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Inquiry-based mathematics activities to improve children's geometric and spatial thinking skills

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ABSTRACT This study aimed to investigate the impact of inquiry-based indoor and outdoor mathematics activities on pre-school children's geometric and spatial thinking skills. Thirty-two children between 48 and 66 months old participated in the study. The study employed as a quasi-experimental research model and employed Non-equivalent Control Group Design. The design included one control group and two experimental groups. The control group continued regular curriculum activities while Experimental Group 1 was exposed to inquiry-based mathematics activities in the classroom, and Experimental Group 2 engaged in the same activities but outdoors, along with the regular curriculum activities. The Geometric and Spatial Thinking Skills Test was used as a data collection tool. According to the results of the study, inquiry-based mathematics activities contribute to preschoolers' geometric and spatial thinking skills. The impact of inquiry-based mathematics activities on experimental groups were similar to each other. Some recommendations for further studies and implementations were made following the results of this study.

Keywords: *Geometric thinking skills, natural outdoors, pre-school education, pre-school mathematics education, spatial thinking skills.*

Çocuklarının geometrik ve uzamsal düşünme becerilerini geliştirmeye yönelik sorgulama temelli matematik etkinlikleri

ÖZ Bu çalışma, sınıf içerisinde ve açık alanlarda yürütülen sorgulama temelli matematik etkinliklerinin okul öncesi dönemdeki çocukların geometrik ve uzamsal düşünme becerileri üzerindeki etkisini incelemeyi amaçlamıştır. Çalışmaya, yaşları 48 ila 66 ay arasında değişen 32 çocuk katılmıştır. Çalışmada Yarı Deneysel desenlerden Eşitlenmemiş Kontrol Gruplu Desen kullanılmıştır. Çalışmada bir kontrol ve iki deney grubu yer almıştır. Kontrol grubu rutin etkinliklerine devam ederken, yürütülen rutin etkinliklere ek olarak Deney Grubu 1'e sınıf içerisinde yürütülen sorgulama temelli matematik etkinlikleri, Deney Grubu 2'ye ise açık alanlarda yürütülen sorgulama temelli matematik etkinlikleri uygulanmıştır. Veri toplama aracı olarak Geometrik ve Uzamsal Düşünme Becerileri Testi kullanılmıştır. Bu çalışmanın sonuçlarına göre, sorgulama temelli matematik etkinlikleri okul öncesi çocukların geometrik ve uzamsal düşünme becerilerinin gelişimine katkı sağlamaktadır. Sorgulama temelli matematik etkinliklerinin sınıf içerisinde veya açık alanlarda uygulandığı deney grupları üzerindeki etkisi ise birbirine benzer bulunmuştur. Bu çalışmadan elde edilen sonuçların ardından ileri çalışmalar ve uygulamalar için bazı önerilerde bulunulmuştur.

Anahtar Sözcükler: *Doğal açık alanlar, geometrik düşünme becerisi, okul öncesi eğitimi, okul öncesi matematik eğitimi, uzamsal düşünme becerisi.*

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INTRODUCTION

Twenty-first-century learning requires learner-centered approaches, and the learners construct the knowledge and maintain it in an appropriate way and share the constructed knowledge (Frasinescu, 2018). In inquiry-based learning, learners take responsibility and the initiative for their own learning (A. W. Khan, 2012) and are active in teaching and learning processes. Learners have opportunities to explore in-depth and perceive the facts by asking their own questions, and thus, learners develop a deeper understanding and construct knowledge through their own experiences. They share and present the things they encountered in the learning processes, their experiences, thoughts, and results, with others (Alberta Learning, 2004).

Inquiry-based learning is mostly associated with science, but it is closely related to mathematics. Inquiry-based learning has become crucial for mathematics education and the approach has been placed at the centre of mathematics education which is considered a focal point to renew many mathematical educational curriculums (Dreyøe et al., 2017; Freudenthal, 1986). Taiwanese Educational Curriculum (Wu & Lin, 2016), Australian Educational Curriculum (Perry, Dockett & Harley, 2012), Alberta's (Canada) Educational Curriculum (Alberta Learning, 2004), the French educational approach La Main Â La Pâte (Sarmant, Saltiel, & Léna, 2011), Primary Years Program of International Baccalaureate (International Baccalaureate Organization, 2012) are some of the programs that countries placed inquiry-based learning in the center of their curricula.

Mathematical learning is a cumulative, target-oriented, constructive, and active learning process. This process should be perceivable to learners; therefore, teachers, as guides, should transform mathematical learning processes into joyful journeys of discovery. They should use well-structured questions to offer these opportunities. In this vein, inquiry-based mathematical learning is considered one of the most appropriate ways to convey the value of this process (Baptist, 2012). Inquiry-based mathematical learning is a process whereby learners make knowledge more meaningful by using the acquired knowledge actively (Jessen, 2017). Learners investigate the concepts and information, then make some predictions and reasoned conclusions about them. They evaluate whether the facts are meaningful on their own. They deepen their knowledge and develop new understandings in cooperative learning processes where teachers, as guides, encourage, organize, or instigate inquiry processes to support learners (Jarret, 1997). Recent studies on the effect of inquiry-based learning on mathematical achievements revealed that inquiry-based geometry education enhances elementary and middle school students' geometrical and mathematical achievements and their interest in geometry and mathematics. (Patterson, 2016; Taylor & Bilbery, 2012). Jurat (1992) found that inquiry-based mental mathematical activities enhance 4th grade students' mathematical achievements and contribute to positive attitudes towards mathematics.

Regarding the geometry sub-learning area Leikin and Grossman (2013) state that inquiry-based learning ensures for teachers to easily transform geometry learning into investigation and discovery processes and for learners to develop a better understanding of geometry. Brune (2010) states that inquiry-based learning increases high school students' ability to solve geometrical problems, and attitudes towards mathematics. Mensah-Wonkyi and Adu (2016) found that an inquiry-based teaching approach improves senior high school students' understanding of circle theorems in geometry. This study also reveals that an inquiry-based teaching approach ensures higher motivation for learning geometry. Lewis' (2009) study reveals that inquiry-based instruction increases 10th-grade students' success in geometry learning. According to Kandil and Işıksal-Bostan's (2019) research study inquiry-based origami activities effects 7th-grade students' achievement in symmetry positively. Their study also reveals that inquiry-based origami activities have positive effects on students' self-efficacy toward geometry. Erbaş and Aydoğan-Yenmez's (2011) study reveals that inquiry-based geometrical exploration processes improve 6th-grade students' achievement in geometry, and motivation toward geometry. According to Uygun (2020), inquiry-based learning ensures a deeper understanding of geometrical transformations and their relations to learners. Sizemore (2020) states that inquiry-based learning improves students' achievement in geometry. Regarding the early childhood period, an inquiry-based mathematics education program for 3- to 6-year-old children contributes to mathematical skills and motivation for mathematics (Henningsen, 2013; Wu & Lin, 2016). Skoumpourdi (2019) states that inquiry-based investigation processes on geometry have many benefits for kindergarteners and their teachers.

