

Effect of Inquiry-Based Mathematics Activities on Preschoolers' Math Skills

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Abstract

Abstract

Practice: An Inquiry-Based Mathematics Activities Module (IBMAM) was developed in accordance with the developmental characteristics, interests, needs, and expectations of preschoolers. The aim of the study was to determine the effect of the IBMAM on preschoolers' numbers and operations skills. A quasi-experimental method, which was a pretest-posttest design with control group, was used. The students of a kindergarten were randomly assigned to three groups: experimental, control, and placebo. Measurements were made on the three groups before and after the IBMAM. The study took place in the academic year of 2016-2017, and the sample consisted of 57 students (19 participants in each group) of a kindergarten in Sincan, Ankara, affiliated to the Ministry of National Education. Interviews were conducted with 18 kindergartens in the same district for the needs analysis. The kindergarten was the study field of choice due to its sufficient number of students and low socioeconomic status and to the students' willingness to participate in the study. Math activities were performed in three classes with children 60–72 months of age. For 6 weeks, the experimental group performed the 30-activity IBMAM, the control group performed no activities, and the placebo group performed Turkish reading activities unrelated to mathematics (TRAUM). Data were collected using the Test of Early Mathematics Ability (TEMA-3). In the current study, 3x3 (three groups: experiment, control, placebo groups with 3 measurements: pretest, posttest, follow up test) experimental mixed design (factorial-split-plot) ANOVA was performed to determine the effect of IBMAM on preschoolers' math skills.

Research Findings: Results show that the IBMAM had a positive and lasting effect on preschoolers' number and operations skills. IBMAM provided the experimental group participants with the opportunity to be engaged in small-group activities in which they were able to have math experiences and inquire about them. This process allowed them to enhance math concepts, learn new ones, and learned in meaningful ways in which they used their math skills. They structured the concepts and skills that they had learned by inquiring, researching, and experiencing, which promoted their curiosity and interest in learning.

Keywords: Preschool mathematics education, inquiry-based mathematics education, math skills, preschool period

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INTRODUCTION

Children encounter mathematics in their daily lives and in games, interactions, and in- and out-of-class experiences (Jackman, 2005). Children develop similar mathematical thoughts, systems, strategies, and skills regardless of sociocultural background. In a sense, all children go through the same processes of skill development (Ginsburg et al., 2008). Some research focuses on understanding how babies and children develop math skills (Griffin, 2004a; Clements & Sarama, 2011; Gould, 2012; Choi & Dobbs-Oates, 2014). Most previous studies have shown that even babies have basic mathematical skills and are equipped with the potential to use certain problem solving, measurement, and spatial skills (Diezmann & Yelland, 2000; Perry & Richardson, 2001; Ginsburg & Golbeck, 2004; Sophian, 2004). In the first years of their lives, babies make mathematical discoveries by putting objects in their mouths, touching them, relocating them, and comparing their quantities. When presented with object groups, children are capable of understanding both which one contains more or less than the other and the changes in quantity when an object is added to or removed from the group, indicating that they develop basic math skills in early childhood (Kamii, 2000). Recent research shows that children use the existing potential to understand mathematical events without having to exert any effort and that environment and experiences significantly help children improve math skills (Aktas Arnas, 2013). For example, the type, quality, and frequency of math activities at home; family members' education level; parents' interest in and perceptions of mathematics; and forms of support provided to children during problem solving affect the development of math skills (Anders et al., 2012; Baroody, Li & Lai, 2008; Bodovski & Farkas, 2007; Gifford, 2004). Similarly, learning environments provided by educators, the diversity of activity materials, in-class math language, and types and forms of activities are also associated with math skills (Klibanoff et al., 2006; Boonen, Kolkman & Kroesbergen, 2011).

Educational settings that enhance the feeling of freedom, facilitate thinking, encourage large and small group discussions, and allow different approaches and activities encouraging risk-taking to be planned and implemented all significantly contribute to the development of math skills (Akman, 2002; Ginsburg, Lee & Boyd, 2008; Klein, Starkey & Ramirez, 2002). It is, however, unreasonable to create such educational environments and expect students to benefit from activities performed in them without systematic math education programs. Education programs should include fun, content-rich, and systematic activities to achieve a high-quality math education in early childhood (Starkey & Klein, 2008; Starkey et al., 1999). Traditional education programs fall short of providing students with the opportunity to develop math knowledge, skills, and attitudes from an early age (TED, 2018). To facilitate the development of math skills, math programs should not only allow students to be active in structuring knowledge but also encourage them to explore, discuss, and put knowledge into practice (Trawick-Smith, Swaminathan & Liu, 2016; Skwarkchuk, Sowinski & Lefevre, 2014; Akman, 2002: p.47).

