Id: 1169494

Participatory Educational Research (PER)
Vol.10(1), pp. 237-250, January 2023
Available online at http://www.perjournal.com
ISSN: 2148-6123
http://dx.doi.org/10.17275/per.23.13.10.1

An analysis of the effects of the Early Mathematics Intervention Program on early mathematics skills of pre-school children at risk

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Article history

Received:
01.08.2022

Received in revised form:
30.10.2022

Accepted:
03.12.2022

Key words:
children at risk, early intervention programs, early mathematics skills, mathematical achievement, sequential activities

Supporting all children, particularly children with special needs, in the field of mathematics is important for their development. Therefore, it is necessary to develop and implement the necessary early intervention programs in relation to mathematics education. Studies indicate that early mathematics education intervention programs provide an increase in children's mathematical knowledge levels improving their mathematics performance. It is also reported that such programs are effective in increasing the mathematical achievement of children at risk and that their effects may last for a longer time. Therefore, it is considered important to support the mathematics skills of the children in the risk group with early mathematics intervention programs, to identify the children whose mathematical skills are deficient or who have not acquired these skills sufficiently in the early period. In this study the is aim to reveal the effectiveness of an intervention program developed in relation to the early mathematics skills to improve such skills of children in the pre-school period between 60-72 months of age, who are in the risk group in terms of mathematics skills. In this study, the multiple probe model inter-subjects, which is one of the single-subject research models, was used. The participants of the study were three kindergarten students from three different schools in Kırşehir, Türkiye. The study was carried out in the special education center located in the said city. The data collection tool is an early mathematics intervention program developed for teaching early mathematics skills. When we look at the findings obtained from the study in general, it appears that the early mathematics intervention program was effective in improving the early mathematics skills of all three students. For this reason, priority should be given to supporting the development of early mathematics skills in all children attending pre-school education institutions.

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Introduction

Pre-childhood period is a significant and sensitive developmental period for children aged between four and six. Because in this period children's physical and psychological functions which are necessary to respond to environmental stimuli improve. In addition, the foundation of their skills and abilities is laid in this period (Mariyana, Listiana and Zaman, 2019). In the pre-school period, children acquire some characteristics that are very important in terms of physical, social, emotional, cognitive and language development and have very significant effects on their future life (Uyanık and Kandır, 2010). Certain conditions and stimuli are required for the children's growth and development to continue (Mariyana, Listiana and Zaman, 2019). The National Council of Teachers of Mathematics (NCTM) (2000) and the National Association for the Education of Young Children argue that a high-quality, engaging and accessible mathematics education for children aged three to six is a critical foundation for children's future mathematics learning.

Academic skills are acquired by children during the pre-school education period. Such skills include early literacy and mathematics skills (Uyanık and Kandır, 2010). Of them early mathematics skills are defined as the ability to use information for different purposes and situations, which, therefore, refer to the mathematical reasoning skills (French, 2014). Preschool children's early mathematics skills are divided into three groups: counting skills, numerical relations, and arithmetic operations. These skills are closely related, but different from each other. (Jordan, Kaplan, Locuniak and Ramineni, 2007).

Research suggests that children's conceptual understanding of mathematics when they start school predicts their future mathematics and reading achievement and that it is one of the important predictors of early mathematics skills and future mathematics achievement (Alexander and Entwisle, 1998; Pagani, Fitzpatrick, Archambault and Janosz, 2010). In addition, early mathematics skills include critical thinking, conceptual understanding and reasoning skills that are valuable across the academic spectrum (Brandon, Melissa and Jennifer, 2020). Quantitative skills such as counting, size comparison, classification of objects, counting skills, knowledge of numbers, memorization of numbers, and ordering which may be acquired before the learning of the formal mathematics are also among the early mathematics skills (Balfanz, Ginsburg and Greenes, 2003). Skills such as arithmetic, counting ability, attention and working memory are among the predictors of the children's early mathematics skills (Cirino, Child and Macdonald, 2018).