Regarding spatial thinking, Kavouras, Kokla, Tomai, Darra, and Pastra (2016) state that, inquiry-based teaching and learning methods are crucial for spatial thinking skills. According to the results of Rankin's (2016) study, technology-enhanced inquiry-based learning promotes primary school children's spatial thinking skills required in geographical learning areas. Susilawati, Suryadi, and Dahlan's (2017) study reveals that inquiry-based cognitive processes promote students' spatial abilities. Similarly, Narpila (2018) states that inquiry-based learning is effective to improve students' spatial capabilities. According to Weakley's (2010) study, inquiry-based learning promotes students' spatial thinking and supports them to apply their spatial abilities outside of educational settings. Malau, Napitupulu, and Armanto's (2017) study reveals that inquiry-based learning improves 10th grade students' spatial abilities and self-confidence. Focusing the early childhood Olver's (2013) study reveals that, inquiry-and play-based learning contributes to kindergarten children's early spatial skills.

Besides the educational programs or approaches, learning environments also affect educational achievements (Cheryan et al., 2014). Outdoor environments offer excellent learning opportunities for early childhood education (Cooper, 2015). Outdoor environments enrich teaching–learning processes, provide different learning experiences and make learning fun. These environments contribute to learners' holistic development and ensure learners gain many different benefits (McMillan, 2014; OFSTED [Office for Standards in Education, Children's Services and Skills], 2008). The National Wildlife Federation (2010) states that outdoor environments contribute to children's attention and concentration skills and enhance their academic achievements. Fjørtoft (2001) suggests that children's playing outdoors contributes to physical development, enhances their playing habits, and enriches game types. Bjorge et al. (2017) state that learning experiences in the outdoors stimulate the development of children's behavioral characteristics. The American Institutes for Research (2005) revealed that outdoor educational activities contribute to children's character, behavioral and social development. The institution also suggests that outdoor activities affect children's environmental awareness and attitudes toward nature and understanding of scientific concepts. McMillan (2014) suggests that, besides physical, social, and emotional development, outdoor environments contribute to children's curiosity, observation skills, and attitudes towards learning. MacDonald (2016) suggests that inquiry-based outdoor activities support children to make their knowledge and experiences more meaningful. She further suggests that inquiry-based outdoor activities ensure opportunities for children to take the initiative and work collaboratively. According to Schindler (2002), there is a unique and different connection between inquiry-based learning and outdoor educational environments. She suggests that children find excellent opportunities to face and challenge real-life situations and reach primary sources. That is why inquiry-based learning and outdoor educational environments have a special and supportive connection. Similarly, Kilburn (2015) emphasizes that inquiry-based learning is the most effective educational method to be used in the outdoors, among the other alternative educational methods. The natural outdoors is an important educational environment for children's health, development, and learning (Early Head Start National Research Center, 2013; Play Scotland, 2011). Considering inquiry-based learning, children are faced with many unexpected, unfamiliar, and challenging situations in the natural outdoors. They find opportunities to explore their surroundings freely and to discover. They overcome challenging situations cooperatively or individually (Early Head Start National Research Center, 2013).

Natural outdoor environments also contribute to children's geometric thinking skills (GTS) and spatial thinking skills (STS). According to the Back to Nature Network (2012), the natural outdoors offer children the chance to experiment with geometric shapes, areas, and geometric patterns. Enerson (2016) and the Natural Learning Initiative (2012) suggest that children develop a deeper understanding of geometric shapes and geometric representations in the natural outdoors. Sutterby and Frost (2013) state that natural outdoor environments offer excellent opportunities and contribute to children's GTS. For STS, Özgece et al. (2015) revealed that features of surroundings, boundaries, or walls of a place affect children's spatial sense. Paskins (2005) stated that children who walk to school and interact with their surroundings have greater spatial representation skills than those who travel by service bus or car. Smith et al. (2008) revealed that children's use of natural landmarks contributes to their STS. According to the National Learning Initiative (2012), and Smith et al. (2008) the more children spend time in the natural outdoors, the more they acquire better STS.

There are a few studies related to the effectiveness of inquiry-based learning and natural outdoors on young children's geometric and spatial thinking skills, among current studies. Considering the contribution of inquiry-based learning to children's geometric thinking (Brune, 2010; Erbaş & Aydoğan-Yenmez, 2011; Kandil & Işıksal-Bostan, 2019; Leikin & Grossman, 2013; Lewis, 2009; Mensah-Wonkyi & Adu, 2016; Sizemore, 2020; Skoumpourdi, 2019; Uygun, 2020) and spatial thinking skills (Kavouras, Kokla, Tomai, Darra & Pastra, 2016; Malau, Napitupulu & Armanto, 2017; Narpila, 2018; Olver, 2013; Rankin, 2016; Susilawati, Suryadi & Dahlan, 2017; Weakley, 2010) and also the contribution of natural outdoors on children's geometric thinking (Back to Nature Network, 2012; Enerson, 2016; Natural Learning Initiative, 2012; Sutterby and Frost, 2013) and spatial thinking skills (National Learning Initiative, 2012; Özgece et al., 2015; Paskins, 2005; Smith et al., 2008) it would be beneficial to use the strength of inquiry-based learning and the natural outdoors to support children's GTS and STS. Therefore, how inquiry-based indoor and outdoor mathematics activities affect children's GTS and STS needs to be explored in early childhood education in a detailed way.

