e-Kafkas Journal of Educational Research
e-KJER
Research Article

Impact of STEM Education on Preschool Children's Scientific Process Skills[1]

Şule Kavak[2] Ebru Deretarla Gül[3]

To cite this article:
Kavak, Ş., & Deretarla Gül, E., (2024). Impact of STEM education on preschool children's scientific process skills. *e-Kafkas Journal of Educational Research*, *11*, 491-509.
doi:10.30900/kafkasegt.1489648

Research article **Received:**24.05.2024 **Accepted:**23.10.2024

Abstract

This study was conducted to reveal the effect on scientific process skills of STEM activities. The study group consisted of 57 children, one experimental group, and two control groups. In this study, a semi-experimental research method was used. In the data collection process, three data tools were used to collect data. One of these is the "Demographic Information Form" containing personal information of the children and their parents. The other is the "Scientific Process Skills Test" developed by the researcher to evaluate the basic scientific process skills of children aged 60-72 months. The "Goodenough Harris" test developed by Florence Goodenough was used to ensure developmental equality among the children participating in the study. In the analysis of the experimental process of this study, a 3x3 mixed design ANOVA method was used. To show the significant difference between the groups, parametric and nonparametric tests were used depending on whether they showed normal distribution or not. The study findings showed that the scientific process skills of the children who participated in the experimental group differed significantly from those of the children in the control groups. The findings obtained in this study suggest that STEM activities improve the basic scientific process skills of 60-72-month-old children.

Keywords: Early STEM, children, 21st century, thinking skills, science.

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[1] This study was produced from the doctoral thesis of Dr. Şule Kavak, under the supervision of Prof. Dr. Ebru Deretarla Gül, in the Department of Pre-School Education at Çukurova University, Institute of Educational Sciences and it was also supported by Çukurova University the Scientific Research Project Unit, with the scientific research project number SDK-2018-10900.

[2] Corresponding Author, kvk.sule@gmail.com, Selcuk University Faculty of Education, Konya, Turkey

[3] Author, Cukurova University Faculty of Education, Adana, Turkey

Introduction

Preschool education is the foundational step in a child's academic journey, where they begin to develop essential skills for future learning (Duncane & Murnane, 2016). During this stage, children are naturally curious and eager to explore the world around them, making it an ideal time to introduce scientific concepts (Heckman, 2011; Eshach & Fried, 2005). Neurological development and curiosity peak during these years, presenting a prime opportunity to engage children in scientific exploration (Shonkoff & Marshall, 2000). Early exposure to science, technology, engineering, and mathematics plays a crucial role in nurturing this curiosity (Tippett & Milford, 2017). STEM education is an interdisciplinary approach that integrates science, technology, engineering, and mathematics teaching. STEM education aims to develop children's critical thinking, creativity, and collaboration skills by providing them with real-life problem-solving opportunities. STEM education also supports children's scientific process skills and design-oriented thinking by developing engineering skills (Bybee, 2010). A holistic view of these disciplines not only improves academic skills, but also prepares individuals for the challenges of the 21st century and supports their innovation and adaptability (Tippett & Milford, 2017; Kanematsu & Barry, 2016). These core competencies support children's ability to adapt to the changing world and enable them to be successful.

STEM education provides children with opportunities to learn through experience, while developing scientific process skills, which include basic skills such as observation, communication, prediction, and measurement (Duran & Ünal, 2016; French, 2004). These skills form the basis of scientific thinking and contribute to the development of metacognitive tasks. Scientific process skills encourage children to produce systematic solutions to problems and their academic development. Recent research emphasizes that more emphasis should be placed on the development of scientific process skills in the early years (Moomaw & Davis, 2010; Morgan, Farkas, Hillemeier, Maczuga, 2016). This shows that there is a need for activities that can develop such skills from an early age and that STEM education is an approach to developing skills in this regard.

This study aims to develop three of the most basic skills of scientific process skills: "scientific communication, estimation, and measurement." Communication skills help children express their observations and findings, which are important in collaborative learning environments (Jones, Lake, & Lin, 2008). Estimation skills allow children to predict outcomes, so they engage in the basic elements of scientific inquiry, such as forward-thinking and hypothesis testing (Jones et al., 2008). Measurement introduces children to quantitative reasoning, teaching them how to evaluate and compare data. measurement is a fundamental skill in both mathematics and science (Bybee & Fuchs, 2006). These fundamental skills were selected because they are compatible with the cognitive development stages of early childhood and are closely related to STEM principles.

The theoretical structure of this study is based on constructivist learning theories that argue that children construct knowledge through experience (Piasta & Wagner, 2010). Piaget and Vygotsky's theories play an important role in understanding the applications of STEM education in early childhood. According to Piaget's theory of cognitive development, children are individuals who actively construct knowledge and learn through experiences (Piaget, 1964). From Piaget's perspective, children expand their cognitive schemas by observing, trying, and discovering. Hands-on experiences and problem-solving tasks in STEM education are compatible with the importance Piaget places on active learning and support children's learning processes. On the other hand, Vygotsky's sociocultural theory emphasizes the importance of social interaction and cooperation in children's learning (Vygotsky, 1978). Collaborative tasks and group work in STEM activities encourage social learning by allowing children to learn from each other, as Vygotsky suggested. STEM activities based on this theory are designed to encourage preschool children to be active participants in their learning, interact with their environment, and explore, experiment, and build (Bybee & Fuchs, 2006).

The main purpose of this study is to develop preschool children's scientific process skills and to present how STEM education should be planned to increase the contribution of these skills to their development. There is a relationship between STEM education and scientific process skills (SPS) in the literature. STEM activities provide children with opportunities to acquire and develop scientific process skills (French, 2004). STEM education enables children to be active in the learning process and develops their thinking skills (Gelman & Brenneman, 2004). These activities also support the development of scientific process skills such as observation, prediction, measurement and communication (Jones, Lake & Lin, 2008).

