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Supporting Pre-schoolers' Acquisition of Geometric Knowledge Through Mind Mapping

Türker Sezer
Bolu Abant Izzet Baysal University

Özgül Polat
Marmara University

ABSTRACT

Mind mapping refers to the use of a specific graphic organizer to support learning. This paper describes the effect of mind mapping on pre-schoolers' geometric learning. Using a pre- and post-test control group quasi-experimental model, researchers found that the use of mind maps resulted in a statistically significant difference in geometry learning for pre-schoolers (mean age = 65.0 months). These results are discussed in terms of their ramifications for pre-school geometry education, as well as for the use of mind maps with pre-school children.

Keywords: young children; early geometry teaching; mind mapping; preschool education

Introduction

Researchers have studied the development of children's geometric thinking since the 1950s. In 1967, Piaget and Inhelder described three sequential and developmental stages of geometric learning (topological, projective, and euclidean) (Piaget & Inhelder, 1967). Since the early 1980s, research on children's geometric thinking has been profoundly influenced by van Hiele's theory of developmental stages (Olkun & Toluk Uçar, 2007). In this theory, the first level of geometric thinking is visualisation, in which the child uses visual reasoning based on the appearance of whole shapes without thinking about separate components (Levenson et al., 2011). For example, when children are asked why they know a shape is a rectangle, they may say, "*It looks like a window*" rather than talking about sides or angles. The second level is the analytical (analysis) at which a shape is described according to its properties. Properties and components of the shapes are analysed, and properties and rules are discovered experimentally. At this level, children may identify right angles and opposite sides being the same length when discussing a rectangle. At the third level (informal deduction), the properties of the shapes are organised logically and hierarchically. Students move from one trait to another. They also use their definitions to distinguish shapes by referring to these characteristics (van Hiele, 1986, 1999). So, for instance, students at this stage understand that a square is also a rectangle, since the definition of a rectangle is a quadrilateral with four right angles. At the formal deduction level, students can understand the meaning and importance of proof based on axioms, theorems, and definitions, and develop an understanding of it (Olkun & Toluk Uçar, 2007). At the last level (rigor), students construct theorems in different hypothetical systems, analyze, and compare these theorems (Fuys et al., 1988), and form abstract deductions (Usiskin, 1982).

For many years and throughout the world, teachers have struggled to teach geometry effectively, and student achievement has been poor (Abdullah & Zakaria, 2013; Alex & Mammen, 2012; Bal, 2014; Fidan & Türnüklü, 2010). For example, elementary and middle school students in the United States were shown to have difficulty learning basic geometric concepts and solving geometric problems, and are not ready for more complex geometric concepts and test-based skills (Clements et al., 2001; Szinger, 2008). The results of research conducted in Turkey also have similar findings. For example, in a study involving 1,270 primary school students (4th, 5th, 6th, and 7th grade), it was determined that 64.5% of the students were at van Hiele's visual level (Bal, 2014). Similarly, in another study involving 1,644 students (5th grade), it was revealed that 47.9% of the students were at the visual level (Fidan & Türnüklü, 2010).

Problems in Early Geometry Education

Like many areas of mathematics, geometric knowledge builds on itself. Early learning can lead to later achievement. Research reveals that children who received preschool education outperformed those who did not (Fidan & Türnüklü, 2010) and high-quality early education positively affects children's geometric thinking in later grades and on international assessments like the Program for International Assessment (Gamboa & Krüger, 2016; Pholphirul, 2017; Usta & Demirtaşlı, 2018). However, if young students do not learn important geometrical ideas, they have difficulty advancing at high levels (Siew et al., 2013).

Unfortunately, researchers have documented widespread problems in early geometry education internationally (Sunzuma & Maharaj, 2019). Researchers from the United States, Scotland, Israel, and South Africa have found that pre-service teachers exhibited low levels of geometric content knowledge (*US*-Clements, 2003; *UK-Scotland*-Fujita & Jones, 2006a, 2006b; *Israil*-Markovits & Patkin, 2020; *South Africa*-van der Sandt, 2007). In one US study, many teacher candidates could only reach van Hiele level 1, and they were not supported in reaching level 2, the descriptive/analytic level (Clements, 2003). These problems were also documented in US pre-school and primary school teachers, not just teacher candidates (Sarama & Clements, 2009). This was also seen to negatively affect the geometry content and techniques that American teachers taught to their students (Clements & Sarama, 2011). According to the results of the studies held in the UK, Scotland, Israel, Zimbabwe, and Malaysia, teachers also had various problems in terms of geometry skills (see Fujita & Jones, 2006a, 2006b; Markowitz & Patkin, 2020; Sunzuma & Maharaj, 2019). For instance, Markowitz & Patkin, (2020) claimed that some of the teachers had negative attitudes towards geometry, that they had insufficient knowledge of content, that they had difficulty in using the correct mathematical language, and they were influenced by the appearance of the figures. A Malaysian study found that teachers don't take into account the individual differences in students' geometric thinking; and they assume that all students have the same cognitive visual-spatial ability and level of understanding (Abd Wahab et al., 2014). Other researchers documented deficiencies invisualizing and solving the geometric figures stemming from a lack classroom practice, lack of appropriate teaching methods and materials, lack of prior knowledge about basic geometric concepts, insufficient teacher-student interaction, lack of motivation in the classroom, and unsuitable learning environment (Chaudhary, 2019). Researchers have also documented problems with early geometry teaching, including a lack of problem-solving (Sulistiowati et al., 2019), a lack of collaborative learning (Chianson et al., 2010), insufficient technology support (Clements & Sarama, 2011; Rohendi et al., 2018) and not allocating time for geometry as much as the other topics in mathematics (such as counting) (Moss et al., 2015; Sarama, 2002). Even parents neglect geometry in favor of numeracy and counting (Zippert & Rittle-Johnson, 2020).