Current Study

This study aimed to investigate the impact of inquiry-based indoor and outdoor mathematics activities (independent variables) on 48- to 66-month-old children's GTS and STS (dependent variables). The instruments used in this study may serve as a model for teachers. It may be investigated how indoor or outdoor learning environments and inquiry-based learning synergistically affect children's GTS and STS. For this study, the following questions were posed:

- How do inquiry-based outdoor mathematics activities affect 48- to 66-month-old children's geometric and spatial thinking skills?
- How do inquiry-based indoor mathematics activities affect 48- to 66-month-old children's geometric and spatial thinking skills?
- Do inquiry-based indoor and outdoor activities have different effects on 48- to 66-month-old children's geometric and spatial thinking skills?

METHODOLOGY

This study was a process of quasi-experimental research and employed a non-equivalent control group design. In this design, participants are not randomly assigned to study groups and included more than two experimental or control groups (Fraenkel & Wallen, 2009; Gall et al., 2003). In this study, study groups were drawn from three different public kindergarten classrooms. Children were already attending to their own classrooms and classrooms were assigned randomly as either control or experimental group through drawing lots. The control group (CG) did not receive any special treatment, except for those regular activities already required by the national curriculum. Experimental Group 1 (EG1) received inquiry-based indoor mathematics activities in addition to regular curriculum activities and Experimental Group 2 (EG2) received inquiry-based outdoor mathematics activities in addition to regular curriculum activities. In this study the hypnotizes were;

- Inquiry-based indoor and outdoor mathematics activities contribute to 48 to 66-month-old children's GTS and STS.

• Inquiry-based outdoor mathematics activities are more effective on children's GTS and STS, than indoor activities.

Study Group

Thirty-two children between 48 and 66 months old participated in the study. Participants were selected according to Homogeneous Sampling which is one of the Purposeful Sampling methods. In this sampling method, participants are selected by considering some similar or common characteristics (Creswell, 2012). For the study, the accessibility of kindergartens to the natural outdoors, the distance between kindergarten buildings and the natural outdoors, and the location of kindergartens in rural areas were decisive. Kindergartens located in rural areas were selected. All the kindergartens had mixed age groups of children. The CG included 12 children (6 girls, Mage = 61 months, SD = 4.42 / 6 boys Mage = 57.33 months, SD = 7.47) 10 children in the Experimental Group 1 (EG1) (3 girls, Mage = 57.66 months, SD = 8.50 / 7 boys Mage = 59.85 SD = 5.30) and 10 children in the Experimental Group 2 (EG2) (6 girls, Mage = 60.33 months, SD = 4.50 / 4 boys Mage = 64 months, SD = 1.50). All the children in the classrooms were included in the study, for each group. During data collection and experimental procedures, none of the participants were adjudged excluded or lost.

Data Collection Tools

The Geometric and Spatial Thinking Skills Test (GEOST-ST) was used as the data collection tool. The test was developed to determine 48- to 66-month-old children's GTS and STS. The Cronbach's Alpha values were reported as 93, 82, 90 for GTS, STS sub-scales, and the whole scale, respectively, by the researcher of the dissertation study. In this study, Cronbach's Alpha coefficient was found to be.76, .89 and, .88 for pre-test, post-test, and follow-up GTS scores of the GEOST-ST, respectively. They were found to be.88, .86 and, .90 for pre-test, post-test, and follow-up STS scores of GEOST-ST, respectively, .80, .87, and .85 for Total Score (TS).

This test was used on face-to-face interactions and task-based interviews with children. The GEOST-ST has two sub-tests-GTS and STS. Each item of the GEOST-ST has an instruction. Children are expected to perform the tasks following the instructions they are given. Teachers or researchers observe them as they perform the task. They wait for children to respond, take an action, or give an answer. Then, they take notes on a tracking form of the GEOST-ST, about the children's performance. information about item numbers, tasks, targeted skills, and sub-tests of the GEOST-ST are presented in Table 1.

Table 1.
Structure of the GEOST-ST

Sub-Tests	Skills	Tasks / Expectations	Numbers of Items		
GTS	Shape	Recognising two-dimensional shapes	4	7	12
		Naming two-dimensional shapes	1		
		Grouping two-dimensional shapes	1		
		Composing two-dimensional shapes	1		
	Area	Creating a certain boundary	1	2	
		Using a certain boundary effectively	1		
	Symmetry	Recognising symmetrical patterns	2	3	
		Creating a symmetrical pattern	1		
STS	Spatial Orientation	Acting in accordance with instructions	2	7	13
		Understanding the concepts referring positions	2		
		Describing the positions of objects	3		
	Spatial Visualization	Orienting in accordance with an image	1	6	
		Picturing the positions of objects	2		
		Matching an image and located objects	1		
		Drawing a simple map	1		
		Using a simple map	1		

Procedures

Before the study, three rural areas equidistant from the city center were identified. There was only one kindergarten in each village, and only one group for 48- to 66-month-old children in each kindergarten. The natural outdoors was accessible from all the kindergartens, and all had their own garden. Teachers were informed about the study and asked if they wanted to participate in the study. Then, legal (Institution: Amasya Directorate of National Education, Number: 47613789-44-E.13747692 Date: 06/12/2016) and ethical (Institution: Hacettepe University, Institution of Educational Sciences, Number: 35853172/433_400, Date: 22/02/2016) permissions were obtained, and parents of children were offered an informed consent form. Approval was obtained from all the parents. Three kindergarten classrooms were randomly assigned as either control or experimental group. Since cluster sampling methodology was used, children were not randomly assigned. This was because children were already attending their own kindergarten. Experimental procedures were carried out during the spring semester in the 2016-2017 academic year. This semester was preferred because teachers and children have more harmony in the classroom compared to the autumn semester as they are better acquainted.

The GEOST-ST was implemented with all groups to obtain pre-test scores after the second and third weeks of the semester. All the kindergartens were visited over a two-week timespan to obtain GEOST-ST pre-test scores. A quiet and comfortable place in the kindergartens was used to interview the children. Implementation of the GEOST-ST took approximately 25 minutes for each child. After obtaining pre-test scores, EG1 received 24 different indoor activities of the Inquiry-Based Activities Module (IBAM) and EG2 received 24 different outdoor activities of the IBAM. This module was developed by the authors in the dissertation study. Implementations of activities lasted for eight consecutive weeks. Three different activities were implemented for each week. The CG simply continued regular curriculum activities. The IBAM consists of 24 indoor and 24 outdoor inquiry-based mathematics activities. These activities are designed to support children's GTS and STS. Indoor and outdoor activities both addressed the same goals and skills. They were based on the same themes, such as building a city, delivering water to the village, describing a sight, finding symmetrical patterns, seeking geometrical shapes, and creating and using a certain boundary. The main differences were the learning environment and the materials. EG2 used stones, leaves, branches, mud, and real sights, while EG1 used pieces, leaf-shaped papers, plastic rods, playdough, and a picture of a landscape. For example, EG2 sought shapes on naturally cracked soils, while EG1 sought shapes on a tray filled with dried mud. In brief, EG2 used natural materials, and EG1 used artificial materials but similar to natural ones. Table 2 presents the skills and goals referred to in the IBAM.