Mathematics skills consist of a series of difficult and complex processes (Waltemire, 2018). Therefore, children may experience difficulties and delays in acquiring the basic concepts and skills of mathematics (Jordan, Kaplan, Ramineni and Locuniak, 2009; Mazzocco, 2007). Such problems seen in the early period increase throughout the school years and can cause difficulties in mathematics learning (Fletcher, Lyon, Fuchs and Barnes, 2007). For this reason, it is reported that children who encounter mathematical concepts in the early period may better understand and use these concepts and may become more successful in terms of their mathematics skills in the future (Geary, Berc and Koepke, 2015). However, children's ongoing problems with mathematics are considered to be as one of the predictors of not graduating from high school or having university education (Duncan and Magnuson, 2011). In fact, children's early mathematics skills have even greater predictive power than early literacy skills in predicting their reading success (Duncan, Dowsett, Claessens, Magnuson, Huston, Klebanov and Japel, 2007; Lerkkanen, Rasku-Puttonen, Aunola and Nurmi, 2005). In addition, the intense exposure of children to mathematics skills in the preschool period increases their language skills in the future school years (Sarama, Lange, Clements and Wolfe, 2012). In short, the mathematical

reasoning skills are basic cognitive skills (Clements and Sarama, 2009) and considering the importance of mathematics for academic success in all subjects, children need to learn the basic concepts and skills of mathematics in the early period (Sadler and Tai, 2007).

Given the critical importance of early mathematics skills, supporting the development of these skills in young children should be seen as a priority in order to ensure that all children are successful and have equal opportunities at schools. Both parents and teachers have roles to play in supporting the children's early mathematics development. Parents can encourage the development of mathematics concepts early on, even before their children start school. Early childhood educators can adopt an approach to use the developmentally appropriate strategies to improve children's early mathematics skills (Brandon, Melissa & Jennifer, 2020).

Supporting all children, particularly children with special needs, in the field of mathematics is important for their development. Therefore, it is necessary to develop and implement the necessary early intervention programs in relation to mathematics education. Thompson and Nelson (2001) argue that such interventions that start at an early age and continue for a long time are effective in the development of children's potential. Intervention programs in mathematics education consist of sequential activities such as counting, numbers, operations, shapes, measurement, and pattern, which are prerequisites of one another. These sequential activities can be employed in different environments such as home and pre-school education institutions (Ginsburg, Lewis & Clements, 2008).

Studies indicate that early mathematics education intervention programs provide an increase in children's mathematical knowledge levels improving their mathematics performance (Huntsinger, Jose and Luo, 2016; Jordan, Dyson and Glutting, 2011; Melhuish, Sylva, Sammons, Siraj-Blatchford, Taggart and Phan, 2008; Starkey, Klein and Wakeley, 2004). It is also reported that such programs are effective in increasing the mathematical achievement of children at risk and that their effects may last for a long time (Whatts, Clements, Sarama, Wolfe, Spitler and Bailey, 2016). Altındağ Kumaş (2019) examined the effectiveness of a large mathematics education program for young children at risk on their early mathematics skills. It is found that the experiment students who took part in the program had much higher scores than the control subjects in a test which evaluated their mathematical development. Çetin (2019) developed an early literacy skills training program, and after implementing it the study concluded that it has significantly positive effects on the kindergarten students' early mathematics skills. Çakır (2019) compared the working memory performance of the kindergarten students with different levels in early mathematics skills. In the study, the relationships between early mathematics skills and the working memory were examined, and it is concluded that there was a low and moderate relationship between the early mathematics skills and sub-components of the working memory and general working memory performance, except for visual short-term memory. In the study, the groups were also divided based on their mathematics achievements as the groups of low, medium, and high achievers. It is found that the early mathematics skills were developed at a significant level only in the group of children with high mathematics achievement. Özturhan (2021) analysed the recognition of the geometrical shapes, preservation skills and other early mathematics skills of the children aged six. The study showed that there is a significant correlation between their early geometry skills and early mathematics skills and between number preservation skills and early mathematics skills.

Early mathematics skills form the basis of children's future mathematics achievement, and therefore, it is important to support their mathematics skills in the early period (Servi, 2021).

Because the school achievement of children who are not adequately supported in the preschool period is negatively affected and approximately 5% of school-age children have learning difficulties in the field of mathematics (Olkun, Altun and Şahin, 2015). Failure to support all developmental areas of children in the early period may make it very difficult or even impossible to overcome deficiencies in other periods of life (Bozarslan and Batu, 2014).