Research in Turkey mirrors the international research described above (see Kandır et al., 2017; Korkmaz & Şahin, 2020; Inan & Temur-Dogan, 2010; Zembat et al., 2013). For instance, as a result of a current study, it was discovered that although prospective teachers were able to partially identify the mistakes made by the children related to the figures in short stories; they had difficulty in suggesting strategies to address those mistakes (Korkmaz & Şahin, 2020). In another study, preschool teachers were unable to use appropriate mathematical language and couldn't develop open-ended questions (Kandır et al., 2017). In addition to this, some Turkish teachers have insufficient content knowledge (Inan & Temur-Dogan, 2010), use ineffective methods and techniques (Zembat et al., 2014), and do not focus on children's participation in the activities (Pekince & Avcı, 2016). Furthermore, materials used for the teaching of pre-school geometry are also problematic - most sources do not present examples that are different from the prototypes (Aslan & Aktaş-Arnas, 2007).

Quality early interventions can support young children in developing foundational geometric knowledge (van Hiele, 1986). In 1999, Clements and colleagues argued that the development of geometric thinking is not determined by age, but can be supported with quality instruction. They suggested that observation, measurement, drawing, and modelling can all support geometric learning for young children. These authors also argued that teachers needed to give examples of shapes that displayed the range of the category (e.g., triangles that did not have a base that was horizontal) so that children did not acquire limited images of those shapes (Clements et al., 1999).

Experimental studies have been performed in Turkey in the last decade to promote geometry skills in children 4-6 years old (Gecu-Parmaksiz & Delialioğlu, 2020; Kesicioğlu & Alisinanoğlu, 2014; Kılıç & Şahin, 2019; Korkmaz, 2017; Öngören, 2008; Şen, 2017). First of all, technology support such as using computer-assisted educational programs and augmented reality-based virtual manipulatives were shown to be effective in early geometry education (Gecu-Parmaksiz & Delialioğlu, 2020; Kesicioğlu & Alisinanoğlu, 2014). In addition, the use of concrete manipulatives such as Montessori materials and Froebel gifts also positively affected children's knowledge of geometry (Öngören, 2008; Şen, 2017), as did inquiry-based activities and geometry educational programs developed by researchers (Kılıç & Şahin, 2019; Korkmaz, 2017). These research results showed that when young children's knowledge of shape and space was supported by qualified instructional aids, significant improvements were made.

Unfortunately, there are some problems in the widespread use of the methods and techniques used in all these experimental studies by preschool teachers. For example, the technical knowledge of the teachers and the technological equipment of the school may not be sufficient to carry out technology-supported studies. Similarly, using Montessori and Froebel materials and research-based programs requires costly training. Therefore, it is clear that there is a need for easily accessible, applicable, and cost-effective methods and techniques by teachers to support young children's knowledge of geometry.

Mind Mapping

Mind map refers to a powerful and unique graphic organiser that dates back to the 1960s and agitates all the functions of the brain (words, imagination, numbers, cause, rhythm, pictures, lists, details, colours, and spatial awareness) (Buzan & Buzan, 2009; Buzan et al., 1999). In a mind map, the main object of study (main text) is placed in the center of the page, and then various ideas related to the main text are placed as sub-texts at the end of colored main branches. Sub-branches are then drawn off of the subtext to show new subsidiary ideas. The most complex relationships between texts are formed by adding numbers, images, arrows, or connecting elements to mind maps (Buzan & Buzan, 2002). Relevant information is simplified with keywords. This method can be used as a learning, study, and application tool (Rustler, 2012). In recent years, mind maps have been used to support students in developing a new idea, taking notes to recall the existing information easily, establishing links to understand a complex concept, and developing memory (Buzan & Buzan, 2002).

From a theoretical point of view, mind mapping is based on "*The Dual Coding Theory*" (Paivio, 1991), and "*Conjoint Retention*" (Kulhavy et al., 1985). The basic assumption of both theoretical perspectives is that there are two separate cognitive subsystems that people use to process information:

the verbal and pictorial cognitive subsystems. Verbal information is processed and encoded only in the verbal system, while pictorial information is processed and encoded in both systems. Effective instruction supports students in encoding information in both systems (Paivio, 1991), and the use of visual images in instruction provides especially powerful support, as they are stored and processed in both the verbal and pictorial cognitive subsystems (Sadoski & Paivio, 2013). Therein lies the rationale for mind maps - they support students in creating and storing information in both cognitive systems (Merchie & Van Keer, 2016).

