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The Effect of a Basic Skills Program on Quantitative Reasoning and Mathematical Performance of Preschool Children

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Given the cumulative nature of mathematical skills, poor performance in basic skills leads to an inability to acquire more complex skills, and the difference in mathematical ability of individuals, compared to their peers, increases over time. The present study aimed to determine the effect of a basic skills training program on quantitative reasoning and mathematical performance of preschool children exposed to math problems. The present study was a quasi-experimental study with a pre-test-post-test design with a control group and a five-week follow-up. For this purpose, 60 children (40 girls and 20 boys) were assessed in an accessible manner using Raven's Colored Progressive Matrices Test, quantitative reasoning and mathematical performance. Findings confirm that implementing a basic mathematical skills training program for children improved their quantitative reasoning and mathematical performance. Basic mathematical skills in preschool play a decisive role in mathematical progress in later years. The connection of mathematics with life creates interest and motivation in students and better understanding and meaningful learning of mathematics in them.

Keywords: basic skills, quantitative reasoning, mathematical performance, preschool children

INTRODUCTION

Mathematics is one of the subjects in which proper performance is always of great importance to students and parents. However, children's problems in learning mathematics have been less studied compared to other areas of learning (such as reading and writing) (Flores et al., 2024). Empirical findings show that basic math skills in preschool are not only able to predict math progress in fifth grade (Berner et al., 2024) and overall academic achievement, but also performance (Outhwaite et al., 2024).

In the preschool period, acquiring mathematical concepts and skills is mostly through experiences gained in daily life (Karadeniz, 2014). In this period, learning mathematics is mostly done through listening to and speaking about concepts through experiences. As individuals interact with their environment, they start to acquire mathematical skills first physically and then mentally (Erdoğan and Baran, 2003). According to Bloom's

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research, a large part of mental development occurs in early childhood (Dursun, 2009). Based on this information, it is important to provide activities that will contribute to the development of mental skills in preschool and to provide opportunities for learning mathematical concepts. Since mathematics is continuous, the acquisition of mathematical concepts should be supported within a program throughout the preschool period (Erdoğan and Baran, 2003).

Akman (2002) states that the preschool mathematics program consists of the subheadings of problem solving, communication, connections, pattern, estimation, number knowledge, geometric concepts and spatial issues, measurement units, probability. Uyanık and Kandır (2010) examined the early academic skills covering preschool under two headings as reading-writing and mathematical skills. Problem solving, time, number, concepts related to money, measurement, geometric shapes and operations were included under mathematical skills. In another study, counting, measuring, shape, time and space concepts were listed among the subjects of mathematics in preschool (Kandır and Tümer, 2013). Durmuşoğlu (2013) stated in his study that the activities that should be done in order to provide mathematical skills to children in preschool are classification, matching, comparison and ordering. After the acquisition of these skills is ensured as a result of teaching, he suggested that studies should be done on number, simple addition and subtraction, geometry, measurement and graphics, respectively.

Quantitative reasoning is the ability to represent quantitative information and act on the representations to come to conclusions not previously known about the quantities represented or about the relationships between them(Terezinha et al., 2015). Mathematical performance is made up of a number of components, such as basic knowledge of numbers, memory for arithmetical facts, understanding of mathematical concepts, and the ability to follow procedures (Dowker, 1998). Charlesworth and Lind (2007) included mathematical skills such as concepts related to size, recognizing objects, naming them, matching, measuring and comparing, grouping, sorting, creating graphs, numbers, addition-subtraction, division, modeling, geometric and spatial logic under early academic skills. The comprehensive program called Big Math for Little Kids, developed by Greenes et al. (2004) for 4 and 5 year old children, consists of 6 sections: numbers, shapes, measurement, operations with numbers (addition-subtraction), patterns and logic (systematically repeated shapes, numbers, colors, rhythmic patterns, odd-even numbers, increasing-decreasing number sequences), spatial concepts (up-down, under-over, etc.) and stories.

Avcı and Dere (2003) grouped preschool mathematical skills under 7 main headings. The first of these is “mathematical thinking” and it is stated that it is necessary to develop mathematical thinking in the preschool period and to encourage the child to use the mathematical language. Secondly, “shapes” are included, and it is emphasized that the child begins to perceive shape and size in this period, and that since the games played are based on shapes, thinking develops.