Educational services offered to children with special needs in Turkey start in the pre-school period. The quality education received during this period may determine the type and level of school where children in the risk group can continue their education. Children in the risk group are generally children who cannot show academic success due to reasons such as low socio-economic level, neglect, and abuse, drifting into crime, living on the streets, war, migration, chronic diseases and needing special education. Such children generally have many problems in their social and emotional development. Identifying the children in the risk group before they start primary school, that is, in the pre-school period, and making them to participate in the early mathematics intervention methods positively affects the degree of being affected by their disability. Therefore, it is considered important to support the mathematics skills of the children in the risk group with early mathematics intervention programs, to identify the children whose mathematical skills are deficient or who have not acquired these skills sufficiently in the early period. The aim of this study is to reveal the effectiveness of an intervention program developed in relation to the early mathematics skills to improve such skills of children in the pre-school period between 60-72 months of age, who are in the risk group in terms of mathematics skills. Therefore, the study attempts to answer the following research questions:

(1) Is the intervention program addressing the early mathematics skills effective in improving the early mathematics skills of the children at risk who are aged between 60-72 months?
(2) How are the mothers' views (social validity) for teaching early mathematics skills to their children in the pre-school period?

Method

In this section, information about the participants, setting, data collection tools, research model, data collection procedure and data analysis are given.

Participants

The participants of the study were three kindergarten students from three different schools in Kırşehir province of Türkiye. In selecting the children, first, the legal permissions were granted. Then the volunteers were identified through the school administrations, teachers, and parents of the children. These children were evaluated using the mathematical thinking skill assessment tool for kindergarten children. In the evaluation of the early math skills assessment tool, a study group was formed from children at risk. In addition, the children were those who could follow the instructions given and direct their attention to the activity for at least 10 minutes.

Arın is the first participants and is aged 68 months. He can do self-care skills himself, communicate with his friends in the classroom and participate in games. İrem is 69 aged months and is very silent. She does not communicate much verbally while participating in the activities. Doğukan, on the other hand, is an active child. He has difficulty in sitting in his desk for a long time during the activities and constantly loses his belongings. He is often warned by the teacher for not following some rules.

Setting

The study was carried out in the special education center located in the city. The classroom where the study was carried out was a 21 square-meter rooms, and there was a whiteboard, a table and a chair suitable for the age and physical characteristics of the participants where they can sit and do activities. All sessions were carried out with one child at a certain period, and two sessions per day were done. The sessions were recorded by a student attending the faculty of education by a camera placed in the classroom. The data on the implementation of the intervention program for early mathematics skills and the follow-up sessions were collected at the special education center.

Data collection tool

The data used to choose the participants were collected at the schools. The data collection tool is an early mathematics intervention program developed for teaching early mathematics skills. The implementation reliability and inter-observer reliability of this tool were ensured by using video recordings, early mathematics skills program sessions for the performance of the participants, the end-of-training examinations and follow-up data forms.

Research model

In this study, in which the effectiveness of an intervention program developed for early mathematics skills in supporting the early mathematics skills of children between 60-72 months of age in the preschool period was examined, the multiple probe model inter-subjects, which is one of the single-subject research models, was used.

Dependent variable

Early mathematics skills are the dependent variable of the study. One of the early mathematics skills is number recognition. The number recognition skill includes the relationship between object groups from 1 to 20, the ability to distinguish numbers and order numbers. Another early mathematics skill is the ability to add and subtract using objects from 1 to 10, which are specifically called addition-subtraction skills. The grouping skills refer to the ability to group objects between 6-10 depending on any feature. The pattern-making skill is the formation of a pattern consisting of three objects. The last early mathematics skill is the ability to recognize geometric shapes and to create new shapes by combining the existing shapes.

Independent variable

The independent variable of the study is the intervention program designed to develop early math skills. It is an intervention program developed in accordance with the modular approach. In the program eight activities were developed for each skill: number recognition, addition, subtraction, grouping, pattern, and early geometry skills. The visual and mathematical tools to be used in the activities were examined by three researchers who are experts in the field. The activities used in the intervention program were designed with paper, pencil and auxiliary materials and game setups for children to have fun. The first three of the activities were developed as more basic activities and were designed to prepare children for the related skill. The content of the activities includes mathematical visuals, matching cards, animal figures, images, etc. Although the activities were developed based on the modular programming approach, the activities developed for each skill were developed in a complementary and holistic manner. Direct instruction method was used in presenting the activities to the students.