Furthermore, mind mapping is compatible with constructivism. When students create a mind map, they actively connect new information to what they already know (Dhindsa & Anderson, 2011). Mind maps also support students in developing metacognition. They are meta-learning tools (for detailed information, see Buzan, 2020), such as concept maps, and Ven diagrams (see Novak & Gowin, 1984) that allow students to discover how they learn (Ismail et al., 2010; Merchie & Keer, 2016; Stull & Mayer, 2007).

Recent research has shown that mind mapping leads to effective results in reading, writing, mathematics, science, problem-solving, creative thinking, and memory development (Abi-El-Mona & Adb-El-Khalick, 2010; Brinkmann, 2003a; Inayah & Argawati, 2019; Irman, 2019; Khatimah & Rachman, 2018; Mardiyah et al., 2018; Widiana & Jampel, 2016). Most of these studies were conducted with participants in secondary school and higher education levels, and were focused on reading and writing. A small, but increasing, number of studies have been done with preschool-age children, showing that mind mapping supported learning in math, science, language, and critical thinking (Polat et al., 2022; Polat & Aydın, 2021; Polat & Aydın, 2020; Polat et al., 2017; van der Wilt et al., 2019). Taken together, these studies show that mind mapping is an important technique that allows the children to interact directly with objects and events, and supports discussing different points of view, generating questions, searching and analyzing information (Polat & Aydın, 2020). Mind mapping also allows young children to visually represent themes/concepts/objects and to associate them with other themes/concepts/objects. This supports deeper understanding and more long-lasting and accessible memory (Polat, 2021) as well as developing their imagination and memory (Polat et al., 2022). This study extends this work on mind mapping with pre-school children into geometry.

Early Education in Turkey

For children to enter primary school in Turkey, they must be 69 months old in September of that year (https://sgb.meb.gov.tr). Preschool education is not compulsory and differs according to age groups and types of institutions. There are independent kindergartens (36-69 months), kindergartens in primary schools (57-69 months), and nurseries (3-36 months) in a variety of educational institutions. There are also private children's clubs (mixed age), and kindergartens affiliated with religious institutions (36-68 months). The Turkish Preschool Education Program was updated in 2013 and its objectives are to support all areas of children's development, to help students acquire good habits, to prepare them for primary school, to provide a common educational environment for children from diverse backgrounds, and to support their Turkish language development. The program is child-centered, flexible, eclectic, balanced, play-based, and spiraling. It also supports creativity and learning by suggesting a stimulating environment suitable for children (learning centers, etc.). The program emphasizes family involvement, family education, and counseling. Additionally, it asks teachers to use a multidimensional assessment (e.g., portfolio) approach. Finally, the program encourages teachers to organise large group (whole class), small group (collaboration), and individual (considering individual differences) activities in a balanced way, to plan activities in an integrated way, and to carry out activities adapted for children with disabilities (if any, is an inclusion student) (MoNE, 2013).

The Turkish Preschool Education Program describes learning goals for geometry that are aligned with the theories of Piaget and van Hiele, as well as the National Council of Teachers of Mathematics (NCTM) standards (NCTM, 2000; Piaget & Inhelder, 1967; van Hiele, 1986, 1999). Preschool children are expected to learn about direction and position in space, as well as simple shapes (circle, triangle, square, rectangle, ellipse, edge, corner). The program suggests teaching this content through game-based activities that support the active participation of young children (MoNE, 2013).

Although the philosophy, theoretical foundations, framework, methods, and techniques of the program are clear, several problems have arisen in early geometry teaching in Turkey (Fırat & Dinçer, 2018; Inan & Temur-Dogan, 2010; Sezer & Güler-Öztürk, 2011; Zembat et al., 2013). However, because of the limited scope and small sample sizes of these studies, it is difficult to make general claims about early geometry teaching in Turkey. Again, this study should help the field move towards making more general claims about pre-school geometry teaching and learning in Turkey; claims that could then inform more effective instruction.

Present Study

Educational and psychological studies show that children learn information about shapes when they have active experiences; young children change their judgments about shapes as they gain rich experience with geometry (Olkun & Toluk Uçar, 2007). Therefore, creating a teaching process that supports intuitive thinking in children, uses explanatory, informal teaching as a base from which to start, utilizes concrete materials to support learning, and ensures active participation is vital for the gaining of geometric concepts (Siew et al., 2013; van Hiele, 1986). In particular, children need research-based educational experiences that provide opportunities to attend to and identify properties of shapes and transformations of those shapes (Clements, 2003).

Mind-mapping would seem to be an appropriate teaching method for supporting pre-school students in learning geometry because it supports both verbal and visual presentations of knowledge and helps children create effective mental images (see Kulhavy et al., 1985; Paivio, 1991). Mind-mapping also provides opportunities for discussion, question generation, information search and analysis, imagination, concretization, and association, all of which align with the recommendations for teaching geometry described above (see Polat & Aydın, 2020; Polat et al., 2022). Finally, mind-mapping has been shown to effectively support geometric learning in older students (Bütüner, 2006).