Various main themes regarding early STEM education stand out in the literature. Gelman and Brenneman (2004) developed the "Preschool Pathways to Science (PrePS)" curriculum and demonstrated that early STEM interaction improves scientific skills and supports the cognitive development of preschool children. Bybee and Fuchs (2006) emphasized the importance of early STEM education in shaping students' long-term attitudes toward science and mathematics, drawing attention to its role in preparing students for future academic and professional success. Similarly, Maltese and Tai (2010) investigated the origins of early science interest and found that early exposure to science-related activities was strongly associated with the development of curiosity and inquiry skills. Clements (2013) emphasized that STEM education should be adapted to diverse cultural and socioeconomic contexts, suggesting that culturally responsive STEM programs can help reduce achievement gaps. In a study on curriculum differentiation, Kershaw et al. (2009) found that parental involvement in early STEM activities had a positive effect on children's knowledge acquisition and contributed to their future success in science and mathematics. The National Research Council (NRC, 2012) provides a framework for effective pedagogical approaches in early STEM education, recommending a focus on hands-on activities that encourage scientific inquiry and problem-solving skills. Darling-Hammond et al. (2020) emphasize the importance of professional development of teachers to assist in the effective integration of STEM education into early childhood programs. Finally, Piasta and Wagner (2010) evaluate the difficulties in assessing scientific process skills in young children and suggest methods for measuring critical skills such as questioning, critical thinking, and communication. Kale and Yoldaş (2021) drew attention to the development of scientific skills in STEM subjects in their study examining the effects of skills related to STEM practices on the scientific processes of preschool teachers. In addition, with the spread of STEM education in preschool education in recent years, the increase in the number of theses and researches on STEM in Turkey also shows the importance of early STEM (Çavaş, Ayar, Turuplu, Gürcan, 2020; Ormancı & Çepni, 2019; Şamlı & Kurtulmuş, 2023).

In conclusion, there is a strong relationship between STEM education and the development of scientific process skills, and this type of education improves children's scientific thinking abilities. The aim of this study is to experimentally examine the effects of STEM education on preschool children's scientific process skills. The following research questions were investigated:

- Is there a statistically significant difference between the scientific communication skills pretest, posttest, and follow-up scores of the experimental and control group children?
- Is there a statistically significant difference between the prediction skills pretest, posttest, and follow-up scores of the experimental and control group children?
- Is there a statistically significant difference between the measurement skills pretest, posttest, and follow-up scores of the experimental and control group children?
- Is there a statistically significant difference between the total scientific process skills pretest, posttest, and follow-up scores of the experimental and control group children?

Design methods

In this study, to determine the effect on children's scientific process skills, one of the quasi-experimental models, the "control group pretest-posttest paired group design" experimental model, was used. ANOVA was used to compare scores between groups and assess the impact of STEM activities on children's scientific process skills (Karasar, 2007).

Table 1.
Design Method

Group	Pre-Test	Intervention	Post-Test	Follow-Up Test
EG	O1	STEM Activities	O4	O7
CG1	O2	National Education Program + Researcher	O5	O8
CG2	O3	National Education Program + Teacher	O6	O9

EG (Experimental Group): The group that takes the STEM-based activities (Science, Technology, Engineering, and Mathematics).
CG1 (Control Group 1): The group where the National Education Program content is implemented by the researcher.
CG2 (Control Group 2): The group where the National Education Program content is implemented by the teacher.

Explanation of Symbols:

O1 – O4 – O7: Pre-test, post-test, and follow-up test measurements for the Experimental Group.
O2 – O5 – O8: Pre-test, post-test, and follow-up test measurements for Control Group 1.
O3 – O6 – O9: Pre-test, post-test, and follow-up test measurements for Control Group 2.

STEM Activities: Activities with a focus on science, technology, engineering, and mathematics, applied to the experimental group.

National Education Program + Researcher: The National Education Program content applied by the researcher in Control Group 1.

National Education Program + Teacher: The National Education Program content applied by the teacher in Control Group 2.

Variables:

Independent Variable: The STEM-based educational activities whose effects are being studied.
Dependent Variable: The scores of 60-72 month-old children on the Scientific Process Skills Scale.

Development of STEM Education Activities

This study was prepared based on STEM research conducted in the world and Turkey. STEM activities implemented especially in early childhood and national and international studies conducted in this field were examined, and activities were planned within the framework of 21st century skills (Fulton et al., 2011). Design-oriented thinking and engineering, science, and mathematics disciplines are at the core of the activities, and it is aimed at children to use their scientific process skills and produce creative solutions throughout the process.

The main theme of the activities is a character named “Kerem” and the STEM adventures of this character are told through a total of 16 stories. Each story directs children to seek solutions by confronting them with different STEM-based challenges and problems. Children follow the “Ask, Plan, Build, Test, Evaluate and Improve” steps to solve each problem situation. During these processes, materials that will help search for solutions are found in Kerem’s backpack, and children are allowed to choose two additional materials, thus encouraging to creative and original solutions.

Each activity lasts approximately two hours and was implemented two days a week for 8 weeks. The activities were prepared with the cognitive and language outcomes of the 2013 Preschool National Education Program and implemented with a preschool group of 20 people as a pilot study. As a result of the pilot study, the duration of the activities, the stages, the materials used, and their suitability for the outcomes were updated. In addition, corrections were made regarding the suitability of the words in the story for children and the originality of the material used in line with the feedback received from three experts.

STEM Building Cycle

Defining the Problem (Asking) Stage: In this stage, a problem situation is presented to the children, and questions are asked to initiate their search for a solution. Children's sense of curiosity is aroused and the conditions necessary for them to find more suitable solutions are clearly explained.

Planning Stage: The solution process is planned based on the questions regarding the solution of the problem. The materials to be used in the solution are determined and their properties are discussed.

Building Stage: In this stage, children build their solution designs with the determined materials. In this process, brainstorming is done, solutions are discussed and the construction process is planned.

Testing Phase: The designs that the children built are tested and if their solutions succeed are observed.

Evaluation Phase: Children discuss how successful the designs they planned and built were and evaluate the results.

Development Phase: Deficiencies that emerged during the evaluation phase are identified and brainstorming is done on how the designs can be improved.

Participants

The study focused on children between the ages of 60-72 months. Developmental differences of children in this age range progress rapidly. Therefore, children with similar characteristics and cognitive levels were selected with the Good Enough Harris test. Using the demographic information form, it was matched in terms of similar characteristics so that the socioeconomic levels and ages of the children in the experimental and control groups were the same. In this way, the groups were matched as homogeneity. In order to reduce the interaction of the students in the experimental group with the control group and thus to control external variables, the morning and afternoon groups were determined so that they could not meet each other.