Then, under the heading of “number”, it is explained that rhythmic counting, object counting, recognizing numbers, comparing quantities such as less-more, and comparing skills are developed. Under the heading of "operations", addition and subtraction operations are mentioned. In another heading, it is stated that children are familiar with "measurement" in this period. Other headings are "position in space", which deals with concepts such as distance, direction and place between objects, and "simple data collection and evaluation" with scientific processes based on object, picture and graphic results (Avcı and Dere, 2003).

Given the cumulative nature of mathematical skills, poor performance in basic skills leads to an inability to acquire more complex skills, and the difference in mathematical ability of individuals, compared to their peers, increases over time (Svane et al., 2023). Some researchers (Palabıyık & Işık, 2024) have reported that children who are in the bottom decile of the population in terms of mathematical skills at the beginning and end of kindergarten are 70% likely to remain in the bottom decile in terms of mathematical skills at the end of elementary school. Other researchers have also concluded that more than 75% of seven- and eight-year-old students with mathematical difficulties in the preschool years are at risk for cognitive mathematical disorder (Palabıyık & Işık, 2024).

The three to seven percent prevalence of math disorder, in addition to the negative and long-term consequences of math problems, plays a role in taking regular measures by identifying and designing timely intervention programs (Lambert and Espinas, 2014). The negative consequences resulting from weakness in basic math skills will be permanent and irreparable in the absence of intervention, so that the entire future educational and occupational conditions of the individual will be affected (Herzog and Casale, 2024). Such negative consequences will be even more devastating when the role of math skills in economic activities and effective participation in society is taken into account (Alptekin & Sönmez, 2022; Mostafa, 2013; Yurt, 2022).

The gap

Although teaching basic skills to children in pre schools are so important, studies are still are. In this context, given that teaching basic skills contributes to mathematics skills in early childhood, there is not enough place in education and detailed studies are not carried out on this subject.

Aims and Hypotheses

In this regard, the findings presented (Albayrak & Yazıcı, 2023 ; Büyükkıdık, 2023; Herzog and Casale, 2024) have shown how intervention in the preschool period strengthens the development of mathematical concepts and links education and informal knowledge in children. A review of the research background also indicates that after the emergence of educational problems, their elimination and reduction becomes more difficult (Büyükkıdık, 2023). Considering the essential role of basic mathematical skills on the one hand and the negative consequences of weakness in this skill, as well as the shortcomings in identifying and providing timely intervention services for children at risk of mathematical disorders, the present study aimed to determine the effect of a basic skills training program on quantitative reasoning and mathematical performance of preschool children exposed to math problems. Therefore, two hypotheses were tested:

1. The basic skills training program improves preschool children's math performance,

2. The basic skills training program improves preschool children's quantitative reasoning.

METHOD

Design

The present study was a quasi-experimental study with a pre-test-post-test design with a control group and a five-week follow-up.

Sample

The statistical population included all children aged five to six who received educational services in one of the preschool schools in Majmaah, Saudi Arabia. Given that in many studies, researchers limit the number of subjects in a sample due to time and financial constraints, in order to determine the minimum sample size required for quasi-experimental research in each experimental and control group, taking into account attrition, 15 people have been suggested (Gall et al., 2008). For this purpose, 60 children (40 girls and 20 boys) were assessed in an accessible manner using Raven's Colored Progressive Matrices Test (RCPM; Raven et al., 1998), quantitative reasoning and mathematical performance. The sample was randomly divided into two groups: experimental (n=30; 19 girls, and 11 boys), and control (n=30; 20 girls, and 10 boys). They were matched on age, IQ, quantitative reasoning and mathematical performance(pre-test stage). The T-values were not significant. The following tools were used to conduct the research:

Raven's Colored Progressive Matrices Test (RCPM; Raven et al., 1998): The instrument consists of a notebook composed of three series (A, AB and B), each containing 12 items, one on each page. Each item consists of drawings, with one missing piece, allowing only one correct answer. The individual is asked to complete it, choosing from six alternatives the one he/she believes to be correct. The instrument was applied according to the instructions contained in its manual to all children, and was applied collectively when indicated. In the applications of the MPCR Test and in accordance with the instructions, the application time was also recorded. The average test execution time was 6 min. 08 sec. (and a standard deviation of 1.04). Regarding the score: one point is assigned to each item related to correct answers and 0 to each error, with 36 being the maximum result that can be obtained, including the first item that is also subject to a score (Simões, 2000). Taking the results into account, and according to the test manual, it is considered that the most satisfactory method of interpreting the score obtained consists of weighting in percentage terms the existence of a similar score in people of the same age, thus making it possible to classify performances into various degrees.