In sum, and according to scholars, mind mapping which affects learning and teaching in a positive way (Liu et al., 2014) will have an influence on introducing geometry skills if prepared and implemented based on the developmental features of pre-schoolers. In addition, it is noteworthy that the number of mind mapping studies conducted with preschool children is quite low in the literature. For the above reasons, this study aims to examine the effect of mind mapping studies on the geometry skills of 5-6-year-old children. A quasi-experimental design with a pre-test and post-test, as well as a treatment and control group were utilized for this study. Hypotheses to be tested for this purpose are as follows:

1. There is no significant difference between the pre-test scores for geometric knowledge from the experimental group and the control group.
2. There is a significant difference between the pre-test and post-test scores of the experimental group after the mind mapping studies are applied.
3. There is a significant difference between the pre-test and post-test scores of the control group after the Preschool Education Program is applied.
4. There is a significant difference between the post-test scores for geometric knowledge from the experimental group and the control group.

Method

Participants

The study group consisted of two classes, totaling 29 children (age 5-6 years), from a preschool in a city located in the western part of Turkey's Central Anatolian Region. One class served as the experimental group and the other served as the control.

There were 14 children in the experimental group (six girls, eight boys, with a mean age of 64.35 months) and 15 children in the control group (eight girls, seven boys, with a mean age of 65.6 months). In the experimental group, three children had preschool education for one year, and 11 children were in their second year of preschool education. In the control group, four children were in their first year and 11 children were in their second year. Children in the experimental and control groups were also similar in terms of their mother's age, parental education, and parental income.[1]

Measures

The research data were obtained using the "Early Geometry Skills Test-EGST" developed by the researcher to determine the geometric thinking skills of children aged 5-7. Several skills were included in the test. These skills are *recognizing typical examples of basic 2D shapes* (MoNE, 2013; NCTM, 2000), *recognizing typical, atypical, and invalid examples of basic 2D shapes* (Clements et al., 1999; Clements, 2003), *drawing basic 2D shapes* (Clements, 2003; Ho, 2003; NCTM, 2000), *recognizing the edges and corners of basic2D shapes* (MoNE, 2013; NCTM, 2000), *placing (rotating) basic 2D shapes in the appropriate space* (Clements et al., 1999; Clements, 2004), *making shapes by combining different shapes, making shapes with sticks* (Clements et al., 1999; Clements, 2003), f*igure-ground relationships* (NCTM, 2000)*, recognizing 3D shapes (intuitively)* (MoNE, 2009), *pattern* (MoNE, 2009; Olkun & Uçar-Toluk, 2007), *perspective taking* (NCTM, 2000), *construction with blocks* (Clements, 2003; Fisher et al., 2013), and *prediction of a surface of shapes 3D* (Yetkin & Dascan, 2010). Secondly, for content validity, 13 expert opinions were solicited (four from the Department of Mathematics, two from the Department of Classroom Teaching, four from the Department of Preschool Education, one from the Department of Measurement and Evaluation, and two experts who are classroom teachers). The *content validity ratio* (CVR) was calculated for each item of the test. Eighteen items that were lower than the determined values (0.54) were excluded from the test. In addition, it was found that the value of the *content validity index* (CVI) for the entire test had a higher value than the value of the *content validity ratio* (CVI = 0.65 > CVR = 0.54). Therefore, the results of the content validity value showed that the test was valid (Lawshe, 1975). Thirdly, the Frostig Visual Perception Test (r=.670, p< 0.05) and Early Number Test (r=.432, p< .05) were used for the criterion validity. After that, the item discrimination results found that there was a significant difference between 27% of the lower group and 27% of the upper group. In addition, statistically significant differences were found between age groups (5, 6, and 7). Finally, the reliability of the EGST was examined. The reliability coefficient of the test was KR20, 0.853. Pearson's correlation coefficient between the two test halves was 0.697. In addition, the Pearson test-retest correlation coefficient of the test was 0.898.

The test is comprised of 42 items. The scoring of 37 items is on a true-false basis (correct=1, incorrect=0). Scoring for the other five items is calculated by the total score (maximum score 8 for Item four, Item five, and Item seven maximum score of six for Item six, and maximum score of four

[1] Most of the mothers of the children in the experimental group are within the age range of 30 to 34 years (n = 7) and have university degrees (n = 10). Similarly, most of their parents are within the age range of 30 to 34 years (n = 12) and have university degrees (n = 12). Furthermore, most of the families had a medium-income level (n = 10). In the control group, most of the children's mothers are within the age range of 35 to 39 years (n = 8) and have university degrees (n = 12). On the other hand, most of their parents are within the higher age range of 40-44 (n = 6) and have university degrees (n = 11) and their families have middle-income (n = 12).

for Item 39). The lowest score that can be obtained from the test is zero, and the highest score is 71 (Sezer & Güven, 2016, 2019). The skill groups of the test items are given below in Table 1.