Especially in preschool education institutions, students should build their math knowledge to be able to develop math skills that they will use in the future (Clements & Sarama, 2007). Researchers note that math is more than just a lesson consisting of distinctive signs, symbols, numbers, and calculations taught in school (Taşkın, 2013; Umay, Akkuş and Duatepe Paksu, 2006); it is an inseparable part of life that people of all ages should enjoy learning and discovering through concrete and inquisitive experiences (Griffin, 2004b; Young-Loveridge, 2004). Many countries have recognized this and attached more importance to math education at an early age, setting their own principles and standards and introducing new and effective programs (Young-Loveridge, 2004). Application outcomes have shown that providing qualified, accessible, engaging, interesting, constructivist, and questioning math education to children aged 3 to 6 years is vital for their future math learning. Based on these results, the National Association for the Education of Young Children (NAEYC) and the National Council of Teachers of Mathematics (NCTM) have recognized both that preschools should have systematic inquiry-based education programs that encourage active student participation and that teachers should have access to appropriate resources (NRC, 2009).

The general education program updated by the Ministry of National Education (MNE) in 2013 includes the acquisitions and indicators of all developmental areas for preschoolers. In general, the program expects preschoolers to be actively involved in practice, research, discussion, and learning processes, and it encourages them to learn by questioning, recognizing, and exploring their environment. Because it was developed to guide teachers, the program includes math acquisitions and indicators; however, it lacks standardized math content. The preschool period is critical for the development of math skills, and the shortcomings of the program can be compensated by a systematic math education module consisting of activities enriched with special materials. Methods and techniques that facilitate preschoolers' math development are not widely used in Turkey. In this way, math processes and achievements that are significant to life are ignored. Turkish students' math skills have been below expectations in some international exams, particularly in recent years (Çelen, Çelik & Seferoğlu, 2011; Eraslan, 2009; MNE, 2013; TED, 2018). It is therefore of paramount significance to conduct research in this field to contribute to the development of preschoolers' math skills. The number of studies using inquiry-based approaches to math education, which enable preschoolers to discover and obtain information, is limited. Therefore, this study will provide insight into how inquiry-based math activities will contribute to preschoolers' numbers and operations skills. For this purpose, an Inquiry-Based Mathematics Activities Module (IBMAM) was developed in accordance with the developmental characteristics, interests, needs, and expectations of preschoolers. The study aimed to determine the effect of the IBMAM on preschoolers' numbers and operations skills. The subproblems of the study are as follows:

- Do the experimental, control, and placebo groups' Test of Early Mathematics Ability (TEMA-3) pretest, posttest, and follow up test scores differ significantly?
- Is there a statistically significant difference in TEMA-3 repeated measurement total scores between any two of the experimental, control, and placebo groups, regardless of the change between pretest, posttest, and follow up test?
- Is there a statistically significant difference in any two of the pretest, posttest, and follow up test scores in terms of TEMA-3 scores, regardless of the experimental, control, and placebo groups?

These inquiry-based activities are used for the first time in preschool math education in Turkey. We believe that the IBMAM will offer a full range of applicable activities for teachers and will be a very useful instrument for the development of preschoolers' inquiry skills. Teachers can use the IBMAM not only as a resource of activities but also as a guide. Therefore, we also expect the IBMAM to be a guide for future preschool education programs.

METHOD

A quasi-experimental method, which was a pretest-posttest-control group design, was used to determine the effect of the IBMAM on preschoolers' numbers and operations skills. The students of a kindergarten were randomly assigned to three groups: experimental, control, and placebo. Measurements were made on three groups before and after the IBMAM (Büyüköztürk et al., 2010, pp. 201-202). The experimental group performed the 30-activity IBMAM, the control group performed no activities, and the placebo group performed TRAUM for 6 weeks. Finally, new measurements were obtained on all three groups by applying the measurement instrument used before the experimental procedure (Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz & Demirel, 2012). A 3x3 (three groups: experiment, control, and placebo; 3 measurements: pretest, posttest, follow up test) experimental research model was developed. The independent variable was the IBMAM, while the dependent variable was the participants' math skills.

A second control group was developed, and placebo activities were performed, to minimize the Hawthorne effect (Fraenkel, Wallen & Hyun 2012) on the assumption that teachers' and students' attitudes towards the IBMAM might bias the results.

Table 1. Experimental Design

	Experimental Group	Control Group	Placebo Group
Pretest	Test of Early Mathematics Ability (TEMA-3)	Test of Early Mathematics Ability (TEMA-3)	Test of Early Mathematics Ability (TEMA-3)
Application	Inquiry-based Mathematics Activities Module	-	Activities Unrelated to Math (Turkish reading activities)
Posttest	Test of Early Mathematics Ability (TEMA-3)	Test of Early Mathematics Ability (TEMA-3)	Test of Early Mathematics Ability (TEMA-3)
Follow up Test	Test of Early Mathematics Ability (TEMA-3)	Test of Early Mathematics Ability (TEMA-3)	Test of Early Mathematics Ability (TEMA-3)

Study Group

The study sample consisted of 57 students (19 participants in each group) of a kindergarten (in Sincan, Ankara) affiliated to the Ministry of National Education in the academic year of 2016-2017. Participants were recruited using purposive sampling, which is a nonprobability sampling technique involving the selection of participants who have experienced a specific phenomenon and meet certain inclusion criteria (Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz & Demirel, 2012).