These children were divided into three groups: the experimental group (n=19), the control group 1 (n=19), and the control group 2 (n=19). The control groups took the Turkey 2013 preschool education program, while the experimental group participated in an eight-week STEM activities program prepared by the researcher in this study. After the intervention, posttests and follow-up tests were performed to compare the scientific process skills of each group.

Data Collection Tools

This study used three data collection tools: “A demographic information form” to collect general characteristics of the children, 'The Good Enough Harris drawing test (GH)' to assess cognitive development and ensure the homogeneity of the groups, 'The Scientific Process Skills Test', consisting of 26 items, divided into three subdimensions, to measure basic skills of the scientific process of the children.

Good Enough Harris Drawing Test (GH): The GH test was developed by Florence Goodenough in 1926 and into its modern form by psychologist Dale B. Harris in 1963. The test provides insight into the cognitive development of children between 5 and 12 years of age. In this respect it is considered reliable for this age range (Scott, 1981). The Good Enough Harris (GH) drawing test was administered to children, instructing them to produce the most detailed human figure possible using conventional drawing materials (Table 2). The purpose of using the GH test in this study was to determine the equality of children's development levels and to include children with similar developmental stages in the experimental groups. This test also served as a measure to control external variables and establish group homogeneity. The results of the GH test analysis have affirmed that all participants in the group were statistically comparable. Ezell (1975) and Loxton, Mostert and Moffatt’s (2006) research show that the GH test is effective in measuring children's development scores and socioeconomic status. As noted by Kağıtcıbaşı and Biricik (2011), the GH test offers multiple benefits, such as its straightforward applicability, absence of cultural and gender biases, and its general acceptance among child participants. This claim was included in the work of Thomas and Silk (1990) and supports the conclusion. Furthermore, the results of the GH test showed that neither gender nor socioeconomic status significantly influenced the performance results.

Scientific Process Skills Test: The Scientific Process Skills Test, developed by Kavak (2021), assessed three subdimensions of scientific process skills through 26 items. The scale consists of scientific communication, prediction, and measurement subdimensions. Scientific communication also includes questions of classification and observation. While developing the scale, each subdimension was defined according to the literature and the items were written according to the expected gains in the appropriate age range. When determining these gains, cognitive acquisitions and language acquisitions were taken into account in the preschool National Education programme. After taking expert opinions, a pilot application was made for a group of 20 children. The content validity ratio (KMO) was determined with the Lawshe test. EFA was carried out based on data collected from 371 children with the items determined. The validity of the construct was demonstrated through tetrachoric analysis, and the main form of the scale, consisting of 26 items and three subdimensions, was obtained. The subdimensions include the establishment of relationships, prediction, and measurement skills. The test answers are scored as "no" (0) or "yes" (1), and the total score ranges from 0 to 26. In the correlation analysis between the factors of the scale, it was found that all three factors were significantly and positively correlated with each other at a moderate level. Accordingly, a total scientific process skills score can be obtained from the overall scale. The lowest score that can be obtained from the scale is 0, and the highest score is 26.

Data Analysis

It is seen that the ratio of standard errors of the skewness and kurtosis values is between -1.96 and +1.96. In this case, it can be said that the scores obtained from these scales from each group are normally distributed (Field, 2009).To determine whether there was a significant difference in the average scores of children's scientific process skills in relation to STEM-based educational activities, a 3X3 mixed-design ANOVA test was employed. To determine whether there was a significant difference between the children's pre-experimental and post-experimental scientific process skills average scores, the ANOVA test was used for groups showing normal distribution, and the Friedman and Kruskal-Wallis tests were utilized for groups not showing. Furthermore, a comparison of the average scores of the groups was performed using the effect size calculations using the eta-squared correlation coefficient method. According to this, regardless of positive or negative values, effect sizes lower than .30 were interpreted to have a small effect, those between .30 and .50 as having a medium effect, and those greater than .50 as having a large effect (Field, 2011).

Findings

Table 2 shows the descriptive statistics for the Good Enough Harris (GH) test scores in each group. The scores in the experimental group ranged from 5 to 15, with a mean of 9.53 and a standard deviation of 3.27. In control group 1, the scores ranged from 4 to 14, with a mean of 8.47 and a standard deviation of 2.74. In control group 2, the scores ranged from 5 to 17, with a mean of 9.74 and a standard deviation of 3.21.

Table 2.
Descriptive Statistics on GH

Group		Min.	Max.	Mean	S	Skewness (SHç: 0,52)	Kurtosis (SHb:1,014)	Skewness/ Error	Kurtosis/ Error
EG	GH total score	5	15	9.53	3.27	.41	-1.09	0.78	-1.08
CG1	GH total score	4	14	8.47	2.74	.41	-.64	0.77	-.63
CG2	GH total score	5	17	9.74	3.21	.69	-.23	1.32	-.23

The skewness and kurtosis values in each group fall within the range of -1.96 to +1.96, indicating that the scores are normally distributed (Field, 2009). Based on the GH test results, which were used to ensure group homogeneity, it could be concluded that all groups were equal and homogeneous.

Table 3.
Results of the One-Way ANOVA Test of GH Scores according to Experimental, Control 1 and Control 2 Groups

Source of Variance		Sum of Square	sd	Mean Square	F	p
GH Total Scores	Between-groups	17.404	2	8.702	.916	.406
	In-group	513.158	54	9.503		
	Total	530.561	56			

Table 3 presents the results of the one-way ANOVA test for the GH scores among the experimental, control 1, and Control 2 groups. The test did not reveal significant differentiation between groups (F(2, 54) = .916; p > .05). Therefore, it can be concluded that the groups were considered equal in terms of their GH scores. The findings indicated that the GH test scores were normally distributed in all groups and that there were no significant differences between the groups, confirming their homogeneity.