The instructions given during the instruction were developed for all activities, and two expert lecturers examined all the activities.

Implementation

The implementation process consisted of four sessions. These stages are as follows: baseline sessions, probe sessions, training sessions, and follow-up sessions. The reinforcers used were determined for the children, and social reinforcement was used based on the feedback received from the parents.

At baseline stage, the data were collected in order to obtain information about the participants' performance in regard to their early mathematics skills. In the training sessions, some concepts and other related mathematics topics were taught using the direct instruction technique and the early math skills intervention method.

Baseline sessions

These sessions were planned to determine the participants' early mathematics skills performance and were conducted simultaneously with all children.

In the collection of data at this level, the items in the early mathematics skills assessment tool were asked to the participants, and their correct and incorrect answers were recorded in the data form. The correct answers were coded as 1 and the wrong answers as 0. Based on these, total scores for all skills were found for each participant. The results are presented in the chart.

Probe sessions

These sessions were carried out with all participants at the end of the instruction to determine their performance levels about the skills which had been taught. In the probe sessions, it was expected that the participants would have results similar to those at the end of the instruction, and that the participants who did not take part in the teaching sessions would have similar results to the baseline data. All probe sessions were conducted similarly to baseline sessions.

Training sessions

Teaching sessions were carried out by the expert and two activities were carried out every weekday. The activities continued until the participants did the activity independently. At the end of each session, the reinforcers which had been reported by the parents in the related form were given to the children. This stage, in which the activities were presented using the direct teaching method, consists of three steps: the stage where the teacher is a model (modelling stage), the implementation of the activity by guiding the child (guided practice), and the unguided practice (independence stage). A sample lesson plan for a teaching session on the ability to distinguish numbers is given as follows:

Activity title: Matching the number in the box with the number

Goal: to recognize the numbers

Materials: desk, nine boxes with different colours (There are beads of the same colour as the box inside each box), visuals of numbers with the same colour as each box.

Implementation of the activity: Each step of the activity was implemented as follows:

Modelling step: The teacher puts the visuals of the numbers, beads, and boxes on the study table to be a model for the child. Then he puts the number and box of the same colour side by side. He puts beads of the same colour in the box and shows each number to the child until the number visuals are finished.

Guided practice: The teacher and the child put the visuals of the numbers on the study table, the beads, and the boxes on the table. They put the number and the box of the same colour together side by side. They put the beads of the same colour in the box and the number next to the box. They complete each number in the same way until the number visuals are finished.

Independent practice: In this stage the child is asked to do the activity himself. He puts the number and the box of the same colour together side by side. He puts the beads of the same colour in the box and the number next to the box. He completes each number in the same way until the number visuals are finished.

Follow-up sessions

Follow-up sessions were carried out two weeks after the implementation and in five sessions.

Data collection

The data were collected in relation to three components. These were about the efficiency of the intervention program, social validity, and reliability.

Data collection about social validity

A form was developed to collect the data about social validity. It was administered to the participants and their parents. The form was reviewed by the field experts. It consisted of six items about the intervention programs and the participation of the children in the program.

Data collection about reliability

In the study two types of reliability data were collected, namely the reliability of the program implementation and the reliability between observers. A video showing 20% of the implementation stages of the program was watched by two observers who are experts in the field.

Data analysis

Data analysis on the effectiveness of the intervention program

In order to determine the effects of the activities developed for early mathematics skills on the participants' early mathematics skills, the correct responses of the participants were recorded. The data obtained before the implementation were compared with the data collected after the implementation of the intervention program. The data obtained in the study are discussed in the related section with graphics.

Data analysis about reliability

In this study, in order to ensure inter-rater reliability, first of all, two independent observers who are experts in the field were used. Video recordings showing at least 20% of the sessions in all activities in regard to each student were watched and evaluated by these two independent observers. Then, the data of the independent observers were calculated with the formula of Consensus \ Consensus + Disagreement X 100 which produced the inter-observer reliability for each session.

Independent observers were appointed for the reliability of the implementation. They watched the recordings of randomly selected sessions of each student and recorded them in the data recording form for the implementation reliability. Then, the reliability of implementation was calculated for each session by calculating the data of independent observers using the following formula: Observed Practitioner Behaviour \ Planned Practitioner Behaviour X 100.