Families with low socioeconomic status are less likely to contribute to their children's math skills (Jordan, Kaplan, Olah & Locuniak, 2006; Karaman & İvrendi, 2015; Manfra, Dinehart & Sembiane, 2014). This study aimed to interpret the effect of the IBMAM on preschoolers' math skills without confounding variables. Therefore, low socioeconomic status was used as a criterion in this study. The other criteria for the selection of the kindergarten were as follows:

- The school management provided a comfortable working environment.
- There were enough students aged 60 to 72 months.
- The teachers were open to cooperation.
- In the needs analysis, the managers' and teachers' responses to the interview questions were appropriate.
- The managers and teachers were willing to participate in the study.

Interviews were conducted with 18 kindergartens in the same district for the needs analysis, and math activities were performed in three classes of the kindergarten of choice with students 60–72 months of age. The study sample consisted initially of 60 students (20 participants in each group); however, each group had one special student who was excluded from the study. Therefore, the final study sample consisted of 57 students. Table 2 shows the characteristics of the participants.

Table 2. Demographic Characteristics of Participants

Characteristics	Experimental Group	Control Group	Placebo Group
Gender			
Female	10	9	9
Male	9	10	10
Number of Siblings			
Only child	3	5	3
2 siblings	6	5	10
3 and more	10	9	6
Mother's Education (Degree)			
Primary school	9	8	7
Middle School	2	4	5

High school	7	5	3
Bachelor's	1	2	1
Mother's Employment Status			
Employed	2	3	5
Unemployed	17	16	14
Father's Education (Degree)			
Primary school	3	3	1
Middle School	2	5	2
High school	11	9	12
Bachelor's		2	4
Average Monthly Income (Turkish Lira)			
500—1000	2	1	-
1001—1500	11	12	10
1501—2000	4	3	6
2001—2500	1	1	1
2501 and more	1	2	2

The experimental group consisted of 10 girls and 9 boys, the control group of 9 girls and 10 boys, and the placebo group of 9 girls and 10 boys. The demographic characteristics (number of siblings, parents' education and employment status, and average monthly income) of the participants were similar.

Data Collection

The TEMA-3 was used to determine the effect of the IBMAM on the participants' math skills. TEMA was developed by Ginsburg and Baroody (1983) to assess the mathematical abilities of children aged 3 years to 8 years and 11 months. It was revised in 1990 and published as TEMA-2. The validity and reliability of TEMA-2 were established by Güven (1997). The Cronbach's alpha coefficient of the scale for all age groups was .95. TEMA-2 was revised in 1993 and published as TEMA-3 (Ginsburg & Baroody 2003). TEMA-2 had been revised to increase the number of items for preschoolers and to make the test more comprehensible. Recent research suggests that children should develop arithmetic and counting skills before learning how to count objects (Ginsburg & Baroody 2003; Erdoğan, 2006).

TEMA-3 was administered to participants individually by the researcher in order to determine the effect of the IBMAM on their math skills. TEMA-3 was administered as a pretest before the IBMAM, as a posttest after the IBMAM, and as a follow up test. Table 3 shows the internal consistency coefficients of TEMA-3 in terms of groups and measurements.

Table 3. Internal Consistency Coefficients of TEMA-3

		Measurement		
		Pretest	Posttest	Follow up Test
Group	Experiment	.83	.94	.94
	Control	.81	.96	.96
	Placebo	.78	.92	.92

The Cronbach's alpha reliability coefficients of the pretest, posttest, and follow up test scores of the groups ranged from 0.78 to 0.96. These results indicate that the pretest scores had high reliability while the posttest and follow up test scores had very high reliability (Fraenkel, Wallen & Hyun, 2012).

IBMAM administration

The current literature, interviews with managers and teachers, and in-class observations were used for the IBMAM needs analysis. Interviews with managers and teachers were conducted using a

written form consisting of such open-ended questions as “What properties should math activities have?,” “Are the current activities sufficient to achieve the desired goals?,” “What kind of methods and strategies do you use to help students improve numbers and operations skills?,” “How can the inquiry-based approach be used in math?,” “What kind of materials do teachers use and how and for what purpose?,” and “How do teachers manage family participation in math activities?” The interview forms were used after they were presented to experienced teachers and academics specialized in preschool education for their feedback. Requirements and program principles were determined according to the interview data. Within the framework of these principles, the IBMAM was developed to determine the developmental characteristics and needs of children aged 60 to 72 months and to provide them with a rich learning environment in order to help them develop inquiry and critical thinking skills.