Table 2.
Skills and Goals Referred in the IBAM

Skills	Sub-Skills	Goals
GTS	Shape	Recognizes, names, distinguishes, sorts, groups, composes, and decomposes the two-dimensional shapes (circle, round, triangle, square, rectangle, ellipse, trapezoid, pentagon, hexagon).
		Recognizes, names, distinguishes, sorts, and groups the three-dimensional shapes (cube, sphere, quadrangle, cylinder, pyramid, cone).
	Area	Creates a certain boundary, conveys the features of a certain boundary, uses a certain boundary effectively, and compares the certain boundaries by their sizes.
	Symmetry	Recognizes symmetrical patterns and creates symmetrical patterns.
STS	Spatial Orientation	Understands spatial words, positions him/herself in accordance with instructions, locates the objects in accordance with instructions, orients someone in accordance with instructions, and specifies his/her location by referring to objects or people around.
	Spatial Visualization	Orients himself/herself in accordance with an image, locate the objects in accordance with an image, pictures the position of objects, finds the target by using a simple map, draws a simple map or simple info map.

Activities of the IBAM are prepared according to Alberta Learning's (2004) seven-step inquiry-based learning process (Planning, Retrieving, Processing, Creating, Sharing, Evaluating, and Reflecting).

Examples of activities were shared in Appendix 1 and 2. Post-test data collection was performed one week after the end of the IBAM activity implementation period. The GEOST-ST was implemented with all groups, to obtain post-test scores, by following previous procedures. Six weeks after the IBAM implementation, follow-up scores were obtained by using the GEOST-ST.

Data Analysis

Forms were coded from C1 to C32 as pseudonyms for each repeated measurement. All the fully completed forms of each child were matched. GTS and STS -addressed in the GEOST-ST- are expected to be set out gradually. Children's responses were scored 0, 2, 4, 6, 8, 10, or 12 points, for each item of the GEOST-ST. It was scored by increasing two points for each upper step. One-way analysis of variance (ANOVA) was performed to examine the initial levels of groups for GTS, STS, and TS. Mixed Design (Split-Plot) ANOVA was performed to analyze the data obtained by repeated measurements.

ANOVA, which is one of the parametric tests, is a robust test and was the primary option for the analysis. However, in order to eliminate the effects of a small sample size, both parametric (ANOVA) and non-parametric tests (Mann Whitney U and Kruskall Walliss H) were run. They showed similar statistical results, and, in that sense, ANOVA results were reported. In order to meet the assumptions of ANOVA; normal distribution, homogeneity of variance, and independence of observations (Field, 2013) were checked. For the assumption of independence, all the measurement procedures followed the same steps for each group. According to the Shapiro-Wilk statistics, the distribution of the data wasn't statistically different from a normal distribution, for each group and measuring period. For the assumption of homogeneity of variance, Levene Statistics showed that the variances of all groups aren't approximately equal for pre-test scores, but for post-test and follow-up scores. The post-test and follow-up data did not seem to meet the assumption of homogeneity of variance, for all groups. Nevertheless, ANOVA was preferred as a robust test to control the Type 1 Error rate.

Validity and Reliability of the Study

Some measures were taken to ensure the reliability and validity of this study. Three kindergartens as close as possible to the natural outdoors were selected. Initial levels of groups were found to be equal, according to pre-test scores. Inquiry-based mathematics activities were limited to eight consecutive weeks, to avoid the effect of the other different variables. All groups continued to receive regular curriculum activities, to better interpret the impact of inquiry-based activities. Kindergartens were selected from three different rural areas, to avoid interactions between groups. Inquiry-based activities were implemented by only one researcher to ensure consistency. Teachers were asked not to implement any special activity beyond their routines and common curriculum to avoid extraneous factors possibly influencing the experimental processes.

RESULTS

In this section, findings regarding the reliability of measurements, the initial levels of groups, and the impact of inquiry-based activities are presented.

Initial Levels of Groups

In this section, ANOVA results for pre-test scores of GEOST-ST were presented. According to the results presented in Table 3, there is no statistically significant difference between the GTS, STS and TS pre-test scores of groups [$F(2.29)= .560$ $p= .577$; $F(2.29)= .129$ $p= .880$; $F(2.29)= .104$ $p= .902$]. It was assumed that the initial levels of groups were equal, for the GTS, STS, and TS pre-test scores of the GEOST-ST.

Table 3.
ANOVA Results for Pre-Test Scores of the GEOST-ST

		Sum of Squares	df	Mean Square	F	Sig.	η2
	Between Groups	12230.469	2	6115.234	.560	.577	.037
GTS	Within Groups	316679.250	29	10919.974			
	Total	328909.719	31				
	Between Groups	1566.919	2	783.459	.129	.880	.008
STS	Within Groups	176673.300	29	6092.183			
	Total	178240.219	31				
	Between Groups	5232.050	2	2616.025	.104	.902	.007
TS	Within Groups	730753.950	29	25198.412			
	Total	735986.000	31				

Impact of Activities on Geometric Thinking Skills

In this section, findings regarding the impact of inquiry-based indoor and outdoor mathematics activities on children's GTS were presented. Table 4 shows the results of the statistical analysis for GTS scores.

Table 4.
ANOVA results for GTS scores of the GEOST-ST

Predictor	Sum of Squares	df	Mean Square	F	p	η2
Intercept	944816.958	31				
GTS	331210.975	2	165605.488	7.827	.002*	.351
Error	613605.983	29	21158.827			
Within Subject	1585844.365	64				
Measure	1138670.261	2	569335.130	95.259	.001*	.767
GTS x Measure	100523.804	4	25130.951	4.205	.005*	.225
Error	346650.300	58				
Total	2530661.323	95				

Considering the results shown in Table 4, there is a significant difference between the mean scores of groups, for repeated measures (F(4.64)= 4.205 p=.005). There is a need to check the multiple comparisons presented in Table 5 to better interpret the results. Considering Table 5, there is a significant difference between the mean scores of EG2 and CG for GTS, on behalf of EG2 (p<.05). There is no significant difference between the mean scores of EG2 and EG1 and between the mean scores of EG1 and CG (p>.05; p>.05). Mean scores of groups by the time were presented in Figure 1.