Table 1

Content of Early Geometry Skills Test

Skill Group	Item No
Recognizing typical examples of basic 2D shapes	(1) (2) (3)
Recognizing typical, atypical, and invalid examples of basic 2D shapes	(4) (5) (6) (7)
Drawing 2D basic shapes (copying)	(8) (9) (10)
Recognizing the edges and corners of basic 2D shapes	(11) (12)
Placing (rotating) 2D basic shapes into the appropriate space	(13) (14) (15)
Making new shapes by combining different shapes (imaginarily)	(16) (17)
Decomposing a shape	(18) (19)
Making new shapes by combining different shapes (with the wooden material)	(20) (21)
Making new shapes with the sticks	(22) (23) (24)
Figure-ground relationships	(25) (26) (27)
Recognizing 3D shapes (intuitively)	(28) (29) (30) (31) (32) (33)
Pattern	(34) (35) (36) (37
Perspective-taking	(38)
Building with blocks	(39)
Predicting a surface of 3D shapes	(40) (41) (42)

Experimental procedure

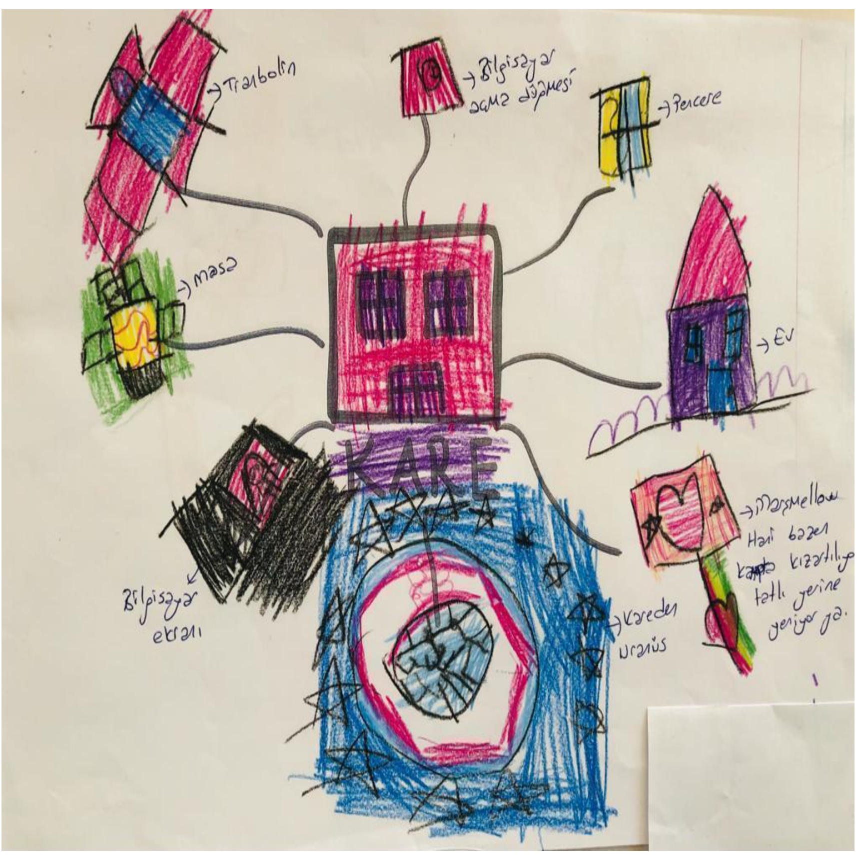
Preparation for the Experiment: After an initial information meeting with school administration, faculty, and parents, two teachers and the parents of their students volunteered to participate in the research project. Four days of mind mapping training was given to the two participating teachers. This training included theoretical underpinnings of mind maps, examination and analysis of example mind maps, creation of mind maps, and methods for conducting mind map studies with children. Lots were drawn to determine which of the two classes would be the control group and which would be the experimental group.

Classroom teachers and advisors received training on administering the EGST and demonstrated that they were able to do so. They then administered the pre-test to study participants. Students in the experimental group engaged in mind-mapping exercises with the researchers once a week for four weeks. These exercises were designed to familiarize the students with mind maps, and focused on the themes of toys, animals, babies, and cars. The relevant theme (e.g., animals) was written in the middle of the page and the children were asked to think about the related ideas and then to illustrate their thoughts. Under each picture created by the children, labels or short explanations were written by the teachers and researchers.

Treatment: In November, December, January, and February children in both the experimental and control groups participated in the same activities prepared by the teachers based on the achievements and indicators in the Ministry of National Education Preschool Education Program. Children in the experimental group created individual mind maps on the second Friday of each month. These children created mind maps with the theme circle, triangle, square, and rectangle (see Figure 1).

Figure 1

Example of the Square-themed Mind Mapping Exercise



Note: Figure 1 shows a mind map drawing of a 65-month-old boy with a square theme (*Turkish spellings of drawings in parentheses*). In the drawing, there are a table surface (masa yüzeyi), a trampoline (trambolin), a computer power button (bilgisayar açma düğmesi), a window (pencere), a house (ev), a marshmallow (lokum/marşmelov), and a computer screen (bilgisayar ekranı). There is also the planet Uranus, designed using squares in the drawing.

After creating their new mind map, children were given their previous mind map and asked if they wanted to change or add anything to their old map. (e.g., after creating a mind map for the triangle, they were given their previous mind map of the circle and given a chance to revise it.) This allowed children to reinforce previously learned information by repeating it, as well as provided opportunities to add new information, to establish relationships between previous and new knowledge, and to restructure relationships. From March to May, this process was repeated with pentagons, hexagons, and ellipses (see Figure 2). At the end of the experiment, each child had produced 7 mind maps.