Considering the interview and observation analysis, all activities in domestic and foreign sources were reviewed. IBMAM subjects were determined based on the interests, needs and developmental characteristics of children aged 60 to 72 months. The researcher focused on numbers and operations skills that form the basis of math learning, analyzing preschool themes and math education content and process standards in Turkey and associating them with basic math education content. The researcher also examined the scientific studies of the NAEYC and the NCTM as well as the preschool math education standards of 15 countries and states. These standards were translated into Turkish and compared with the 2013 Preschool Education Program (PEP) prepared by the General Directorate of Basic Education of the MNE. Acquisitions and indicators were collected and used to develop activities suitable for the IBMAM. Acquisitions and indicators that were not included in the PEP but should be included in the IBMAM were re-determined. Then, the determined acquisitions and indicators were presented to six academics specialized in preschool education and mathematics for their opinions and recommendations. Based on their feedback, a skills development list consisting of 18 acquisitions and 88 indicators regarding numbers and operations skills was developed. These acquisitions and indicators were integrated as inquiry-based activities into the IBMAM.

A pool of inquiry-based math activities was developed. Four specialists and one experienced preschool education institution manager were consulted and asked to analyze all aspects of the program and to provide feedback. The activities were reviewed in detail based on this feedback. The aim was to make sure that the IBMAM would help the development of number and processing skills through inquiry-based activities. Acquisitions and indicators for each skill were analyzed, and 30 integrated activities with an eclectic and spiral structure were developed. The IBMAM consisted of four sets of skills: arithmetic, numeracy, addition, and subtraction. The research steps are as follows.

Table 4. Research Steps

Process	
STEP 1 (Needs Analysis)	
Data Collection	Interview + Observation + Document Analysis
Tool	
Objective	Eliciting information on managers’ and teachers’ views of what properties math activities should have; whether the current activities are sufficient to achieve the desired goals; what kind of methods and strategies the teachers use to help preschoolers improve numbers and operations skills; how the inquiry-based approach can be used in math; what kind of materials are used and how and for what purpose the teachers use them; and how the teachers manage family participation in math activities.
Rationale	To elicit information on current math education
Material	Interview forms, observation field notes, and daily education charts and monthly plans prepared by teachers
Application	Interviews were conducted with 15 administrators and 126 kindergarten teachers of 18 independent official kindergartens in a low-socioeconomic district of Ankara. After the interview analysis, four different classes from two out of 18 kindergartens were observed for a month, and teachers’ daily education charts and monthly plans were examined.

STEP 2 (Developing Activities)	
Objective	To ensure preschoolers' active participation and math learning through doing-it-and-living-it education and to improve their inquiry skills, discover their potential, strengthen preschooler-teacher interaction and cooperation, and draw attention to the role of teachers in math education
Rationale	Inadequacy of the MNE's acquisitions and indicators for the IBMAM
Material	Web pages of countries' math education standards
Application	After determining the principles and objectives of the program, the math education standards of 15 countries were examined to identify acquisitions and indicators for the IBMAM. Based on expert opinion, 18 acquisitions and 88 indicators were included.
STEP 3 (Pilot Study)	
Data Collection Tool	Field Notes + Interview
Objective	Assessing the IBMAM in terms of level, content, and method and overcoming the shortcomings, if any, before putting the module into practice
Rationale	Putting the activities into practice and overcoming shortcomings, if any, in order to improve the IBMAM
Material	Interview records and field notes
Application	The first 10 activities were conducted between 21 September 2016 and 14 October 2016 in a class of 16 preschoolers aged 60 to 72 months in another school in the same district.
STEP 4 (Pretests)	
Data Collection Tool	TEMA-3
Objective	To determine preschoolers' math skills before the IBMAM
Rationale	To determine whether there is a statistically significant difference in pretest scores across groups
Material	TEMA-3
Application	TEMA-3 Form A was administered as a pretest to all participants between 26 September 2016 and 07 October 2016.
STEP 5 (IBMAM)	
Objective	To encourage preschoolers to use inquiry steps and improve numbers and operations skills
Rationale	The traditional math education offered to preschoolers aged 60 to 72 months does not allow them to discover their potential.
Material	Inquiry-Based Mathematics Activities Module (IBMAM)
Application	The 30-activity IBMAM was administered to the experimental group from 24 October 2016 to 06 January 2017, 3 days a week for 10 weeks. Three activities were performed every week. The control group was taught the curriculum of the PEP-2013. The placebo group performed, once every 2 weeks, TRAUM developed by the researcher.
STEP 6 (Posttests)	
Data Collection Tool	TEMA-3
Objective	To determine preschoolers' math skills after the IBMAM
Rationale	To determine the effectiveness of the IBMAM
Material	TEMA-3
Application	TEMA-3 Form A was administered as a posttest to all participants between 09 and 17 January 2017.
STEP 7 (Follow up Tests)	
Data Collection Tool	TEMA-3
Objective	To determine the retention effect of the IBMAM on preschoolers' behavior and math skills
Rationale	To determine the long-term effect of the IBMAM
Material	TEMA-3
Application	TEMA-3 Form A was administered to all participants between 20 and 28 February 2017, about 5 weeks after the posttest.