Quantitative reasoning test. This test was developed particularly for this study. It contains: Classification (according to color, size , and shape), Spatial relationship (behind, on, under, or in front of), and pattern recognition. This test consists of 30 questions that are administered individually. After establishing familiarity and rapport with the child using cards and images of attractive games in the test, the child performs the test and is rewarded after completing each stage of the test. Each of the test items is assigned a score of zero or one. The range of scores for this test varies from zero to 30, with a test mean of 22 and a standard deviation of 3.2. A score of one standard deviation below the mean (below 18) on the test indicates poor mathematical performance. The reliability of this test using the test-retest method was reported to be 0.86, and the correlation of the test with mathematical academic achievement was reported to be 0.77. The test has acceptable psychometric properties and its Cronbach's alpha is 85.

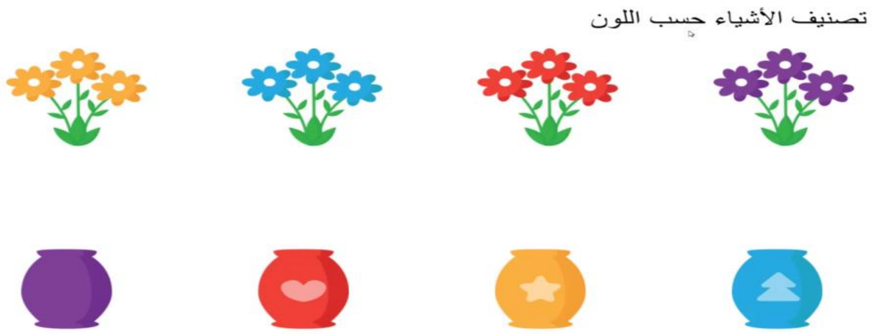

Figure 1
Classifying things according to color

Mathematical performance Test. This test was developed particularly for this study. it contains : counting ability, one-to-one relation, synchronous and shortened counting, Understanding comparisons. This test consists of 27 questions that are administered individually. After establishing familiarity and rapport with the child using cards and images of attractive games in the test, the child performs the test and is rewarded after completing each stage of the test. Each of the test items is assigned a score of zero or one. The range of scores for this test varies from zero to 27, with a test mean of 20 and a standard deviation of 3.8. A score of one standard deviation below the mean (below 13) on the test indicates poor mathematical performance. The reliability of this test using the test-retest method was reported to be 0.85, and the correlation of the test with mathematical academic achievement was reported to be 0.72. The test has acceptable psychometric properties and its Cronbach's alpha is 84.

Figure 2
Counting ability

Procedure

The target schools were paid a visit by the researcher. The purpose of the research was explained to the schools staff, and after the staff agreed, a meeting was held with the children's parents and the necessary explanation was provided about the importance of the research. Then, the parents completed a written consent form agreeing to their child's participation in the research. Initially, 80 children (42 girls and 38 boys) were assessed using using Raven's Colored Progressive Matrices Test (RCPM; Raven et al., 1998), quantitative reasoning and mathematical performance. Among them, 60 children (40 girls and 20 boys) who scored one standard deviation below the mean in quantitative reasoning and mathematical performance were identified as children at risk of mathematical disorder. Children were selected according to the inclusion and exclusion criteria and, after matching based on age and gender, were randomly and equally (30 children in each group) placed in one of two experimental (n=30; 19 girls, and 11 boys), and control (n=30; 20 girls, and 10 boys). Due to the effectiveness of the program in small groups, the children in the experimental group were divided into six subgroups of five children and were trained in 12 mathematical skills training sessions. The experimental and control groups participated in the intervention program (three times a week; 30 to 40 minutes per session), while the control group received only the usual programs (including educational programs based on preschool books, teaching concepts and counting in the form of games and drawings) in the preschool center. After the last educational session (fourth week) and five weeks after that, the experimental and control groups were again assessed using the quantitative reasoning and mathematical performance. In order to comply with ethical considerations, the educational games used in the intervention program were briefly implemented for the control group in two sessions.