Table 4.
Descriptive Statistics on the Scientific Process Skills Test (SPST)

Group		Min.	Max.	Mean	S	Skewness (SHç:0.52)	Kurtosis (SHb:1.014)	Skewness/Error	Kurtosis/Error
EG	Total pretest	5	24	13.32	4.98	.37	-.07	.71	-.07
	Posttest total	17	26	22.42	2.55	-.69	-.37	-1.31	-.37
	Total followup	19	26	23.68	2.00	-.86	.37	-1.64	.36
CG 1	Total pretest	5	22	14.05	4.87	.03	-.67	.05	-.66
	Total posttest	12	24	16.95	3.69	.14	-1.08	.26	-1.06
	Total followup	9	24	17.89	4.19	-.40	-.30	-.76	-.30
CG 2	Total pretest	4	22	14.16	5.53	-.51	-.62	-.97	-.61
	Total posttest	6	24	16.95	6.18	-.49	-1.22	-.94	-1.20
	Total followup	7	24	17.37	5.51	-.56	-.93	-1.07	-.91

Control group 2 also showed an ascending trend in mean scores from the pretest to followup, with standard deviation patterns consistent with the previous groups.

Skewness and kurtosis values in all groups and tests were restricted between -1.96 and +1.96, suggesting a normal distribution of SPST scores in all measurements. In summary, descriptive analyses intimate that all cohorts demonstrated growth in scientific process skills from the initial measurement to the subsequent tests. The trend in standard deviations implies increased consistency of the score in followup assessments, underscoring the efficacy of applied interventions in improving the abilities of scientific process of children.

Table 5 includes the skill scores for the scientific process of the children who participated in two different training. Consequently, it was found that the joint effects of being in different process groups and repeated measures factors on scientific process skills were significant (F(4, 108)=17.00; p < .05, partial η2=0.39). This finding showed that different practices in the groups had different effects on the increase in the scientific process skills score. It was understood that the scientific process skill scores of the children in the experimental group in which STEM activities were applied were higher. As a result of the Bonferroni comparison test, it was seen that the mean of the experimental group differed significantly from the control 1 and 2 groups.

Table 5.
Pretest-Posttest-Follow-up Test ANOVA Results of SPST Scores

Source of Variance	KT	sd	KO	F	p	Effect Size	Sig. Diffr.
Between Groups	3311.02	56					1-2
Group	487.30	2	243.65	4.66	.01	.15	1-3 2-3
Error	2823.72	54	52.29				
Within Groups	2066.667	114					
Measure	1117.088	2	558.54	103.52	.00	.66	E-C1
Group*Measure	366.877	4	91.72	17.00	.00	.39	E-C2
Error	582.702	108	5.40				
Sum	7444.351	170					

When Table 6 is examined, in the experimental group, the scientific process skills scientific communication subdimension scores ranged from 1 to 13 in the pretest, ranged from 6 to14 in the posttest, and ranged from 8 to 14 in the follow-up test; their averages increased progressively from the pretest to the follow-up test. It was seen that the standard deviations decreased.

Table 6.
Descriptive Statistics on the SPST Scientific Communication Subtest

Group		Min.	Max.	Mean	SS	Skewness (SHç:0.52)	Kurtosis (SHb:1.014)	Skewness/Error	Kurtosis/ Error
EG	pretest	1	13	7.37	3.00	-.36	.28	-.68	.28
	posttest	6	14	11.37	2.27	-.87	.05	-1.65	.05
	followup	8	14	12.26	1.79	-1.03	.44	-1.96	.43
CG1	pretest	2	12	7.47	3.04	-.40	-.79	-.77	-.78
	posttest	3	12	8.26	2.42	-.40	-.19	-.76	-.19
	followup	3	13	9.11	2.90	-.60	-.38	-1.15	-.37
CG2	pretest	1	12	7.37	3.55	-.63	-.76	-1.21	-.75
	posttest	1	14	8.42	4.03	-.59	-.82	-1.13	-.80
	followup	1	14	8.68	3.97	-.60	-.80	-1.15	-.79

The scientific communication subdimension scores in the control 1 group were found to vary from 2 to 12 in the pretest, from 3 to 12 in the posttest and from 3 to13 in the follow-uptest; their averages increased from the pretest to the follow-up test. On the other hand, it was seen that the standard deviations increased in the posttest compared to the pretest, and decreased in the follow-uptest compared to the posttest, but nevertheless increased compared to the pretest.

Scientific communication subdimension scores in the control 2 group ranged from 1 to 12 in the pretest, from 1 to 14 in the posttest, and from 1 to 14 in the follow-up test; their averages increased progressively from the pretest to the follow-up test; on the other hand, it was seen that standard deviations decreased in the posttest compared to the pretest, and increased in the follow-up test compared to the posttest, but nevertheless decreased compared to the pretest.

When the ratio of the skewness and kurtosis values to standard errors was examined, it was seen that all values fell between -1.96 and + 1.96. In this case, it can be said that the scores obtained from these tests in each group were normally distributed (Field, 2009). The results of the 3X3 ANOVA test conducted to determine whether the scores obtained from the tests differed according to the pretest, posttest and follow-uptests are given below.

When Table 7 is examined, it was found that there was a significant difference in the scientific communication subdimension of the children participating in different education programs from before to after the experiment. In other words, the common effects of being in different process groups and repeated measurement factors on scientific process skills were significant (F(4, 108)=10, 04; p < .05, partial η2=0.27). This finding showed that the program applied in each group had different effects on increasing the scientific communication subdimension of scientific process skills. As a result of the Bonferroni comparison test, it was seen that the mean of the experimental group differed significantly from the Control 1 and 2 groups.

Table 7.
Scientific communication Subtest of SPST Pretest-Posttest-Follow-up Scores ANOVA Results

Source of Variance	KT	sd	KO	F	p	Effect Size	Sig.Diffr.
Between Groups	1464.01	56					1-2
Group	170.26	2	85.13	3.55	.04	.12	1-3
Error	1293.75	54	23.96				2-3
Within Groups	548.0	114					
Measure	210.33	2	105.16	46.14	.00	.46	EG-CG1 EG-CG2
Group*Measure	91.53	4	22.88	10.04	.00	.27	
Error	246.14	108	2.28				
Sum	2560.01	170					

As shown in Table 8, the prediction subdimension scores in the experimental group ranged from 1 to 6 in the pretest, 4 to 7 in the posttest, and from 5 to 7 in the follow-up test; their averages increased progressively from the pretest to the follow-uptest; it was seen that the standard deviations decreased.