Data Analysis

All participants were administered a pretest, the IBMAM, a posttest, and a follow up test at the beginning of the 2016-2017 school year. 3x3 (three groups: experiment, control, placebo groups with 3 measurements: pretest, posttest, follow up test) experimental mixed design (factorial-split-plot) ANOVA was performed to determine the effect of the IBMAM on the preschoolers' math skills. A mixed-design ANOVA is the best statistical method to assess the effect of experiments in designs consisting of two or more measurements and groups. The method used in this study focuses on whether measurements at different times vary according to groups; therefore, its primary focus is on the ANOVA. If the ANOVA reveals a statistically significant difference, then the main effects at each group and measurement level are tested. It tests not only the common effect of *group x measurement* but also the main effects of groups and measurements. In other words, a mixed-design ANOVA takes into account the common change in groups and measurements and analyzes the differences between the means of more than two groups and the changes between more than two measurements, thus reducing the possibility of Type 1 error. It is therefore considered a robust statistical method (Field, 2009; Kirk, 2008; Tabachnick & Fidell, 2013).

Preliminary analyses should be conducted to establish whether parametric assumptions are met prior to a 3x3 mixed-design ANOVA. A chi-square test was used to determine whether the three groups were independent of each other and whether there were missing data. The groups were independent of each other, and their number was sufficient for a mixed-design ANOVA (Green & Salkind, 2005). Moreover, a total score can be obtained from TEMA-3. Therefore, the dependent variable was continuous. Finally, tests were conducted to determine whether the score of each group was normally distributed, whether the variances of the total scores of the groups were homogeneous, and whether the covariances were equal for the pairwise combinations of measurement groups (Field, 2009; Kirk, 2008).

For normal distribution analysis, the distribution of the pretest, posttest, and follow up test scores of the groups was separately controlled. The score distribution of each group and measurement was analyzed using such descriptive methods as mode, median, arithmetic mean, and skewness and kurtosis coefficients as well as graphical methods such as histogram, Q-Q, and P-P (Abbott, 2011; Howitt & Cramer, 2011). Data were analyzed using the Statistical Package for Social Sciences (SPSS), version 20, and Excel 2010 at a significance level of 0.05. An effect size was calculated to interpret the results of the analysis. Effect size is unaffected by sample size and gives information about the significance of results. Effect size, referred to as partial eta-squared (η^2), is used to describe the size of the effect of an independent variable on a dependent variable or to indicate how much of the total variance of the dependent variable is explained by the independent variable. In a mixed-design ANOVA, the partial eta-squared (effect size) is calculated as the ratio of the between-groups sum of squares to the sum of the between-groups sum of squares and the error. Regardless of the sign, effect size has a value between 0 and 1. A value in the range of .01 to .06 indicates a small effect size, in the range of .07 to .14 a medium effect size, and greater than .14 a large effect size (Green & Salkind, 2005).

FINDINGS AND DISCUSSION

Effect of the IBMAM on Participants' Math Skills

A 3x3 mixed-design (factorial-split-plot) ANOVA was used to determine whether there was a statistically significant difference in pretest-posttest and follow up test total scores across the groups. Table 5 shows the descriptive statistics of the groups' pretest, posttest, and follow up test scores.

Table 5. Descriptive Statistics of Groups

	Groups	N	\bar{X}	SD
Pretest	Experimental	19	9.36	3.59
	Control	19	9.15	3.46
	Placebo	19	9.10	2.13
Posttest	Experimental	19	25.68	8.44
	Control	19	17.31	9.29
	Placebo	19	16.73	6.74
Follow up Test	Experimental	19	25.94	8.92
	Control	19	17.05	9.83
	Placebo	19	16.36	6.99

The three groups had similar pretest scores, indicating that they had similar math skills prior to the IBMAM. This result is expected in experimental studies (Kaptan, 1998). The experimental group had pretest, posttest and follow up test scores of 9.36, 25.68 and 25.94, respectively. The control group had pretest, posttest, and follow up test scores of 9.15, 17.31 and 17.05, respectively. The placebo group had pretest, posttest, and follow up test scores of 9.10, 16.73 and 16.36, respectively. These results show that there was an increase in the math skill scores of all participants and that the experimental group's participants had the highest increase; the control group had a slightly higher mean posttest score than the placebo group. ANOVA was used to determine whether the between-groups differences were statistically significant.

Table 6 shows the ANOVA test results of the groups' pretest, posttest, and follow up test scores.