Findings

Findings on reliability

The inter-rater reliability coefficient was found to be 100% for each session. Therefore, a desired reliability level was achieved for the dependent variable. The reliability of the implementation is found to be at the acceptable level for the activities towards all participants (85% and higher). Table 1 presents the findings on the reliability of the implementation.

Table 1. Reliability coefficients of the implementation components (baseline, training, probe and follow-up) for Arın, İrem and Doğukan

Participants	Beginning level	Training sessions	Probe			Follow-up
			1.	2.	3.	
Arın	% 85,7	% 100	% 98	% 98	% 100	% 100
İrem	% 88,3	% 100	% 98	% 99	% 100	% 100
Doğukan	% 87,5	% 100	% 100	% 100	% 100	% 100

Table 1 indicates that a desired and acceptable reliability level was achieved for the independent variable.

Findings about the efficiency of the intervention program

The findings about the efficiency of the intervention program were discussed in relation to the steps used in the implementation: baseline level, training level and follow-up level.

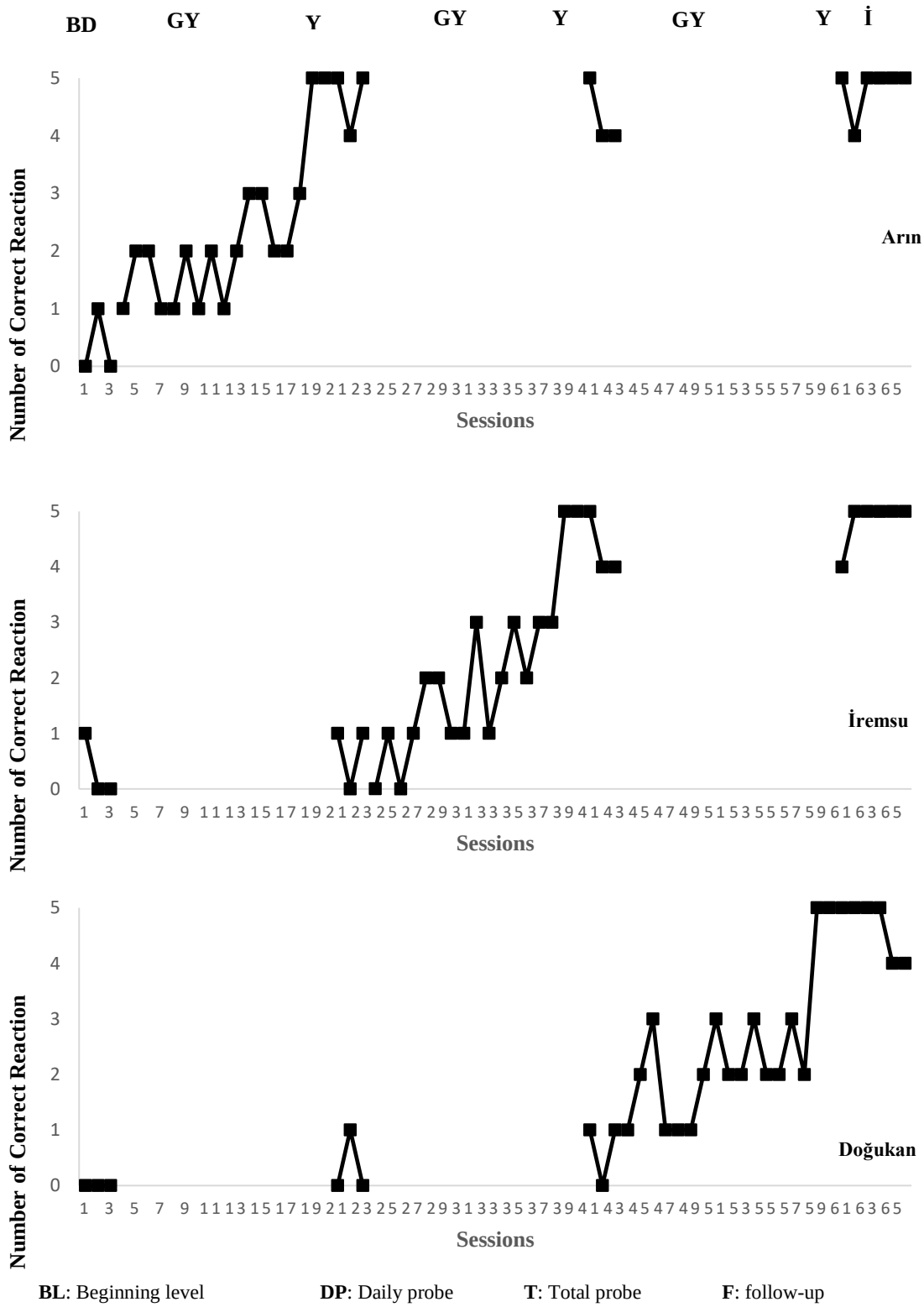
The first participant, Arın, gave an average of 0 correct answers regarding the number recognition skill at the baseline level, more specifically, in the skills of relating the object groups from 1 to 20, distinguishing numbers from 1 to 20, and ordering numbers up to 20. Regarding the addition-subtraction skill, this participant gave an average of 0 correct responses in the skills of adding items from 1 to 10 and subtracting items from 1 to 10. In regard to the grouping skill, the same participant gave an average of 0 correct answers in the grouping skills of 6-10 objects based on any feature. Regarding the patterning skill, this participant gave an average of 0 correct answers in the pattern-making skill consisting of 3 objects. Regarding the