Table 8.
Descriptive Statistics on the SPST Prediction Subtest

Group		Min.	Max.	Mean	SS	Skewness (SHç:0.52)	Kurtosis (SHb:1.014)	Skewness /Error	Kurtosis/ Error
EG	pretest	1	6	3.74	1.59	-.07	-.69	-.13	-.68
	posttest	4	7	6.37	.83	-1.48	2.41	-2.83	2.37
	followup	5	7	6.58	.69	-1.44	.91	-2.74	.90
CG1	pretest	2	6	3.79	1.32	.27	-.57	.51	-.56
	posttest	2	7	4.79	1.32	-.39	-.47	-.74	-.46
	followup	2	7	5.00	1.25	-.19	.79	-.37	.78
CG2	pretest	1	6	4.16	1.54	-.40	-.69	-.76	-.68
	posttest	1	7	4.68	1.80	-.43	-.46	-.82	-.45
	followup	2	7	4.95	1.27	-.44	.43	-.84	.43

The prediction subdimension scores in the control 1 group varied from 2 to 6 in the pretest, from 2 to 7 in the posttest, and from 2 to 7 in the follow-up test; their averages increased progressively from the pretest to the follow-up test; it was seen that the standard deviations remained at the same values in the pretest and posttest, and decreased in the follow-up test compared to the pretest and posttest.

The prediction subscale scores in the control 2 group ranged from 1 to 6 in the pretest, 1 to 7 in the posttest, and between 2 and 7 in the follow-up test; their averages increased progressively from the pretest to the follow-up test; on the other hand, it was seen that the standard deviations increased in the posttest compared to the pretest, and decreased in the follow-up test compared to the pretest and posttest.

When the ratio of the skewness and kurtosis values to standard errors was examined, it was seen that some of the values were not between -1.96 and + 1.96 in the experimental group. In this case, it can be said that the scores obtained from these tests were normally distributed in the control 1 and control 2 groups, but not normally in the experimental group (Field, 2009). Thus, ANOVA was used in the control groups and the Friedman test in the experimental group for measurements related to whether the pretest, posttest, follow-up tests differed. The Kruskal-Wallis test was used to determine whether the measurements differed in the groups. The results of the Friedman test conducted to determine whether the scores obtained from these tests differ in the experimental group according to the pretest, posttest and follow-uptests are given below.

As shown in Table 9, there was a statistically significant difference between repeated measures of the prediction subtest $\chi 2$ (sd=2, n=19) = 34.06, $p < .05$. The increase seen from the pretest to the posttest and from the pretest to the follow-up test was statistically significant.

Table 9.
Friedman Test Result of Pretest, Posttest and Follow-up Tests in the Experiment Group

Measures	Mean rank	sd	χ^2	p	Sig.diff.	η^2
Pretest	1.03	2	34.06	.00*	1-2	.61
Posttest	2.39				1-3	.62
Follow up	2.58					
*p<.05						

There was a statistically significant difference between repeated measurements of the prediction scores of the students in the control 1 group (F(2, 36) = 8.56, $p < .05$, partial $\eta 2$= .32). As a result of the Bonferroni comparison test performed to determine between which measurements these differences were, a significant difference was observed between the mean scores of the pretest and posttest, pretest, and follow-up test (Table 10).

Table 10.
Result of the ANOVA Test of the Pretest, Posttest, and Follow-up Tests in the Control 1 Group

Source of Variance	KT	sd	KO	F	p	Effect Size	Sig. diff.
Between Groups	56.877	18	3.160				1-2
Measure	15.895	2	7.947	8.556	.00*	.322	1-3
Error	33.439	36	.929				
Sum	106.21	56.00					

According to Table 11, there were no statistically significant differences between repeated measurements of the prediction scores of the students in the control 2 group (F(2, 36) = 3.08, p > .05). In addition to these, the results of the Kruskal-Wallis test to determine whether the repeated measurements differed between the groups are given below.

Table 11.
ANOVA Test Result of Pretest, Posttest and Follow-up Tests in Control 2 Group

Source of Variance	KT	sd	KO	F	p
Between Groups	93.719	18	5.207		
Measure	6.140	2	3.070	3.082	.06
Error	35.860	36	.996		
Sum	135.72	56.00			

As shown in Table 12, the pretest scores of the groups did not differ (χ2 =.99; sd =2; p>.05), and the posttest and follow-up tests were not different between the experimental group and the control 1 (χ2 =15.81; sd =2; p<.05) and 2 (χ2 =20.69;sd =2; p<.05).

Table 12.
Kruskal-Wallis Test Results whether Repeated Measurements Differentiated between Groups

Measures	Groups	Mean rank	sd	χ^2	p	Sig. Diffr.	η^2
Pretest	EG	27.37	2	.99	.61		
	CG 1	27.63					
	CG 2	32.00					
Posttest	EG	41.05	2	15.81	.00*	EG-CG1	.61
	CG 1	22.50				EG-CG2	.51
	CG 2	23.45					
Follow up	EG	42.66	2	20.69	.00*	EG-CG1	.63
	CG 1	22.32				EG-CG2	.66
	CG 2	22.03					

*p<.05

When Table 13 is examined, in the experimental group, the measurement sub-dimension scores ranged from 0 to 5 in the pretest, 4 to 5 in the posttest, and from 4 to 5 in the follow-up test; their averages increased progressively from the pretest to the follow-up test. It was seen that the standard deviations decreased.