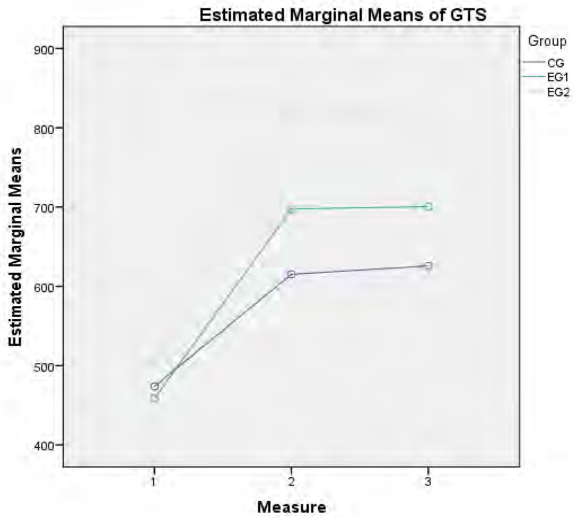
Table 5.
Multiple Comparisons Regarding GTS Scores of the GEOST-ST Repeated Measures

Pairwise Comparisons

(I) GTS	(J) GTS	Mean Difference (I-J)	Std. Error	Sig. b	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
CG	EG1	-47.32	43.810	.541	-161.74	67.11
	EG2	-141.02*	24.353	.001	-203.49	-78.55
EG1	CG	47.32	43.810	.541	-67.11	161.74
	EG2	-93.70	40.163	.094	-202.57	15.17
EG2	CG	141.02*	24.353	.001	78.55	203.49
	EG1	93.70	40.163	.094	-15.17	202.57

* The mean difference is significant at the ,05 level.
b. Adjustment for multiple comparisons: Bonferroni.

Figure 1.
Changes in Mean Scores of Groups for GTS, by Time



According to Figure 1, post-test scores increase for all groups. EG2 has the biggest rise and EG1 has the second biggest improvement. Follow-up scores of EG1 and CG are slightly increasing, while EG2 is slightly decreasing.

Impact of Activities on Spatial thinking Skills

In this section, findings regarding the impact of inquiry-based indoor and outdoor mathematics activities on children's STS were presented. Table 6 presents the findings regarding repeated measures for STS scores of the GEOST-ST. According to Table 6, there is no significant difference between the mean scores of groups, for repeated measures (F(4.64)= 2.234 p=.076). It is not needed to see the multiple comparisons, but it may be informative. Multiple comparisons are presented in Table 7.

Table 6.
ANOVA Results for STS Scores of the GEOST-ST

Predictor	Sum of Squares	df	Mean Square	F	p	η2
Intercept	236626.500	31				
STS	21033.700	2	10516.850	1.415	.259	.089
Error	215592.800	29	7434.234			
Within Subject	218613.631	64				
Measure	41916.818	2	20958.409	7.940	.001	.215
STS x Measure	23592.913	4	5898.228	2.234	.076	.134
Error	153103.900	58				
Total	455240.131	95				

Table 7.
Multiple Comparisons Regarding STS Scores of GEOST-ST Repeated Measures

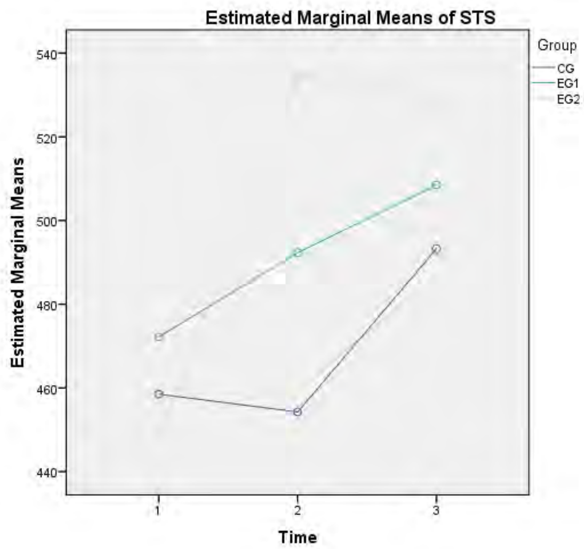
Pairwise Comparisons

(I) STS	(J) STS	Mean Difference (I-J)	Std. Error	Sig. b	95 % Confidence Interval for Difference	
					Lower Bound	Upper Bound
CG	EG1	-22.33	21.315	.553	-74.97	30.31
	EG2	-35.13	21.315	.242	-87.77	17.51
EG1	CG	22.33	21.315	.553	-30.31	74.97
	EG2	-12.80	22.262	.834	-67.78	42.18
EG2	CG	35.13	21.315	.242	-17.51	87.77
	EG1	12.80	22.262	.834	-42.18	67.78

b. Adjustment for multiple comparisons: Bonferroni.

There was no significant difference between the mean scores of groups, due to previous analysis. The detailed results were showed in Table 7 ($p>.05$) and changes in mean scores of groups by the time were presented in Figure 2.

Figure 2.
Changes in Mean Scores of Groups for STS, by Time



According to Figure 2, the post-test mean score of EG2 is considerably increasing. EG1 is slightly increasing, while CG is slightly decreasing. Follow-up scores of EG2 are slightly decreasing, while EG1 is steadily, and CG is considerably increasing. Nevertheless, EG2 has the highest follow-up scores, and CG has the lowest.