At the end of the experiment, children were given the EGST again. After the post tests were administered, mind mapping studies were carried out with the control group starting in the 3rd week of May and into June. These mind mapping exercises followed the same steps as those in the experimental group but were accelerated to take place over a shorter period of time. These maps were not subject to evaluation in the research process and were created with the sole aim of providing equal learning opportunities to all research participants.

Figure 2

Example of the Hexagon-themed Mind Mapping Exercise

Note: Figure 2 shows a mind map drawing of a 63-month-old girl with a hexagonal theme (Turkish spellings of drawings in parentheses). In the drawing, there is a cat (kedi), a mushroom (mantar), a television (televizyon), a sign (tabela), a toy (oyuncak), and a snowman (kardan adam).

Data Analysis

In evaluating the research data, the children's personal information and EGST scores were first analysed and converted into data sets. The data sets were then analysed using a statistical package program. Finally, a Shapiro-Wilk test was used to determine if the data were normally distributed. The normality results are presented in Table 2.

Table 2

Normality Test

Group	Shapiro-Wilk		
	Statistic	df	*p*
Exp. group: pre-test	.888	14	.077
Cont. group: pre-test	.932	15	.290
Exp. group: post-test	.944	14	.475
Cont. group: post-test	.944	15	.441

In Table 2, it was concluded that the distribution was normal (p> .05). Therefore, parametric tests were used to analyse the data that were found to have a normal distribution. The Independent group *t*-test was performed for the pre-tests and an analysis of covariance (ANOVA) for the post-tests. In addition, the effect size was calculated and reported.

Results

The means of the EGST scores before and after the test of the experimental and control groups were examined and the results are presented in the tables below.

Table 3

Independent Samples t-test Result of Pre-tests

Group	*n*	$\bar{x}$	*sd*	*t*	*df*	*p*
Experiment	14	42.15	4.39	-.931	27	.360
Control	15	43.73	4.79			

In Table 3, according to the results of the independent samples *t*-test conducted between the pre-test scores of the experimental group (M = 42.15, SD = 4.39) and control group (M = 43.73, SD = 4.79) obtained from the EGST, no significant difference was found t (27) = 4.30, p= .360. These findings showed that children in the experimental and control groups prior to the application (mind mapping) were at a similar level in terms of geometry knowledge.

Table 4

Descriptive Statistics for Pre- and Post-tests

	Pre-test		Post-test		Total	
	$\bar{X}$	sd	$\bar{X}$	sd	$\bar{X}$	sd
Experiment	42.14	4.39	55.21	4.62	48.68	7.10
Control	43.73	4.79	50.13	4.25	46.10	5.51
Total	42.97	4.59	52.59	5.07	47.78	6.81

These results show that the children in the experimental group (pre-test: M = 42.14, SD = 4.39; post-test: M = 55.21, SD = 4.62) and in the control group (pre-test: M = 43.73, SD = 4.79; post-test: M = 50.13, SD = 4.25) showed higher levels of geometry skills in the post-tests. A 2x2 ANOVA with test (pre-test, post-test) and group (experiment, control) was performed to determine the effect of variables on the geometry knowledge of young children. The assumptions required were then tested and homogeneity of variance $F= .149$, $df1 = 3$, $df2 = 54$, $p = .930$ were found to be adequate for the two-way ANOVA. The findings were given in the following table.

Table 5

Two-way ANOVA Results

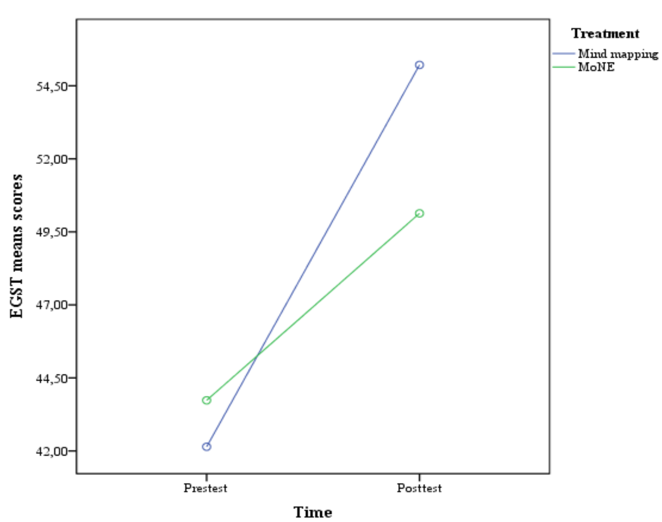
Source	*SS*	*df*	*MS*	*F*	η_p^2
Intercept	132396.112	1	132396.112	6483.307***	.992
Group	44.112	1	44.112	2.160	.038
Test	1372.736	1	1372.736	67.222***	.555
Group * Test	161.150	1	161.150	7.891**	.128
Error	1102.738	54	20.421		
Total	135037.000	58			

**$p < .01$. ***$p < .001$.

There was no significant difference according to the group $F(1, 54) = 2.160$, $p= .147$, $\eta_p^2= .038$. On the contrary, it was determined that the effect of the test variable was significant $F(1, 54) = 67.222$, $p = .000$, $\eta_p^2 = .555$. In addition, it was understood that the main effect between group and test variables on EGST scores was significant $F(1, 54) = 7.891$, $p = .007$, $\eta_p^2= .128$. In the Post Hoc test, the difference in the test variable was found to be in favour of the post-tests. Furthermore, when the main effect between group and test variables was examined, it was determined that there were significant differences in favour of the post-tests of the experimental group. In Figure 3, the interaction graph presented shows the change in the EGST scores of the experimental and control groups as a function of the measurement time.

