In addition, when the target criterion was reached regarding Sinan baseline data began to be collected for Ayşe.

Ayşe: When Figure 3 is examined, it is seen that Ayşe gave correct responses at the level of 0%, 0%, 0% and 0% in the baseline sessions, respectively. Considering this result, this student did not answer any of the ten problems presented to her in the baseline sessions correctly. The first of these sessions shows the probe started simultaneously with three students. The other three are the baseline performance obtained after reaching the target criterion in the intervention phase for Sinan. The intervention phase was started for Ayşe when stable data were obtained from three consecutive sessions in the baseline phase. In the intervention phase, the TouchMath technique was used and teaching was delivered via the prepared picture cards. In the daily probe sessions held after the intervention sessions, Ayşe gave the correct response as 30%, 40%, 50%, 60%, 70%, 70%, 80%, 100%, 100% and 100%, respectively. A total of 10 intervention sessions and 100 trials were carried out in the teaching of problem-solving skills. Ayşe reached the target criterion (100%) in the eighth intervention session. Teaching this student was continued until the target criterion was achieved in three consecutive sessions. In addition, when the target criterion was reached for Ayşe, baseline data began to be collected for Şeyma.

Şeyma: It is indicated in Figure 3 that Şeyma gave correct responses at the level of 0%, 0%, 0% and 0% in the baseline sessions, respectively. This result shows that this student did not answer any of the 10 problems presented to her in the baseline sessions correctly. The first of these sessions shows the probe started simultaneously with three students. The other three are the baseline performance obtained after reaching the target criterion in the intervention phase for Ayşe. The intervention phase was started for Şeyma when stable data were obtained from three consecutive sessions in the baseline phase. In the intervention phase, the TouchMath technique was employed and teaching was carried out through the prepared picture cards. In the daily probe sessions held after the intervention sessions, Şeyma gave the correct response as 20%, 20%, 30%, 50%, 50%, 60%, 70%, 80%, 100%, 90% and 100%, respectively. A total of 11 intervention sessions and 110 trials were conducted in teaching problem-solving skills to Şeyma. Şeyma reached the target criterion (100%) in the ninth intervention session. Teaching was delivered until the target criterion was achieved in three consecutive sessions.

3.2. Maintenance findings

In this study, it was investigated whether students with intellectual disabilities could maintain the problem-solving skill 10 and 20 days after the end of the teaching through the TouchMath technique. To this end, maintenance data were collected. The data obtained were displayed in Figure 3. As seen in Figure 3, in the maintenance sessions held after the intervention sessions through the TouchMath technique were completed, Sinan gave 100%–100%, Ayşe 100%–100% and Şeyma 100%–90% correct responses, respectively. These findings show that students maintain the skills they have acquired for a while after the teaching is completed.

3.3. Generalization findings

Another major aim of the study was to examine the effect of generalising problem-solving skills across different settings and materials after the participant students acquired the target skill through the TouchMath technique. To this end, generalization data were collected. The data obtained are given in Figure 3. As presented in Figure 3, all three students gave correct responses at the 90% level in the generalization sessions held after the intervention sessions through the TouchMath technique were completed. These findings reveal that students can generalise the problem-solving skills taught to them through the TouchMath technique across different settings and materials.

Overall, this study showed that the TouchMath technique is effective, permanent and generalisable in teaching problem-solving skills to students with intellectual disabilities. When Figure 3 is examined, the performances of students in the baseline phase and that of in the intervention phase can be compared. As a result of this comparison, it is seen that students did not have problem-solving skills at the beginning, but their performance on the target skill increased after the independent variable started to be taught. This also applies to maintenance and generalization sessions.

4. Discussion and conclusion

This study attempted to determine whether the TouchMath technique is effective in teaching problem-solving skills to students with intellectual disability; whether this skill is maintained 10 and 20 days after the end of the instruction; and whether this skill can be generalised to different settings and materials. The findings of the current study revealed that (1) TouchMath technique is effective in teaching problem-solving skills to students with intellectual disability, (2) students can maintain the permanence of their problem-solving skills 10 and 20 days after the end of the instruction and (3) all the participating students generalise this skill to different setting and tool.

The first finding of the study is that the TouchMath technique is effective in teaching problem-solving skills to students with intellectual disability. This result is consistent with other studies in the literature in which the TouchMath technique is employed in teaching mathematics concepts and skills to students with special needs (Avant & Heller, 2011; Calik & Kargin, 2010; Cihak & Foust, 2008;

Fletcher et al., 2010; Green, 2009; Newman, 1994; Rudolph, 2008; Simon & Hanrahan, 2004; Terzioğlu & Yıkmış, 2018; Valesco, 2009; Wisniewski & Smith, 2002; Yıkmış, 2016). When these studies are examined, it is seen that the participants are from different diagnostic categories such as intellectual disability and an autism spectrum disorder. In addition, in these studies, four operations skills were generally taught. However, no research was found in which the TouchMath technique was used in teaching problem-solving skills to students with special needs. In this respect, it is safe to claim that the present study has potential to contribute to the field.

When the maintenance findings of the research are examined, it can be stated that the TouchMath technique provides permanent learning in teaching problem-solving skills to students with intellectual disability. The findings indicated that students maintain their acquired skills 10 and 20 days after the end of the instruction. This finding of the study is congruent with the findings of previous studies investigating the permanence of the TouchMath technique in teaching mathematics to students with intellectual disability (Scott, 1993; Calik & Kargin, 2010; Eliçin et al., 2013). However, the maintenance findings of one study are inconsistent with the current study and other studies. In that study, the effectiveness and permanence of the TouchMath technique in teaching money calculation skills to three students with intellectual disability, aged between 14 and 15, were examined (Waters & Boon, 2011). The result of that study revealed that the TouchMath technique was effective and yet there were limitations in the maintenance sessions for some time after the instruction. For this reason, the permanence of the TouchMath technique in teaching mathematical concepts and skills to students with intellectual disability should be supported by future studies.

Having acquired the target skill, the participating students were able to generalise problem-solving skill to a different environment and tool. This finding of the current study corresponds to other studies in the literature (Badır-Polat & Yıkmış, 2019;Calik & Kargin, 2010; Eliçin et al., 2013; Scott, 1993; Simon & Hanrahan, 2004). In those studies, it was found that the participants with intellectual disability were able to generalise the targeted various mathematical concepts and skills acquired through the TouchMath technique to different situations.

This study is the first to use the TouchMath technique with visuals in teaching problem-solving skills to students with intellectual disability. TouchMath is a technique that includes visuality. Students' seeing dots on numbers serves as the visual stage of Bruner's theory of cognitive development (Vinson, 2004). In this study, the visuals of the items mentioned in the problem statement were used instead of the dots. It can be claimed that it can contribute to the effectiveness of the visualised TouchMath technique. What's more, the teaching process has become more fun and interesting for students.

Finally, a few suggestions for practice and further research can be mentioned. Teachers working in this field can make use of the TouchMath technique in teaching mathematical concepts and skills. In order for teachers to use this technique more effectively, they can be trained on this technique. Besides, the effectiveness of the TouchMath technique in teaching different mathematical concepts and skills with different participant groups can be investigated.

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