geometry skill, this participant gave an average of 0 correct responses on recognizing geometric shapes and creating new shapes by combining them. Regarding these skills, while he answered only 2 of the 5 sub-skills correctly in the first skill acquisition session, he gave correct answers to all five sub-skills in the last daily probe session (implementation phase) after the teaching sessions.

İremsu, gave an average of 0 correct answers regarding the number recognition skill at the baseline level, more specifically, in the skills of relating the object groups from 1 to 20, distinguishing numbers from 1 to 20, and ordering numbers up to 20. Regarding the addition-subtraction skill, this participant gave an average of 0 correct responses in the skills of adding items from 1 to 10 and subtracting items from 1 to 10. In regard to the grouping skill, the same participant gave an average of 0 correct answers in the grouping skills of 6-10 objects based on any feature. Regarding the patterning skill, she gave an average of 0 correct answers in the pattern-making skill consisting of 3 objects. Regarding the geometry skill, this participant gave an average of 0 correct responses on recognizing geometric shapes and creating new shapes by combining them. Regarding these skills, while she answered only 2 of the 5 sub-skills correctly in the first skill acquisition session, she gave correct answers to all five sub-skills in the last daily probe session (implementation phase) after the teaching sessions.

Doğukan gave an average of 0 correct answers regarding the number recognition skill at the baseline level, more specifically, in the skills of relating the object groups from 1 to 20, distinguishing numbers from 1 to 20, and ordering numbers up to 20. Regarding the addition-subtraction skill, this participant gave an average of 0 correct responses in the skills of adding items from 1 to 10 and subtracting items from 1 to 10. In regard to the grouping skill, the same participant gave an average of 0 correct answers in the grouping skills of 6-10 objects based on any feature. Regarding the patterning skill, this participant gave an average of 0 correct answers in the pattern-making skill consisting of 3 objects. Regarding the geometry skill, this participant gave an average of 0 correct responses on recognizing geometric shapes and creating new shapes by combining them. Regarding these skills, while he answered only 2 of the 5 sub-skills correctly in the first skill acquisition session, he gave correct answers to all five sub-skills in the last daily probe session (implementation phase) after the teaching sessions.

When the findings are examined in general, it is seen that the early mathematics intervention program is effective in improving the early mathematics skills of children sampled in the study.



BL: Beginning level **DP**: Daily probe **T**: Total probe **F**: follow-up

Figure 1.

Findings about the efficiency of the intervention program

The social validity form was administered to the parents at the end of the teaching sessions. They stated that the authors fulfil their duties and responsibilities in the process of skills teaching that should be acquired for their children and that the training environment and materials were properly arranged and available at each teaching session. They also reported that

they always wanted their children to ask themselves questions about the skills they had learned. In short, the parents reported positive opinions about the intervention program indicating its social validity.