Figure 3

Interaction Graph of Group and Time Variables



When Figure 3 is examined, it is seen that there is a change in the pre and post-test scores of the experimental and control groups over time. The post-test scores of the children in the experimental group were significantly higher than the post-test scores of the children in the control group.

Results and Discussion

One significant result of this study is that even absent mind mapping, the Ministry of Education Preschool Program supported the geometry learning skills of the children in the control group considerably. For some of the skills measured by the EGST, both groups experienced gains and there were no statistically significant differences in those gains. These skills included recognizing typical examples of basic 2D shapes, recognizing edges and corners of basic 2D shapes, rotating, creating shapes by combining different shapes and sticks, and the relationships between form and ground, recognition of 3D shapes (intuitively), patterning, taking perspective, and estimating a surface of 3D shapes. These findings serve as evidence that theoretical underpinnings of the Pre-school education program in geometry are sound, as well as the constructivist facets of the program, including its child-orientation, flexibility, play-based, emphasis on creativity and exploration, and participation of family.

However, despite the geometric learning demonstrated by the control group, the results of this quasi-experimental study show that mind mapping does have a statistically significant, positive effect on the geometry learning of pre-school children. When compared with a control group who was not taught using mind-mapping, pre-school children who were taught using mind-mapping did better on a post-test of geometry learning. The effect size was seen as medium ($\eta_p{}^2=.128$; Cohen, 1988) and 13% of the improvement in the experimental group is explained by the application of mind maps.

The EGST scores indicated that the mind mapping exercise contributed to children's learning of how to draw figures, how to distinguish typical, atypical, and invalid examples of the shapes, and how to develop a new shape from different shapes and develop various structures with the blocks. This helps us understand ***how*** mind mapping supports geometric learning for pre-school children. One way mind mapping supports pre-school children is that it provides opportunities to draw shapes. Mind mapping supports students' drawing skills because students begin the mind-mapping process by drawing the shapes. This is consistent with other studies highlighting the contribution of drawing shapes by children in early geometry education (see Clements, 2003; Ho, 2003; NCTM, 2000).

A second way mind mapping assists pre-school children's geometric learning is by supporting the development of relational thinking. This was seen in the experimental group's better scores in distinguishing between typical, atypical, and invalid examples of shapes. Mind mapping supports relational thinking by supporting students in presenting and processing visual and verbal information together, supporting the creation of mental images (see Kulhavy et al., 1985l; Paivio, 1991), providing opportunities for active participation, discussion, generating questions, searching and analyzing the information, concretization, association (see Polat & Aydın, 2020; Polat et al., 2022), hierarchical organization of the information (concretization of complex relations) (see Buzan & Buzan, 2002). Mind mapping also supports the focus of the brain on details, nourishes associations, develops memory, and eases recall with its multi-dimensional structure (Farrand et al., 2002).

Finally, mind mapping has supported the child's ability to develop a new shape from different figures and various structures with the blocks. The ability to create geometric shapes from different figures and obtaining shapes from one figure to another has been described as a skill group and a significant conceptual area within the field of geometry (NCTM, 2000). Moreover, this important skill is in no way trivial for young learners. In a study, conducted by Copley (2000) it was recorded that 4-year-olds were surprised when they observed that two triangles were obtained after the square was cut by turning it diagonally, and that a square was formed after these triangles were brought together again. Thus, it can be hypothesized that using mind maps supported students' imaginative knowledge, which, in turn, contributed to their relatively greater success on a range of geometric tasks.

In addition to these specific supports, it can be hypothesized that mind mapping provides more general support for students learning geometry. Research results have shown that when conducting geometry studies with young children, play, concrete materials, and the use of technology have positive effects on the acquisition of geometry knowledge (Fisher et al., 2013; Keren & Fridin, 2014; Kılıç & Şahin, 2019). Furthermore, when the activities supported thinking skills such as classification and comparison, it was concluded that they positively affected the early teaching of geometry (Kılıç & Şahin, 2019; Parks, 2015; Şen, 2017). Mind mapping provides opportunities for fun, an exchange of ideas, comparison, classification, teacher-child interaction, and problem-solving, all elements of effective geometry pedagogy for pre-school children. Another reason mind-mapping may have supported pre-schoolers' geometry learning may have to do with the nature of pre-schoolers' minds. The learning capacity, memory, and attention of young children are limited (Berk & Meyers, 2015). Mind mapping supports understanding by reducing the cognitive burden of learning through visual materials (Schwamborn et al., 2011). It emancipates the learner from unnecessary cognitive burdens (Stull & Mayer, 2007). Hence it ensures the effective use of the limited capacity of memory (Anderson, 2011). Mind maps also work by forcing students to attend to relationships between new information and what they already know (Dhindsa & Anderson, 2011), and by drawing on a wide range of skills such as attention, coordination, reasoning, thinking, analyzing, creativity, imagination, memory, planning, integration, visuality, hearing, and kinesthetics into use (Wang et al., 2010).