Table 6. ANOVA test results of the groups' pretest, posttest, and follow up test scores

Source of Variance	SS	DF	MS	F	P	η^2
Between groups	8040.188	56				
Group	1393.556	2	696.778	369.302	.006	0.17
Error	6646.632	54	123.086	5.661		
Within groups	6546.000	114				
Measurement (Pretest-Posttest-Follow up)	4302.678	2	2151.339	145.368	.000	0.73
Group*Measurement	645.006	4	161.251	10.896	.000	0.29
Error	1598.316	108	14.799			
Total	14586.188	170				

SS: Sum of Squares; DF: Degrees of Freedom; MS: Mean Square; η^2 : Effect Size, $p < 0.01$

The analysis shows that there was a statistically significant difference between pretest and posttest scores across the three groups [$F(4,108)=10.89$; $p < 0.01$, $\eta^2=0.29$], indicating that the IBMAM had a positive effect on the participants' math skills. In other words, the factors of both measurement time and group had a significant effect on the participants' math skills. This result shows that the use of the IBMAM, PEP-2013, and TRAUM had a different effect on the math skills of the participants in the experimental, control, and placebo groups. The effect size reveals the difference between the effect of the IBMAM on the experimental groups and that of the 2013 PEP on the control group (Cohen, 1988). The IBMAM was administered to the experimental group for 10 weeks; meanwhile, PEP-2013 was applied to the control and placebo groups. PEP-2013 improves cognitive, social-emotional, linguistic, and psychomotor skills and therefore also improved the control and placebo groups' math skills. There are studies confirming these findings.

Dinç (2013) reported that preschool education supports the development of cognitive skills. Aslan and Aktaş Arnas (2015) and Unutkan (2007) also reported that students who receive preschool education have more advanced math skills and are more prepared for the next level of education than those who do not. PEP-2013 contains math goals and associates them to various concepts under

subheadings such as number, operation, geometric shape, size, or quantity. The aim of the IBMAM is to help students develop number and operations skills. Both the IBMAM and PEP-2013 aim to help preschoolers improve similar skills. This similarity might be the reason for the statistically significant difference in mean scores between the control and placebo groups. TEMA-3 results show that the IBMAM improved participants' total scores more than PEP-2013 did. The eta-squared value ($\eta^2 = 0.29$) can be interpreted as the factors interacting greatly with each other and affecting the math skills' total scores. In other words, the different groups and measurements explained 29% of the total variance of math skills and had a large effect (Green & Salkind, 2005, Tan, 2016) (Figure 1).

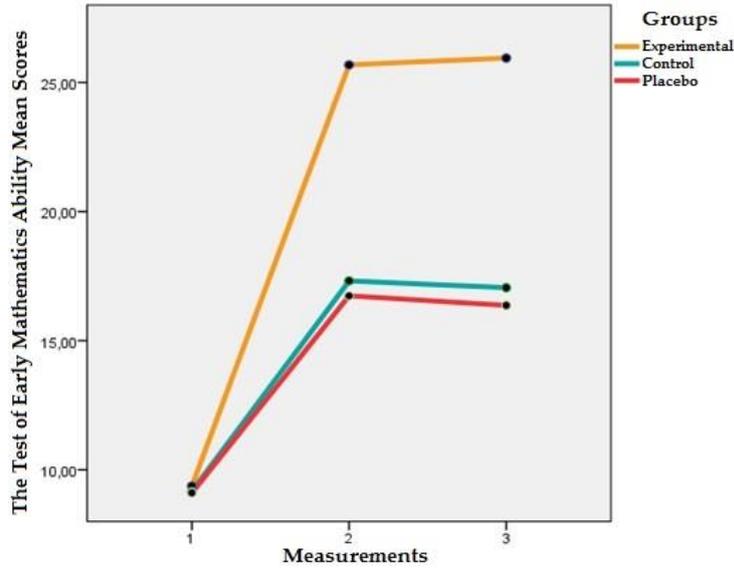


Figure 1. Changes in TEMA-3 Scores by Measurements

The experimental group's mean score increased 16.32 points from pretest to posttest and 0.26 points from posttest to follow up test. The control group's mean score increased 8.16 points from pretest to posttest and decreased 0.26 points from posttest to follow up test. The placebo group's mean score increased 7.63 points from pretest to posttest and decreased 0.37 points from posttest to follow up test. These results indicate that the IBMAM improved the experimental group's mean math skills score more than PEP-2013 improved the control and placebo groups' mean math skills scores. Thus, the main effect of repeated measurements and processing groups can also be examined, regardless of the changes in measurements and groups.

Regardless of the changes in measurements, there was a statistically significant difference in pretest and posttest total scores between at least two of the three groups [$F(2.54)=369.30$; $p<0.01$, $\eta^2=0.17$]. A Bonferroni test was used to determine the groups between which the significant difference existed (Table 7).