Table 13.
Descriptive Statistics on the Measurement Subtest

Group		Min.	Max.	Mean	SS	Skewness (SHç:0.52)	Kurtosis (SHb:1.04)	Skewness/ Error	Kurtosi /Error
EG	pretest	0	5	2.21	1.65	.29	-1.12	.55	-1.11
	posttest	4	5	4.68	.48	-.86	-1.42	-1.65	-1.40
	followup	4	5	4.84	.37	-2.04	2.41	-3.90	2.38
CG1	pretest	1	5	2.79	1.44	.16	-1.20	.31	-1.18
	posttest	2	5	3.89	.99	-.15	-1.36	-.28	-1.34
	followup	2	5	3.79	.98	-.33	-.74	-.64	-.73
CG2	pretest	0	5	2.63	1.21	-.24	.21	-.46	.21
	posttest	1	5	3.84	1.12	-.99	.86	-1.88	.85
	followup	1	5	3.74	.99	-.94	1.90	-1.79	1.88

The measurement sub-dimension scores in the control 1 group varied from 1 to 5 in the pretest, from 2 to 5 in the posttest, and from 2 to 5 in the follow-up test; means increased from the pretest to the posttest and decreased in the follow-up test compared to the posttest; it was seen that the standard deviations decrease from the pretest to the follow-up test. The measurement sub-dimension scores in the control 2 group ranged from 0 to 5 in the pretest, 1 to 5 in the posttest, and from1 to 5 in the follow-up test; means increased from the pretest to the posttest and decreased in the follow-up test compared to the posttest; it was seen that the standard deviations decreased from the pretest to the follow-up test. When the ratio of the skewness and kurtosis values to standard errors was examined, it was seen that some of the values were not between -1.96 and + 1.96 in the experimental group. In this case, it can be said that the scores obtained from these tests in the control 1 and control 2 groups were normally distributed but not in the experimental group (Field, 2009). Hence, ANOVA was used in the control groups and the Friedman test in the experimental group for the measurements related to whether the pretest, posttest, follow-up tests differed. The Kruskal-Wallis test was used to determine whether the measurements differed in the groups.

According to Table 14, there was a statistically significant difference between repeated measurements of children's measurement subtest. χ2 (sd=2, n=19) = 30.47, p < .05. The increase seen from the pretest to the posttest and from the pretest to the follow-up test was statistically significant.

Table 14.
Friedman Test Result of Pretest, Posttest and Follow-up Tests in the Expreriment Group

Measures	Mean rank	sd	χ^2	p	Sig.diffr.	η^2
pretest	1.16	2	30.47	.00*	1-2	.57
posttest	2.34				1-3	.58
followup	2.50					
*p<.05						

According to Table 15, there was a statistically significant difference between repeated measurements regarding the measurement scores of the students in the control 1 group (F(2, 36) = 9.136, p < .05, partial η^2= .34). As a result of the Bonferroni comparison test performed to determine between which measurements these differences were, a significant difference was observed between the mean scores of the pretest and posttest, pretest, and follow-up test.

Table 15.
ANOVA Test Result for Pretest, Posttest and Follow-up Tests in Control 1 Group

Source of Variance	KT	sd	KO	F	p	Effect Size	Sig.Diffr.
Between Groups	44.246	18	2.458				1-2
Measure	14.140	2	7.070	9.136	.001	.337	1-3
Error	27.860	36	.774				
Sum	86.25	56.00					
*p<.05							

As shown in Table 16, there was a statistically significant difference between repeated measurements for the measurement scores of the students in the control 2 group (F(2, 36) = 19.743, p < .05, partial η^2= .52). As a result of the Bonferroni comparison test performed to determine between which measurements these differences were, a significant difference was observed between the mean scores of the pretest and posttest, pretest, and follow-up test. In addition to these, the results of the Kruskal-Wallis test performed to determine whether repeated measurements differed between groups are given below.

Table 16.
ANOVA Test Result for Pretest, Posttest and Follow-up Tests in Control 2 Group

Source of Variance	KT	sd	KO	F	p	Effect Size	Sig. Diffr.
Between Groups	51.053	18	2.836				1-2
Measure	17.088	2	8.544	19.743	.000	.523	1-3
Error	15.579	36	.433				
Sum	83.72	56.00					

As shown in Table 17the groups did not differ in their pretest scores (χ2 =1.52; sd =2; p>.05) and that the posttest and follow-up tests were 1 (χ2 =9.00; sd =2; p<.05) between the experimental group and the control group 2 (χ2 =18.77; sd =2; p<.05) differed in groups.

Table 17.
Kruskal-Wallis Test Results whether Repeated Measurements Differentiated between Groups

Measures	Groups	Mean rank	sd	χ^2	p	Sig.diffr.	η^2
pretest	EG	25.32	2	1.52	.47		
	CG 1	31.47					
	CG 2	30.21					
posttest	EG	37.71	2	9.00	.01*	EG-CG1 EG-CG2	.42 .44
	CG 1	24.68					
	CG 2	24.61					
followup	EG	41.61	2	18.77	.00*	EG-CG1 EG-CG2	.60 .65
	CG 1	23.13					
	CG 2	22.26					

*p<.05

Discussion

The impact of STEM education activities on preschool children's scientific process skills has been an area of interest for researchers and educators. Introducing STEM concepts at a young age can not only foster early academic skills, but also lay the foundation for lifelong scientific curiosity and learning (Bybee, 2013; Çiftçi, 2018).

The descriptive statistics of the Scientific Process Skills Test (SPST) indicate that the initial data were uniform across all groups, providing a consistent baseline for the study (Table 3-4). This uniformity ensures that any changes observed can be attributed to the interventions applied during the experimental process. The ANOVA results, which compare the pretest, posttest, and follow-up scores, reveal moderate efficacy of the experimental protocol (Table 5). This suggests that the STEM-centered activities had a positive effect on children’s scientific process knowledge, regardless of their group assignment. These findings align with existing literature, which emphasizes the importance of STEM education in enhancing children’s understanding of scientific concepts. Studies have shown that early exposure to STEM activities fosters the development of critical scientific skills, including observation, hypothesis generation, and experimentation (Honey, Pearson, & Schweingruber, 2014). By engaging in hands-on, inquiry-based learning, children can better grasp abstract scientific ideas and apply them in real-world contexts (Bybee, 2013). Moreover, the moderate efficacy observed in this study is consistent with previous research suggesting that while STEM interventions can have a positive impact on scientific literacy, the extent of this impact may vary depending on factors such as the duration and intensity of the intervention (Trundle, Atwood, & Christopher, 2002). This highlights the need for continuous and sustained engagement in STEM activities to maximize their effectiveness in fostering scientific process skills.