This study also builds on the work of researchers who have studied mind mapping with older students. Mind mapping affected language skills (Hsin-Yi, 2015), critical thinking skills (Polat & Aydın, 2020), and school readiness (Polat et al., 2017) in young children. In addition, mind mapping contributed to the teaching of geometry in studies conducted with different grades (high schools) (Kariyana & Sonn, 2016; Loc & Loc, 2020). Kariyana and Sonn (2016) explained that the positive development in students' knowledge of geometry, with the effect of mind maps, is that since learning and teaching become more animated, student motivation increases and it's easier to remember what they learned. Additionally, mind maps can develop new ways for students to take initiative while learning and enhance their creativity and thinking skills (Loc & Loc, 2020). Furthermore, it can be said that mind mapping, which makes mathematics enjoyable (Entrekin, 1992), develops mathematical reasoning (Ayal et al., 2016), and mathematical creativity (Vijayakumari & Kavithamole, 2014) is an effective technique for young children to learn geometry. Mind maps as instructional aids help young children learn because they are manipulable and meaningful (Clements & Sarama, 2007).

Mind mapping is a powerful technique that activates many brain functions (Buzan & Buzan, 2002). It supports words, imagination, numbers, causes, rhythm, pictures, lists, details, colours, and spatial awareness effectively (Buzan et al., 1999), facilitates learning, and ensures permanence (Buzan & Buzan, 2002). All of these happen by allowing learners to visualize the relationships of mathematical objects in a structured way (Brinkmann, 2003b). Mind mapping allows for the support of many skills (thinking about themes, imagination, emotions, attention, identifying the possible causes, reasoning, analyzing, creativity, memory, coordination, reading, writing, visualization, planning, and application) (Wen-Cheng et al., 2010) facilitates the organization of geometric concepts as hierarchies and categories via colours, shapes and pictures, visualization of the relationships between shapes and their features through brainstorming, active participation, and interaction of children (Budd, 2004). Mind mapping, which is based on a constructivist approach, caused children to expand their conceptual schemes. It enabled the children to use their personal experiences, emotions, and intuitions as well (Dhindsa & Anderson, 2011; Ültanır, 2012).

All of the above research indicates that there is great possible potential for the effective use of mind mapping with pre-school children. The claim can be made that this experiment shows that mind maps do, indeed, support pre-school geometry learning. This aligns with van Hiele's contention that geometric learning, although developmental, is not constrained by age, and can be supported and accelerated through the use of effective pedagogy (van Hiele, 1999). According to van Hiele, it is essential for children to explore, discuss, and solve problems in order to learn new ideas. In this context, it can be suggested that the children in the experimental group had opportunities to do exactly that.

Conclusion

In summary, it was concluded that mind mapping is a technique that can be used in early childhood and a practice that enhances the geometry skills of young children. The results of this study made contributions to the literature both regarding mind mapping and early geometry teaching. In addition, it was understood that the constructivist-based curriculum, which has been applied in preschools in Turkey since 2013, promotes early geometry skills as well. However, the size of the study, and the relatively narrow context, make generalization of the obtained results difficult. More research is needed to test if these findings may hold true for larger and more diverse groups of participants in a wider range of settings.

Another implication of this study is the possibility that geometric thinking levels and skills, which are specified separately from each other, may be considerably less static and discrete. Students often exhibit different van Hiele levels on different questions, and the levels of their thinking show dynamism and continuity, which echoes previous research studies (Burger & Shaughnessy, 1986; Clements & Battista, 1992; Fuys et al., 1988). This indicates that continued research is needed to refine and clarify van Hiele levels and other aspects of children's geometric thinking.

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Türker Sezer (sezer_t@ibu.edu.tr) is an assistant professor of Preschool Teacher Education in the Education Faculty at the Bolu Abant Izzet Baysal University of Central Bolu in Turkey. He has national and international experience with early math teaching and preschool teacher education. His major research interests include (1) preparing and supporting pre-service and in-service preschool teachers to teach children under six years, and (2) exploring and comparing teaching strategies and mathematical performance of children in an international context. His recent publications can be found in Participatory Educational Research and the International Journal of Psychology and Education Studies.

Özgül Polat (ozgul.polat@marmara.edu.tr) is an associate professor of Preschool Teacher Education in the Ataturk Education Faculty at the Marmara University of Central Istanbul in Turkey. She has been working in the Preschool Education Program Writing and Dissemination Commission of the Ministry of National Education since 2002. She is also one of the authors and consultants of the 0-18 Age Family Education Programs of the General Directorate of Lifelong Learning. In addition, she is taking part in many national and international projects and has many books on various topics such as Preparation for Primary Education and Primary Education Programs, Reading and Writing Awareness, Visual Reading, Sound and Writing Education, Preschool Education Programs, Sensory Education, Multiple Intelligence Applications, Family Education, Multicultural Education, Children's Capacity Building, etc. Furthermore, she has her signature as a writer, editor, and consultant in many resources on preschool and primary school through first grade education. Her recent publications can be found in Education and Science, Thinking Skills and Creativity, and Early Child Development and Care.

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