Table 7. Multiple Group Comparisons

Bonferroni				
(I) Group	(J) Group	Mean Difference (I-J)	Standard Error	p
Experimental	Control	5.8246*	2.07	.021
	Placebo	6.2632*	2.07	.012
Control	Experimental	-5.8246*	2.07	.021
	Placebo	.4386	2.07	1.000
Placebo	Experimental	-6.2632*	2.07	.012
	Control	-.4386	2.07	1.000

The Bonferroni test results show that there was a statistically significant difference in total scores among the three groups, regardless of the change between pretest, posttest, and follow up test scores. The experimental group had statistically significantly higher mean TEMA-3 score (\bar{X} =25.68) than the control (\bar{X} =17.31) and placebo (\bar{X} =16.73) groups.

There was a statistically significant difference between at least two of the three test (pretest, posttest and follow up) scores, regardless of the groups [$F(2,108)=145.36$; $p<0.01$, $\eta^2=0.73$]. The Bonferroni post-hoc test was used to determine significant differences among the means of the three tests (Table 8).

Table 8. Multiple Group Comparisons

(I) Measurement	(J) Measurement	Mean Difference (I-J)	Standard Error	p
Pretest	Posttest	-10.702*	.84	.000
	Follow up	-10.579*	.90	.000
Posttest	Pretest	10.702*	.84	.000
	Follow up	.123	.17	1.000
Follow up	Pretest	10.579*	.90	.000
	Follow up	-.123	.17	1.000

The Bonferroni test results show that the posttest scores of all groups (\bar{X} Experimental=25.68; \bar{X} Control=17.31; \bar{X} Placebo=16.73) were significantly higher than their pretest scores (\bar{X} Experimental=9.36; \bar{X} Control=9.15; \bar{X} Placebo=9.10). However, the posttest scores of the groups did not significantly differ from their follow up scores. According to these results, both IBMAM and PEP-2013 improved participants' math skills significantly and had a lasting effect.

The IBMAM enabled participants to have meaningful experiences in class and also provided them with math information that they might need in everyday life (Klein et al., 2008; Clements, Sarama & DiBiase, 2004; Jordan, Kaplan, Ramineni & Locuniak, 2009; Holloway, Rambaud, Fuller & Egger-Pierola, 1995). The statistically significant increase in the experimental group's score may be due to the fact that they engaged active learning using an inquiry-based approach. The teacher's do-it-and-live-it and inquisitive approach enriched participants' learning and provided them with meaningful experiences (Clements & Sarama, 2013). Through the inquiry-based activities, participants increased their interest and curiosity, constantly developed inquisitive thoughts, compared their results with their prior knowledge, and had meaningful and active experiences. Inquiry-based education programs make preschoolers' learning more active, encouraging them to integrate new knowledge with their prior knowledge in order to use it for new acquisitions (Clements & Sarama, 2014). High-quality preschool education is positively associated with cognitive and experiential acquisitions (Üstün & Akman, 2003). Inquiry-based education programs provide preschoolers with the opportunity to participate in activities and acquire and structure new knowledge. It is, therefore, of paramount importance to stimulate preschoolers' curiosity and interest, which initiates inquiry (NRC, 2000b).

Research shows that daily life examples, interesting events and situations, and observable math experiments and activities initiate children's inquiry in terms of the construction of math knowledge (Doruk and Umay, 2011; Aunio et al., 2004). Math skills should be developed and supported at an early age (Austin et al., 2011), as math activities facilitate the development of preschoolers' future skills (Akman, 1995). Wu and Lai Lin (2016) applied inquiry-based math activities to preschoolers and examined changes in peer relations, teacher roles, educational environment, and learning process in order to determine the long- and short-term benefits of the program. The results show that the program led to positive changes in learning and that changes made to the educational environment improved preschoolers' math skills and peer relationships.

Uyanık and Kandır (2014) emphasize that academic skills developed in early childhood directly affect future abilities and that social relationships, environmental stimuli, and qualified

preschool education are critical in this process. A serious, scientific, and systematic education is needed for the development of early academic skills, including literacy and math skills. Regarding early academic skills as a prerequisite for future academic skills, researchers recommend that teachers and parents provide opportunities and activities to help children develop academic skills. Preschool math education programs applied in positive and effective educational settings that encourage active participation and interaction and provide new experiences significantly facilitate the development of arithmetic skills.

Delacour (2016) stated that experiences in rich educational settings improve preschoolers' ability to associate math with real life. The IBMAM and the math materials provided participants with the opportunity to make sense of math by "doing and living" and to communicate effectively with their peers at the math center. In-class settings, materials, interactions, activities, and experiences contributed positively to participants' inquiry and math skills.

Clements, Sarama, and Liu (2008) reported that inquiry-based teaching methods are more useful than other approaches to teaching math skills. Aslan and Aktas Arnas (2015) stated that qualified math education programs, designed according to preschoolers' needs, facilitate the students' development of math skills and significantly influence their math achievement.