DISCUSSION

The study results revealed that inquiry-based outdoor mathematics activities of the IBAM are effective in promoting children's GTS. Inquiry-based outdoor mathematics activities of the IBAM were used to support 48 to 66-month-old children's GTS. Children had greater GTS after implementing inquiry-based outdoor mathematics activities ($p<.05$). This finding is in line with current studies. As found in this study, the Back to Nature Network (2012), the Early Head Start National Research Center (2013), OFSTED (2008), and Sutterby and Frost (2013) suggest that the outdoors as a learning environment contributes to children's GTS. Miller et al. (2013) worked with pre-school and kindergarten age children in natural settings, and they reported that children find excellent opportunities to experience geometrical relationships by physically and concretely experiencing natural materials. According to Enerson (2016) and the Natural Learning Initiative (2012), children can interact with the natural representations of geometric relations in the natural outdoors. In the present study, children sought, collected, and used natural materials such as stones, branches, mud, and leaves, in the natural outdoors. Athey (2007) suggests that just moving or walking around the outdoor environments encourages children to develop a deeper understanding of geometrical relations. In the present study, EG2 explored the natural outdoors during all experimental procedures. This result can be explained by the strength of inquiry-based learning and the positive outcomes of natural outdoors.

The results of this study showed that inquiry-based indoor mathematics activities of the IBAM were not effective in supporting children's GTS. Again, inquiry-based indoor mathematics activities were used to support 48- to 66-month-old children's GTS. Children's GTS were not improved statistically after implementing inquiry-based indoor mathematics activities ($p>.05$). This result conflicts with other current studies. Contrary to the results of this study, Calder and Brough (2013) stated that inquiry-based activities contribute to children's GTS by offering excellent opportunities. In Casey et al.'s (2008) study, it was found that inquiry-based indoor activities supported by stories and puzzles contribute to children's GTS. T. Many researchers also suggest that inquiry-based learning is an effective method for learners to develop a better understanding of geometrical relations (Leikin & Grossman, 2013; Mensah-Wonkyi & Adu, 2016; Salim & Tiawa, 2015; Sizemore, 2020; Skoumpourdi, 2019; Uygun, 2020). Patterson (2016) stated that children's communication, responses, questions, interactions, and learning processes are as important factors as the strength of inquiry-based learning. This can be explained by both the specificity of inquiry-based learning and the dynamics of EG1.

It was found that there is no difference between the effects of inquiry-based indoor and outdoor activities of the IBAM on children's GTS. Inquiry-based indoor and outdoor mathematics activities were implemented with two different experimental groups. Inquiry-based indoor and outdoor mathematics activities did not have a different effect on children's GTS ($p>.05$). This result is somewhat contradictory in terms of what some other researchers suggest. It was expected that outdoor environments and activities designed especially for outdoor environments will synergistically affect outcomes, as stated in current studies (Kilburn, 2015; MacDonald, 2016; Schindler, 2002). It is likely that inquiry-based indoor mathematics activities are as effective as outdoor activities. This can be explained by the strength of inquiry-based learning or indoor activities. They were already inquiry-based and addressed the same goals and skills. Also, EG1 used artificial materials equivalent to natural ones.

Another result of this study is that inquiry-based outdoor mathematics activities of the IBAM are not effective in promoting children's STS. The inquiry-based outdoor mathematics activities of the IBAM were used to promote 48- to 66-month-old children's STS. Inquiry-based outdoor mathematics activities did not have a significant effect on children's GTS ($p>.05$). This result conflicts with other current studies. According to these studies (Dunkley & Smith, 2016; Natural Learning Initiative, 2012; Özgece et al., 2015; Paskins, 2005; Smith et al., 2008), children having experiences in the outdoors are more competent at STS. Herrington (2005) suggests that outdoor learning environments encourage children in spatial exploration. Considering the synergy between inquiry-based learning and outdoor learning environments (Kilburn, 2015; MacDonald, 2016; Schindler, 2002) this result is surprising. Outdoor activities had two strong sides as positive outcomes of outdoor environments and the strength of inquiry-based learning. This result can be explained by the dynamics of groups or by the complexity of STS.

The results of this study showed that inquiry-based indoor mathematics activities of the IBAM are not effective in promoting children's STS. Children who received inquiry-based indoor mathematics activities to promote 48- to 66-month-old children's STS. Inquiry-based indoor mathematics activities did not have a significant effect on children's GTS, as for outdoor activities ($p>.05$). This result conflicts with other current studies. Contrary to the results of this study, Olver (2013) suggests that inquiry and game-based indoor activities support kindergarten children's STS development. Some other studies (Kavouras, Kokla, Tomai, Darra & Pastra, 2016; Malau, Napitupulu & Armanto, 2017; Narpila, 2018; Rankin, 2016; Susilawati, Suryadi & Dahlan, 2017; Weakley, 2010) reveal that inquiry-based learning improves students' spatial abilities. Except to inquiry-based learning Keren, Ben-David, and Fridin (2012) stated that a robot interacting with children indoors supports children's STS. Tzuriel and Egozi (2010) stated that a strategic spatial processes-based program implemented indoors contributes to children's STS. Casey et al. (2008) suggest that storytelling-based indoor activities contribute to children's acquisition of spatial concepts. EG1 received inquiry-based mathematics activities but this result can be explained by the regular curriculum being as effective as our indoor activities and can be explained by the dynamics of groups and the complexity of STS.

Lastly, it was found that there is no difference between the effects of inquiry-based indoor and outdoor activities of the IBAM on children's STS. EG1 received inquiry-based indoor mathematics activities and EG2 received inquiry-based outdoor mathematics activities. This result conflicts with other current studies. Contrary to the results of this study, Abad (2018) suggested that outdoor play and outdoor experiences are the essentials for children's STS development. King et al. (2019) studied twins and they revealed that environmental factors such as the outdoors affect children's STS. Considering the effects of hiking (Athey, 2007) and experiencing the outdoors (Herrington, 2005) on children's STS, outdoor activities should have been more effective. EG1 received only indoor activities but children are already living in villages, nested in the natural outdoors. This may also be explained by the dynamics of groups and the nature of STS. Children already had excellent opportunities by inquiry processes in indoor and outdoor settings. It may be that the acquisition or learning processes for children in EG2 and EG1 are still ongoing.

RECOMMENDATIONS

Some recommendations for further research and implementations could be made in accordance with the results of this study. For further research, different mathematics activities should be developed and implemented with different age groups. Longitudinal studies should be implemented for in-depth investigations. It is recommended that the experimental design has a third experimental group receiving both inquiry-based indoor and outdoor mathematics activities. Different tools such as direct observations, tape recording, anecdotes, or some other interactive tools could be used to enrich the source of data, for further research. For implementations, activities of the IBAM could be used as routine activities to diversify and enrich the learning processes. Outdoors, especially the natural outdoors can be used for educational purposes more.