Discussion and conclusion

When we look at the findings obtained from the study in general, it appears that the early mathematics intervention program was effective in improving the early mathematics skills of all three students, and the skills acquired lasted as evidenced in the follow-up sessions. Considering the research findings, it is seen that all three students showed improvement in number recognition, addition-subtraction, grouping, pattern and geometry skills. In the light of these findings, it can be said that the early mathematics intervention program is effective in improving their early mathematics skills. Considering the findings about the number recognition skill, which is one of the early mathematics skills, it is seen that the activities are influential for all participants. This finding is consistent with the findings of the study conducted by Altındağ Kumaş (2019). Altındağ Kumaş (2019) found that the children in the experimental group were able to answer more questions about the recognition of numbers and could show them in different ways after participating in the training program.

Considering the findings about addition-subtraction, grouping and pattern skills, which are among the early mathematics skills, it is seen that the early mathematics intervention program was effective for all three subjects. These findings are consistent with the findings of other studies. For example, the results of the mathematics intervention prepared by Starkey, Klein, and Wakeley (2004) for 4-5-year-old children from the lower socio-economic level group revealed that the mathematical knowledge levels of the children from the lower socio-economic level improved to the mathematics levels of their peers from the middle socio-economic level. The results of the study by Çelik and Kandır (2013), in which they aimed to determine the effect of the Big Math for Little Kids Education Program on children's mathematical development, revealed that there was a significant difference between the experimental and control groups in favor of the former group. Therefore, the program has shown to be effective. The findings of this study on addition-subtraction, grouping and pattern skills are also similar to the findings of a study conducted in Australia. Gervasoni, Perry, and Parish (2015) aimed to determine the effect of a program called Let's Count on the mathematics learning of 3–5-year-old children. In the study it is found that the children in the experimental group who participated in the Let's Count program improved their ability to add and subtract with small objects, matching the patterns, correctly count at least 20 objects and rank numbers from 0-9. On the other hand, the results of an experimental study (Opel, Zaman, Khanom and Aboud, 2012) which was conducted to examine the effect of the Greater Mathematics for Young Children education program on children's mathematical skills (Opel, Zaman, Khanom and Aboud, 2012) revealed that the children who participated in the education program had higher scores in the fields of numbers, shapes, addition-subtraction, and patterns. Therefore, the findings obtained in this study are generally consistent with the previous findings. Therefore, through the early mathematics intervention program the early mathematics skills of children at risk in the pre-school period can be supported.

Concerning the findings about geometry skills, it is found that the early mathematics intervention program was effective in all three subjects. As Altındağ Kumaş (2019) stated, the participants matched the visuals of the shapes with their names and used the geometry terms such as triangle, square, rectangle, circle, pentagon and hexagon to describe the shapes. The results of Özturhan's (2021) study on early mathematics skills revealed that there is a significant

relationship between children's early geometry skills and their early mathematics skills. Therefore, the findings of the studies conducted by Altındağ Kumaş (2019) and Özturhan (2021) are consistent with the present finding.

The results of the study indicate that the early mathematics intervention program employed in this study positively supported the early mathematics development of the children at risk. This finding is consistent with the previous findings. For instance, Whatts et al. (2016) reported that early mathematics intervention programs are effective in increasing the success of children at risk and that their effects may last for many years. For this reason, priority should be given to supporting the development of early mathematics skills in all children attending pre-school education institutions. As a matter of fact, it is reported that the school success of children who are not adequately supported in the preschool period is adversely affected and that approximately 5% of school-age children have learning difficulties in the field of mathematics (Olkun, Altun and Şahin, 2015).

Based on the conclusions of the study it is possible to offer some suggestions to parents, teachers and researchers. For example, researchers can conduct new studies to compare the impact of different early mathematics intervention education programs on children's early mathematical development. They can administer such programs to large participant groups and conduct new studies that show the long-term effects of these programs. Teachers' knowledge about early mathematics can be improved. Therefore, in-service training programs can be organized to this end, and related seminars and conferences can be given. Thus, teachers can support the mathematical development of preschool children. Similarly, knowledge and skills can be transferred to parents about associating mathematics with daily life.

This study was carried out with three students. This limits the generalizability of the findings. Therefore, similar studies should be conducted with larger participant groups. The research findings are limited to three kindergartens in three schools affiliated to Kırşehir Provincial Directorate of Republic of Türkiye Ministry of National Education. Therefore, it is thought that it will be important to support the results with future studies which will be carried out in different provinces and regions.

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