Hope-Southcott (2016) stated that inquiry-based games and drama activities help preschoolers think more deeply in different areas and encourage them to use math more. Ryan and Laurent (2016) suggested that inquiry-based approaches allow preschoolers not only to configure their own knowledge and improve their knowledge retention but also to integrate new knowledge with their prior knowledge (Alake-Tuenter et al., 2012). Therefore, math activities centered on preschoolers that provide them with doing-it-and-living-it learning opportunities and encourage them to develop and use different thinking skills can be used to develop academic skills. This allows preschoolers to learn basic academic concepts that facilitate future learning (Üstün & Akman, 2003). The form and quality of preschool math education affect the retention of math knowledge, learning of mathematical concepts, and development of math skills. Therefore, preschool math education is also associated with the students' future achievements or failures in math (Anders & Rossbach, 2015; Aslan & Aktaş Arnas, 2015; TED, 2018). This is why the NCTM, national science education reforms, and research results all suggest the use of inquiry-based approaches that offer more qualified math education (NCTM, 2000; NRC, 2000a; Clements, 2007; Biggs, 2011; Harlen, 2013).

Research shows that inquiry-based teaching, which is a modern teaching method, is more effective than traditional methods (Clements & Sarama, 2013; Hope-Southcott, 2016; Harlen, 2013). Learning that encourages preschoolers to inquire into and engage in the process allows them to comprehend and internalize math more than traditional approaches, in which teachers are more active than the students, because the preschoolers ask questions to construct knowledge, search for answers together, conduct experiments, and use facts (Abdelraheem & Asan, 2006).

Our participants' math skills improved, which is consistent with the literature. Therefore, preschooler-centered math activities that allow active engagement, offer inquiry and research opportunities, and encourage preschoolers to "make their own learning" help them develop math skills. The control and placebo groups were mostly engaged in teacher-centered, desk-bound, large-group activities in which individual differences were of secondary importance and the exchange of ideas was limited. On the other hand, the IBMAM provided the experimental group participants with the opportunity to be engaged in small-group activities in which they were able to have math experiences and inquire about them. This process allowed them to enhance math concepts, learn new ones, and learned in meaningful ways in which they used their math skills. They structured the concepts and skills that they had learned by inquiring, researching, and experiencing, which promoted their curiosity and interest in learning. In contrast, the control and placebo groups were taught through traditional methods and therefore failed to inquire and put the new knowledge into practice. Further, the experimental group's participants discussed and exchanged ideas during the inquiry-based activities, thus engaging in peer teaching. The teacher acted as a guide rather than a knowledge

transmitter during the activities, which also contributed to the participants' development of math skills. The IBMAM and the math center provided the experimental group's participants with the opportunity to put their new knowledge to practice. The higher mean posttest score of the experimental group was the result of the IBMAM's superiority to traditional methods.

CONCLUSION AND SUGGESTIONS

In this study, an Inquiry-Based Mathematics Activities Module (IBMAM) was developed in accordance with the developmental characteristics, interests, needs, and expectations of preschoolers. The effect of the IBMAM on their math skills was analyzed.

There was no statistically significant difference in TEMA-3 pretest scores among the three groups, indicating that all participants had similar math skills prior to the IBMAM.

There was a statistically significant difference in TEMA-3 pretest and posttest scores across the three groups. The experimental group had significantly higher mean posttest score than the control and placebo groups, with the placebo group having the lowest mean score. This result indicates that the IBMAM improved the math skills of the experimental group's participants.

TEMA-3 posttest and follow up test scores show no statistically significant difference. The follow up scores of the three groups were similar to their posttest scores. This result indicates that the IBMAM provided effective and long-lasting improvement in the experimental group participants' math skills.

The recommendations based on the results are as follows: An IBMAM developed based on numbers and operations skills can be modified according to different math achievements and skills. Different disciplines can be integrated into the IBMAM. Projects can be designed that involve teachers and adopt an inquiry-based education approach. This provides teachers with the opportunity to learn about inquiry-based approaches through practices and activities.

Undergraduate math courses should be inquiry-based and practice-oriented. Preservice teachers should attend national projects and receive preservice training. Parents should also be involved in inquiry-based education processes to ensure preschoolers' retention of math skills and achievements. If necessary, children and their parents should participate in workshops at national projects. Activities should be extended over a longer period of time to increase their effectiveness. Parents should provide a qualified math environment to support the development of their children's math skills. Settings and materials should be prepared to enrich children's experiences in math. The home environment should be designed to support children's math skills. When spending time with their children, parents should frequently use mathematical expressions and create situations that will encourage their children to use them. Parents should follow their children's classroom math activities and participate regularly in them.

Future studies should investigate the effect of IBMAMs on the social and emotional development of children. Math activities should be developed for children with different socioeconomic statuses to investigate the effects of demographic characteristics on their math skills. Longitudinal studies should be conducted to examine changes in students' math skills and future academic achievement. The follow up test should be performed at certain intervals. Alternative programs should be developed and implemented to support children's math skills. The validity of the results should be tested by using different measurement tools.

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