In addition, the affirmative influence of STEM activities, regardless of group designation, supports the notion that STEM education can be universally beneficial. Research has shown that STEM-based curricula are particularly effective in promoting equitable learning outcomes, as they provide opportunities for all children, irrespective of background or ability level, to engage in meaningful scientific exploration (Clements & Sarama, 2020). Research by Zorlu & Zorlu (2017) reveals a moderate and positive association between scientific process skills and the inclination towards STEM professions. Echoing this sentiment, the current study substantiates that STEM pedagogies bolster children's scientific process proficiencies, potentially augmenting their future affinity for STEM-orientated career paths. In conclusion, the results of this study contribute to the growing body of evidence supporting the integration of STEM activities in early childhood education. The moderate efficacy observed indicates that while STEM interventions are beneficial, further research is needed to optimize their implementation and assess their long-term impact on children's scientific process skills.

Among the characteristics measured under the scientific communication skill, children's observation, classification, and grouping which are at the base of the scientific processes, are also included. The scientific communication scores of all children participating in STEM activities, which were the same in the pretest, showed an increase of four points in the experimental group compared to the other groups in the posttest. The children in the experimental group were observed to reach the maximum score (Table 6). When the SPST communication subtest was analyzed and the results of the Friedman and Kruskal-Wallis test were interpreted, significant score enhancements were discerned in the experimental group after the intervention (Table 7). This finding revealed the tangible impact of STEM activities on the refinement of scientific skills, such as observation and classification. Preschool children are naturally curious and have an innate ability to engage in scientific enquiry. The findings of the study, such as improving children's thinking skills, align with the results found in the literature (DeJarnette, 2018; Kavak & Gül, 2021; Mercan & Kandır, 2019). Children can learn by taking care of their pets in their classrooms, observing daily weather conditions, experimenting with water and mud, etc. basics of life and earth sciences; they learn engineering skills by playing with structures and blocks (Aldemir & Kermani, 2017). When doing these, they actually realize many of their scientific process skills by themselves. In fact, children are already gaining some STEM experience in their daily lives. The quality of observations they make in these processes, how they relate to situations, and how they can develop these processes depend on the extent to which they are supported by the adults around them. In their studies, Dejonckheere et al. (2016) clearly demonstrated that children's exploration and scientific reasoning skills are further developed as a result of their studies involving STEM activities at the level of scientific reasoning in preschool.

Indeed, there is a connection between preschool and STEM education. Especially from a young age, instead of memorizing information, it is necessary to engage in activities that support children's relationships with what they have learned, their experience, and reasoning. Thus, children will be able to use their tendency to understand the relationships in the scientific process steps and to use all of their processes in both their social and professional life experiences. Millar (1994) argues that observation is not a process specific to the method of science but is just one of the approaches that people always use to understand the world, whether they act scientifically or not. Thus, he argues that observation is a content-independent process. Therefore, when viewed separately from the cognitive processes that come with skills, such as observation, classification, and scientific communication, it will cease to be a skill that can be gained through any practice or teaching approach.

In fact, scientific processes do not only give children a scientific perspective and expe-rience. At the same time, it brings in contact with scientific environments rich in language. Providing a language-rich environment supports children's language acquisition and pragmatic functions of language, enabling them to communicate with adults (French, 2004). A scientific lesson plan and its outcomes provide significant benefits for the development of scientific communication skills. The foundation of scientific communication is based on observation, as data gathered through observation plays a critical role in sharing and understanding scientific information. While teachers may view observation as a time-consuming skill, it is actually the most fundamental and essential component of scientific processes. The results of this study also support this perspective. Therefore, to enhance observation skills and strengthen scientific communication, the use of STEM activities from an early age should be encouraged more effectively.According to descriptive statistics, there was a significant increase in the prediction skills of the children in the experimental group than the children in the control groups (Table 8). In this study, STEM activities increased children's prediction skills. When the prediction scores of the groups were examined, it was observed that there was no significant increase in the control 1 and 2 groups (Tables 9-10-11), while the average scores of the children in the experimental group increased from 3.74 to 6.58.

To use their prediction skills, children are expected to have previously acquired knowledge (Turan, 2012) and be able to establish a cause-effect relationship between this information. STEM education provides structured opportunities for children to hone these skills. For example, Gelman and Brenneman (2004) observed that children as young as three can engage in hypothesis testing, prediction, and experimentation, all of which are core components of the scientific process. STEM activities include processes that will support children's understanding of cause-and-effect relationships. Hanauer (2018) states that skills, such as drawing and crea-ting graphics, will strengthen students' prediction skills and they will be able to establish cause-effect relationships more easily. In the environment where research and inquiry-based STEM activities are performed, individuals' skills are supported to use scientific processes, such as observation, measurement, classification, use of numbers, data collection, data analysis, hypothesis formulation, prediction, and experimentation, are supported (Gökbayrak & Karişan, 2017). Preschool prediction skills are generally associated with science activities and almost most of the studies (Aydoğdu & Ergin, 2008; Gökbayrak & Karişan, 2017; Kavak, 2019; Kefi, 2013; Kunt, Özel, Kunt, 2015; Özdemir, 2004; Strong, 2013; Tan & Temiz, 2003; Tatar, 2006) tried to gain prediction processes with these activities. The results of the studies of Kunt et al. (2015) show that while 60-72-month-old children's observation, classification and space-spatial skills develop better, although measurement, inference and prediction skills increased, observation showed that they lagged behind their classification skills. According to this result, it can be said that children's prediction and measurement skills also develop, but they are less supported in activities compared to other skills. Thus, it can be said that activities that improve the prediction and measurement skills of these children should be included more frequently.

According to the findings of the comparison tests, there is no significant difference between the experimental group and the two control groups (Control 1 and Control 2), and there is also no statistically significant difference between the Control 1 and Control 2 groups (Tables 12, 13, 14). In early childhood, measurement skills are often limited to mathematics and, occasionally, science activities. These activities are typically grounded in Piaget's conservation principle (Piaget, 1970). Since preschool children may not fully grasp standard units of measurement, they are encouraged to use non-standard tools based on familiar objects. STEM activities enhance the understanding and practical use of measurement, making it a more concrete and accessible process for young children.

Due to their developmental stage, children naturally become aware of changes in their height and weight and often express a desire to measure these. It is important to provide them with measurement results in a way that helps them understand comparisons and outcomes, even during their free play and routine activities. In this case, it is crucial to support children to be aware of their measurement skills and to use them in a conscious and concrete way. This skill should be also supported in a way that parallels children's intellectual and scientific skills. Ostlund (1992) defines measurement as the results obtained using standard or non-standard measurement tools. To comprehend the nature of measurement and gain measurement skills, an individual must be able to recognize measurement tools and have the ability to use them practically. However, the development of measurement skills depends on the development of both cognitive, affective and psychomotor skills (Maral, Oğuz Ünver, Yürümezoğlu, 2012).