The program content is organized according to two principles. The goal of each session is to teach concepts, organized from simple to difficult, with attention to "direct instruction" and "learning by doing" and includes: counting numbers like a parrot, identifying the sequence and order of numbers, one-to-one correspondence, identifying geometric shapes, pattern making, encountering the concepts of large, medium, and small, the concepts of similarity and difference, the concepts of less and more, counting backwards, leap counting of twos and threes, the concept of addition, orientation, the concept of volume, visual-spatial skills, the concepts of up and down, identifying the place value of numbers one and ten, measuring, three-dimensional geometric shapes, the concept of dividing and halving, completing the pattern, the concept of subtraction, and classifying numbers. The data were analyzed through analysis of variance with repeated measures using SPSS version 23.

Data analysis

Data were analyzed using SPSS 23.0. The effect of basic skills program on quantitative reasoning and mathematical performance in preschool children was assessed using pre- and post- testing design. The changes from pretest to posttest were tested by t-test ($p<.05$ was considered statistically significant). Covariance analysis test, and multi comparisons were used.

FINDINGS

Test for normality

Shapiro–Wilks test and the Kolmogorov–Smirnov test were used to test data normal distribution. The Sig. value of the Shapiro-Wilk Test was greater than 0.05, the data is normal. So the it is useful to use parametric statistic. The distribution is approximately normal. So the assumption of t-test was met.

To test hypotheses, mean and standard deviation of quantitative reasoning and mathematical performance scores in the pre- and post-tests for each group. As shown in

Table 1, differences existed between the mean scores of the experimental and control groups in the pre-test and post-test. Children in experimental group had higher scores in quantitative reasoning test (18.12 ± 0.874; 27.55 ± 0.687) than did those in the control group (18.44 ± 0.812; 18.60 ± 0.803) (P ≤ 0.01). Also, children in experimental group had higher mathematical performance scores after the basic skills program (14.12 ± 0.254; 23.48 ± 0.266) than did those in the control group (14.19 ± 0.735; 14.23 ± 0.354) (P ≤ 0.01).

After that, the covariance analysis test was used to determine how significant were the differences, as shown in Table 2. After controlling for the pre-test effect, there was a significant difference between the pre-test and post-test scores of children in the experimental group in quantitative reasoning and mathematical performance scores (P ≤ 0.01).

Table 1
Mean and standard deviation of Quantitative reasoning and Mathematical performance scores in the pre- and post-tests for each group

Variables	Mean ± SD
Quantitative reasoning	
Experimental	
pretest	18.12 ± 0.874
Posttest	27.55 ± 0.687
Control	
pretest	18.44 ± 0.812
Posttest	18.60 ± 0.803
Mathematical performance	
Experimental	
pretest	14.12 ± 0.254
Posttest	23.48 ± 0.266
Control	
pretest	14.19 ± 0.735
Posttest	14.23 ± 0.354

Table 2
Covariance analysis test results for comparing Quantitative reasoning and Mathematical performance scores in the control and experimental groups

Source of Change	Sum of the Squares	Df	Mean Squares	F	p-value	Effect Size
Quantitative reasoning						
Pretest	18.12	1	18.12	11.01	0.001	0.32
Group	27.55	1	27.55	108.2	0.001	0.86
Mathematical performance						
Pretest	14.12	1	14.12	8.4	0.001	0.29
Group	23.48	1	23.48	93.6	0.001	0.80

Note.: ETA Square ranged from 0.32 to 0.86 , 0.29 to 0.80 respectively . High size effect (Cohen, 1988 suggested that =0.2 be considered a 'small' effect size, 0.5 represents a 'medium' effect size and 0.8 a 'large' effect size).

Table 3 and 4 show data on Scheffe test for multi-comparisons. The tables show that there are statistical differences between pre and post measures in favor of post test, and between pre and follow up measures in favor of follow up test, but no statistical differences between post and follow up test.

Table 3
Scheffe test for multi- comparisons in Quantitative reasoning test score.

Measure	Pre M=18.12	Post =27.55	Follow up M=26.80
Pre	-	-	-
Post	3.50*		
Follow up	3.27*	.19	

Table 4
Scheffe test for multi- comparisons in Mathematical performance.

Measure	Pre M=14.12	Post =23.48	Follow up M=22.77
Pre	-	-	-
Post	3.22*		
Follow up	3.11*	.20	

DISCUSSION

Considering the important role of basic mathematical skills in children's academic achievement and on the other hand, the negative consequences of inadequacy in basic skills and delays in identifying and providing timely intervention services for children at risk of mathematical disorders, the present study was conducted to determine the effect of a basic skills training program on quantitative reasoning, and mathematical performance of preschool children. Findings confirm that implementing a basic mathematical skills training program for children improved their mathematical performance. This finding is consistent with the results of studies (Cayang & Ursabia, 2024).