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APPENDICES

Appendix 1: Activity plan "We are the frame hunters"

Activity Number		7
Name of Activity		We Are the Frame Hunters
Sort of Activity		Mathematics Activity
Learning Environment		Outdoor Learning Environments
Age Group		48 to 66-month-old Children
Target Skills		Spatial Thinking (Spatial Orientation, Spatial Visualization)
Goals		Positions the items in accordance with an image, Draws the positions of items on a paper.
Materials		Rectangular frames made of cardboard for half of the number of children in our group, a natural landscape, photos of landscape previously taken.
Vocabularies		Location, Settlement, Proportion, View, Appearance, Photo, Camera.
Learning Processes	Planning	After warm-up exercises, children are requested to sit on mats. Children are told that they will hunt frames, a bit later. Children are asked how could frame hunting be like. They are expected to participate the discussions.
	Retrieving	Children are requested to freely explore the surroundings. Children discuss with friends about what they just saw and noticed. They are encouraged to participate sub-groups of two. Children are free to decide which one will be the director, and which will one be the frame hunter. They are also free to change their roles in process.
	Processing & Creating	Teacher serves some photos on different perspectives of the landscape he/she took before, for children to examine. Each group receives two different photos. One of the photos is more detailed and other one is less. After than each group is served an empty frame. Children try to catch the same view with the photos they were given, by using the empty frames. One of the group members directs his/her friend to catch the view while other one tries to understand how the view should be. Children are expected to draw the picture of the view of landscape when they are certain of that they caught the view. If it is possible polaroid cameras of standard cameras would be useful in this activity. Thence children may compare the original view and the one they caught concretely.
	Sharing, Evaluating & Reflecting	Pictures drawn by children and photos taken by teacher would be exhibited together, by cinevision or concrete photos. Children are allowed to examine other friends' photos and pictures, also to discuss with them.

Appendix 2: Codes (Coding categories with operational definitions)

Activity Number		15
Name of Activity		Secret Shapes on Cracked Soils
Sort of Activity		Mathematics Activity
Learning Environment		Outdoor / Indoor Learning Environments
Age Group		48 to 66-month-old Children
Target Skills		Geometrical Thinking (Shape, Area)
Goals		Recognizes geometrical shapes. Composes geometrical shapes. Recognizes the features of geometrical shapes. Effectively uses a certain area.
Materials		Stones, Barks, Branches, Soil and Water (Mud)
Vocabularies		Shape, Circle, Round, Square, Triangle, Rectangle, Ellipse, Trapezoid, Pentagon, Hexagon, Area.
Learning Processes	Planning & Retrieving	After warm-up exercises, children get together in circle line. Such topics desert, life in desert, water, sun, sunshine, are discussed with children. Teacher asks to children if they want to have soils as in deserts. After than he/she asks how to do that. Each child is encouraged to express his/her idea. Teacher goes for a walk with children to collect some stones and branches. Children are encouraged to participate sub-groups of three.
	Processing & Creating	All the groups are free to choose which shape they want. All groups choose one shape which will be the symbol of their group. Teacher offers them round, square, triangle, rectangle, ellipse, trapezoid, pentagon, and hexagon. Each group draws the symbol (shape) on the ground and gives height to it by using the stones or branched they collected before. After creating the shapes on the ground, everyone gets some mud to fill in the shape. Teacher asks children that how to get a flat surface of mud on shapes. After having flat surfaces, they let the muds to be dried by sun. All groups and teacher go for a walk while muds are getting dry. They observe the ground and especially cracked soils. Children take photos or draw a picture of the cracked soil. After walk, all the groups return to the shapes filled by mud. Teacher asks children if the cracked surface evokes new shapes. They are expected to examine the surfaces of shapes and try to find their symbol within the arising shapes on dried up surface. They are expected to find examples of other shapes on dried up surface. They are encouraged to draw the surface on a blank paper, also take photos.
	Sharing, Evaluating & Reflecting	All the groups are expected to visit all the shapes and cracked surfaces. They are free to discuss the shapes, evoking shapes on cracked surface. Teacher waits for children to discuss about their experiences in all the procedures. Teacher shares the photos taken during the activity and expects children to compare their observations, drawings and photo memories.

TÜRKÇE GENİŞLETİLMİŞ ÖZET

Bu çalışmanın amacı sınıf içerisinde ve doğal açık alanlarda uygulanan sorgulama temelli matematik etkinliklerinin okul öncesi dönemdeki çocukların geometrik ve uzamsal düşünme becerilerine etkisini araştırmaktır.

Sınıf içerisinde ve doğal açık alanlarda uygulanan sorgulama temelli matematik etkinliklerinin geometrik ve uzamsal düşünme becerilerine olan etkisinin incelenmesi açısından gerçekleştirilen bu Yarı Deneysel çalışmada Eşitlenmemiş Kontrol Gruplu Desen kullanılmıştır. Araştırmaya yaşları 48 ila 66 ay arasında değişen ve 3 farklı okul öncesi eğitim kurumuna devam eden toplam 32 çocuk katılmıştır. Araştırmaya katılan olan çocukların belirlenmesinde amaçsal örnekleme yöntemlerinden homojen örnekleme yöntemi kullanılmıştır. Çocukların devam ettikleri eğitim kurumlarının kırsal alanlarda yer alması, doğal açık alanlara erişim imkanı ve mesafesi açısından, kırsal alanda yerleşim-konum özellikleri açısından birbirine benzer özelliklerde olmaları belirleyici olmuştur.

Araştırma kapsamında 3 farklı grup yer almıştır. Normal olarak uygulanmakta olan okul öncesi eğitim programının ve rutin olarak uygulanan etkinliklerin uygulanmaya devam edildiği Kontrol Grubu; Normal rutinler ve programa ek olarak sınıf içerisinde sorgulama temelli matematik etkinliklerinin uygulandığı Deney Grubu 1; Normal rutinler ve programa ek olarak doğal açık alanlarda sorgulama temelli matematik etkinliklerinin uygulandığı Deney Grubu 2 yer almıştır. Araştırmanın 3 farklı grubunu oluşturan ve benzer özelliklere sahip 3 okul öncesi eğitim kurumu rastgele olarak deney grupları veya kontrol grubu olarak atanmıştır.