Measurement skills form the foundation of all sciences (Maral et al., 2012). The ability to measure is essential for developing skills such as questioning, reasoning, and drawing conclusions by comparing events, which are especially emphasized among 21st-century skills (National Research Council, 2012). It is evident that measurement activities conducted in preschool are usually integrated with mathematics and science, while separate studies focusing specifically on this skill are scarce. However, measurement is a critical skill that we frequently need and use in our daily lives, and awareness of this skill should be cultivated from an early age (Clements & Sarama, 2020; Baroody, Lai, & Mix, 2014). In STEM education, measurement forms the foundation for processes such as sharing information, collaborating, and presenting findings (Bumbacher, Salehi, Wieman, & Blikstein, 2018; Honey, Pearson, & Schweingruber, 2014). Thus, STEM activities provide a valuable approach for developing and applying measurement skills (Bybee, 2013).

The role of STEM activities in the development of scientific process skills is inevitable, and its effect has been proven by many studies (Strong, 2013; Kavak, 2019; Çiftçi, 2018). However, most of the studies conducted cover children at the primary and secondary school levels. Exposure to STEM activities in preschool can instil a positive attitude towards science, making children more likely to pursue STEM fields later in life. A report from the National Research Council (2012) indicated that early STEM education has a strong potential to foster positive attitudes toward science and mathematics, reducing anxiety around these subjects in the later academic years. Gonzalez and Freyer’s (2014) results also relate STEM education from the preschool period to support children in developing a positive attitude toward STEM fields. However, there are challenges associated with implementing STEM activities in preschool settings. Teachers need appropriate training to effectively integrate these concepts into the classroom (McClure et al., 2017). Additionally, it is crucial to strike a balance between structured learning and play, ensuring that STEM activities are age-appropriate and engaging.

Conclusion and Suggestions

To show that the groups are on an equal level, the Good Enough Harris (draw a human) test was applied in psychometric dimension and the children and homogeneous groups were determined according to their scores. This test showed that the children participating in the present study were of the same developmental age and level. A statistically significant difference was found when the scores obtained before the application of preschool children participating in STEM activities were compared with the overall scores of the scientific process skills test obtained after the application. When the scientific communication sub-dimension of the test was examined, the scores of the children in the experimental group differed statistically significantly than the scores of the children in the control groups. This finding shows that STEM activities applied in the experimental group are effective in the communication sub-dimension. Scientific communication sub-dimension includes questions about classification, grouping and communication skills, which are among the basic skills and develop depending on the observation skills. Therefore, the acquisition of this skill after the experiment process of the children also shows an increase in their ability to communicate scientifically and their ability to classify and observe. In the prediction sub-dimension, it was concluded that the scores of the children in the experimental group and control 1 group differed statistically significantly in the posttests. No statistically significant differences were found in the control 1 and 2 groups. The effect of the applications in the experimental group on the prediction skills was calculated by removing the researcher effect. When the measurement sub-dimension was examined, it was concluded that the posttest scores of the children in the experimental group and control 1 group differed statistically significantly, while there was no statistical difference in the control 2 group. This finding shows that the experimental process is also effective in the measurement sub-dimension. The significant difference seen in the control 1 group is seen as the researcher effect, as in the prediction sub-dimension. It is thought that this effect may have arisen due to the Hawthorne effect. According to the findings of the general scores of scientific process skills and sub-dimensions of STEM activities, it is concluded that there is a significant relationship between STEM and scientific process skills in general.

In addition to the results, off-the-record interviews with parents during the experimentation period accrued that children's STEM activities also showed progress in 21st-century skills, such as cooperation, communication, questioning, flexible and creative thinking, and sharing skills in other areas of children, during the experimental study. This result corroborated by parental feedback shows our exploration of broader underscores the holistic developmental attributes of STEM activities, such as 21st-century skills. The relationship between our findings and existing literature reinforces the validity and significance of the results.

In conclusion, this study contributes to the growing body of knowledge on the multifaceted benefits of integrating STEM activities into early childhood education. The insights obtained here have implications for pedagogical practices and policy considerations aimed to improve the holistic development of children.

Limitations

This experimental study period covers a period of one semester. Some of the participants could not attend all of the sessions due to their health problems; therefore, their results were not included in the final tests. Children whose cognitive levels differ according to the homogeneity distribution test. Thus, they were not included in this study were not kept out of the classroom during the activities. The differences of the practising physicians in the control groups were not evaluated by a second researcher.

It is essential to acknowledge the limitations of our study, which include potential confounders and the relatively short-term nature of the investigations. Hence, we recommend that further research encompasses more comprehensive and longitudinally orientated approaches to provide a more nuanced understanding of the enduring impact of early exposure to STEM on a broader range of cognitive and practical skills.

Acknowledgment

Ethics statement: In this study, we declare that the rules stated in the "Higher Education Institutions Scientific Research and Publication Ethics Directive" are complied with and that we do not take any of the actions based on "Actions Against Scientific Research and Publication Ethics". At the same time, we declare that there is no conflict of interest between the authors, which all authors contribute to the study, and that all the responsibility belongs to the article authors in case of all ethical violations.

Author Contributions: Authors contributions are “Conceptualization, Ş. Kavak and E. Deretarla Gül; methodology, and validation, Ş. Kavak and E. Deretarla Gül; analysis, Ş. Kavak.; writing, review and editing, Ş. Kavak; supervision, and project administration. E. Deretarla Gül.

Funding: This study was supported by Çukurova University the Scientific Research Project Unit, with the scientific research project number SDK-2018-10900 within the scope of the doctoral thesis.

Institutional Review Board Statement: The study has been approved by the Ethics Committee of Çukurova University (Approval Date: 2018/04/26). Besides, necessary permissions for implementation were obtained from the Gaziantep National Education Directorate before the groups were formed (reg. No. 34659092-605.01-E 14023941).

Data Availability Statement: Data generated or analyzed during this study should be available from the authors on request.

Conflict of Interest: Authors should declare that there is no conflict of interest among authors.

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