The basic mathematics skills training program improved quantitative reasoning in children in the experimental group. This finding is consistent with the results of studies (Capio et al., 2024; Safarzadeh et al., 2024). Early childhood is the best opportunity and time to teach basic mathematical concepts and skills to preschool children because children's attitudes towards mathematics are formed during this period. On the other hand, preschool is considered one of the most sensitive periods for the formation and teaching of mathematical concepts in terms of development. Understanding mathematics in preschool children and understanding the concept of number are important and fundamental aspects for understanding counting, the relationship between numbers and performing simple mathematical operations, and this skill is considered an important background for other mathematical skills. (Capio et al., 2024).

Researchers have shown that understanding the concept of quantity (amount) and number begins in children from the age of three, and the child can understand numbers in accordance with their age. At first, children usually count and understand numbers based on visual patterns, they understand the components and elements of their environment in the context of numbers and learn to count. Mathematical reasoning in children is also one of the skills that is formed in childhood. Children from the age of three are able to understand some simple mathematical arguments and can benefit from them in solving some of their problems in the environment (van Oers, 2023).

The explanation of this finding is that during the basic mathematics skills program training sessions, given the structured characteristics of the session and the focus on teaching content through games, images and visual stimulation, and purposeful and meaningful practice, it can be expected that mathematical performance will improve (Munda et al., 2024). Since regular behaviours related to building and completing patterns are correlated with spatial skills and mathematical skills in later years (Bower et al., 2020), the use of various types of games along with repetition of exercises in the intervention program has led to a better understanding of mathematical concepts and improved children's performance in mathematics (Russo et al., 2021). Presenting the program in the form of a game helps teachers to tailor mathematics education to the child's developmental level, thereby increasing the mathematical knowledge of the children who participated in the program (Russo et al., 2021).

Since solving mathematical problems is a complex mental activity, and in the intervention program used in the study, mathematical education was presented to the child in the form of games and entertainment instead of being presented in a space combined with reasoning, analysis, planning, monitoring, and evaluation. Therefore, it can be expected that children will understand mathematical concepts and learn how to use these skills instead of memorizing formulas themselves in real-life situations. Children in the basic math skills program had the opportunity to gradually understand concepts and gain confidence in their abilities, and since they participated in obtaining results and discovering mathematical rules, their interest and motivation for learning increased, and their quantitative reasoning improved.

CONCLUSION

Basic mathematical skills in preschool play a decisive role in mathematical progress in later years. The connection of mathematics with life creates interest and motivation in students and better understanding and meaningful learning of mathematics in them. Since improving prerequisite mathematical skills increases mathematical understanding and problem-solving skills, enriching children's learning environment and including concepts related to mathematics can help children increase their ability to calculate and understand mathematical concepts before entering school. Timely intervention programs in the field of mathematics education provide an opportunity, especially for those who have poor performance in prerequisite mathematical skills, to compensate for their backwardness and achieve the skill level of their peers. Using educational programs that can provide the prerequisites for learning mathematics in children will strengthen and improve children's calculation ability and can prevent the occurrence of mathematical problems in the years of formal education.

LIMITATIONS

The present study has limitations that should be considered with caution when interpreting the results. The first limitation was the small sample size of children. This may hinder generalization. As such, the results should be considered with caution. Therefore, it is suggested that in future studies, by considering a larger sample size and a wider age range, the role of gender and age variables should be considered.

RECOMMENDATIONS

One of the practical solutions to prevent the occurrence of mathematical disorders is to provide effective education and to satisfy the prerequisites for understanding numerical concepts (including quantitative reasoning and working memory) to provide the necessary foundation for understanding mathematical problems and prevent the occurrence of mathematical disorders in later years. On the other hand, the cumulative nature of mathematics education and the persistence of the problem in this area in the absence of an appropriate intervention program indicates the need for planning for timely identification and intervention for children at risk of mathematical disorders. The importance of this topic is highlighted when, according to research findings, mathematical problems can be identified before formal education and preschool, and by providing a timely intervention program for at-risk individuals, the occurrence of mathematical disorders in the future can be prevented.

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