Ön-test, son-test ve izleme testi verilerinin elde edilebilmesi açısından veri toplama aracı olarak bu araştırmanın yazarları tarafından geliştirilen, 48-66 aylık çocukların şekil, simetri, alan, uzamsal yönelim ve uzamsal görselleştirme becerilerini ölçmeye yönelik Geometrik ve Uzamsal Düşünme Becerileri Testi kullanılmıştır. Bu test çocukların kendilerine yöneltilen aşamalı görevleri yerine getirmeleri, aşamalı olarak sorulan sorulara cevaplar vermeleri sonucunda uygulayıcının sürece dayalı gözlemlerini yazılı olarak kaydetmesi ile uygulanır. Grupların başlangıç seviyelerinin tespit edilmesi açısından ön test verilerinin elde edilmesinden sonra Deney 1 Grubu ile sınıf içerisinde, Deney 2 Grubu ile doğal açık alanlarda haftada 3'er etkinlik olmak üzere 8 haftada toplam 24 sorgulama temelli matematik etkinliği uygulanmıştır. Bu etkinlikler geometrik düşünme becerisi açısından çocukların şekil, alan ve simetri becerilerini geliştirmeye; uzamsal düşünme becerileri açısından ise uzamsal yönelim ve uzamsal görselleştirme becerilerini geliştirmeye yönelik etkinliklerdir. Kontrol Grubu ise normal rutinlerine ve programına devam etmiştir. Etkinlik uygulamalarının bitişini takip eden haftada sonra son-test verileri ve 6 hafta sonra ise izleme testi verileri elde edilmiştir.

Araştırmanın iç geçerliğini ve güvenirliğini artırmak açısından bazı önlemler alınmıştır. Öncelikle araştırma kapsamında uygulamaların yürütülebilmesi için gerekli olan tüm yasal ve etik izinler edinilmiştir. Doğal açık alanlara erişim, kırsal bölgelerdeki yerleşimi-konumu, kendisine ait bir bahçesi olması gibi özellikler açısından birbirine benzer okullar tercih edilmiştir. Ön test verilerine göre grupların ortalamaları arasındaki farkın istatistiksel olarak anlamlı farklılık göstermemesi başlangıç seviyesinde düzeylerinin eşit olduğu varsayımını kuvvetlendirmiştir. Araştırma kapsamında yürütülen etkinliklerin uygulanma süresi diğer dışsal faktörlerin etkilerini en aza indirebilmek açısından 8 hafta ile sınırlandırılmıştır. Gruplar arasındaki etkileşimi engellemek ve daha tutarlı sonuçlar elde edebilmek açısından gruplar benzer özelliklerde ancak birbirinden ayrı 3 kırsal bölgeden seçilmiştir. Tutarlılığın sağlanması açısından uygulamalar sadece 1 araştırmacı tarafından yürütülmüştür. Öğretmenlerden deneysel uygulamaları etkileyebilecek herhangi bir özel fazladan uygulamalar yürütmemeleri ricasında bulunulmuş, etkinlik plan örnekleri incelenmiştir.

Araştırmaya katılan çocuklara ait veriler Ç1 ile Ç32 aralığında kodlanmıştır. Çocuklar testin her bir maddesine verdikleri cevaplar ve yerine getirdikleri görevler aşamalı olarak "0", "2", "4", "6", "8", "10" ve "12" puan ile puanlandırılmıştır. Bu şekilde çocukların geometrik düşünme becerilerinden ve uzamsal düşünme becerilerinden elde ettikleri test puanları oluşturulmuştur. Araştırmaya dahil olan grupların başlangıç seviyelerinin belirlenmesi açısından elde edilen ön-test verileri bir istatistik yazılımı kullanılarak ANOVA testine tabi tutulmuş, tekrarlı ölçümlerle (ön-test, son-test ve izleme testi) elde edilen veriler ise yine bir istatistik yazılımı kullanılarak Mixed-Design ANOVA (Split-Plot ANOVA) testi ile analiz edilmiştir.

Araştırmanın sonucunda doğal açık alanlarda uygulanan sorgulama temelli matematik etkinliklerinin çocukların geometrik düşünme becerilerinin gelişimine istatistiksel olarak anlamlı düzeyde etkisinin olduğu ortaya koyulmuştur. Sınıf içerisinde uygulanan sorgulama temelli matematik etkinlikleri çocukların geometrik düşünme becerilerini yükseltmiş görülmekle birlikte bu yükseliş istatistiksel olarak anlamlı düzeyde bir fark oluşturmamaktadır. Bunun yanında sorgulama temelli matematik etkinliklerinin sınıf içerisinde veya doğal açık alanlarda uygulanması durumları açısından çocukların geometrik düşünme becerilerinin gelişimi üzerinde istatistiksel olarak anlamlı düzeyde bir farklılığın oluşmadığı görülmüştür.

Uzamsal düşünme becerileri açısından araştırmanın bir diğer sonucuna göre, sınıf içerisinde veya doğal açık alanlarda uygulanan sorgulama temelli matematik etkinliklerinin çocukların uzamsal düşünme becerilerinin gelişimine istatistiksel olarak anlamlı düzeyde etkisinin olmadığı ortaya koyulmuştur. Aynı şekilde doğal açık alanlarda uygulanan sorgulama temelli matematik etkinlikleri sonrası çocukların uzamsal düşünme becerileri kayda değer artış gösterse de bu artış istatistiksel olarak açıklanamamaktadır.

Araştırmanın sonucunda doğal açık alanlarda uygulanan sorgulama temelli matematik etkinlikleri yani deneysel etki olarak ifade edebileceğimiz etkinlik uygulamalarının sonlanması durumunda çocukların geometrik ve uzamsal düşünme beceri puanlarında dikkate değer düşüşler yaşanmıştır. Sınıf içerisinde uygulanan etkinliklerin ortadan kalkması veya normal rutinlerin devam etmesi durumlarına göre izleme puanlarında çok daha fazla oranda hissedilir düşüşlerin olması doğal açık alanlarda yürütülen sorgulama temelli matematik etkinliklerin çocukların geometrik ve uzamsal düşünme becerileri açısından kıymetli deneyimler olduğunu düşünmemizi sağlar. Ayrıca bu deneyimlerin geliştirilerek farklı çalışmalarla, tasarımlarla desteklenmesi gerektiğini ve farklı boyutlarıyla araştırılmaya ihtiyaç duyduğunu göstermektedir.