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Examining the Effects of Presented Activities for a Strong Supported Geometry Instruction

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Research Article
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Abstract

In this study, based on the expectation of high achievement and the need for strong support from all students in mathematics education, the effect of geometry instruction enriched with various activities on students' Van Hiele Geometric Thinking Levels and spatial abilities was examined. The participants of the present study, in which the weak experimental design was adopted, consisted of 22 students, who passed from the 6th grade to the 7th grade, living in disadvantaged areas in a medium-sized province of Turkey and studying at public schools in those regions. In the research, Van Hiele Geometry Test and Spatial Ability Test were used as pre-test and post-test. In the training given between the pre-test and the post-test, creative drama, digital story writing, origami, geometric construction, GeoGebra, GeoCadabra, SketchUp, educational games, and Small Basic activities were included. While no significant difference was found between the pre-test and post-test in the scores obtained from the Van Hiele Geometric Thinking Test, i. It was determined that there was a significant difference in favour of the post-test in the scores obtained from the Spatial Ability Test. In this test, the effect size value was 0.591, and it was seen that the effect was large. The study emphasizes the positive effects of presenting different types of activities in order to provide strong support in geometry instruction.

Keywords: Geometry, van hiele geometric thinking level, spatial ability, strong support

Kuvvetli Desteğe Dayanan Bir Geometri Öğretimi İçin Sunulan Etkinliklerin Etkilerinin İncelenmesi

Öz

Matematik eğitiminde tüm öğrencilerden yüksek başarının beklenmesi ve kuvvetli desteğin verilmesini temel alan bu çalışmada, çeşitli etkinliklerle zenginleştirilmiş bir geometri öğretiminin öğrencilerin Van Hiele Geometrik Düşünme Düzeyleri ve uzamsal yeteneklerine etkisi incelenmiştir. Zayıf deneysel desenin benimsendiği mevcut çalışmanın katılımcıları, Türkiye'nin orta ölçekli bir ilinde dezavantajlı bölgelerde yaşayan ve o bölgelerdeki devlet okulların öğrenim gören, 6. sınıftan 7. sınıfa geçen 22 öğrenciden oluşturmaktadır. Araştırmada Van Hiele Geometri Testi ve Uzamsal Yetenek Testi ön test ve son test olarak kullanılmıştır. Ön test ile son test arasında verilen eğitimde, geometrik deneyimler sunan yaratıcı drama, dijital hikâye yazımı, origami, geometrik inşa, GeoGebra, GeoCadabra, SketchUp, eğitsel oyun ve Small Basic etkinliklerine yer verilmiştir. Van Hiele Geometrik Düşünme Testinden alınan puanlarda ön test ile son test arasında anlamlı bir fark saptanmazken; Uzamsal Yetenek Testinden alınan puanlarda son test lehine anlamlı bir fark olduğu belirlenmiştir. Bu testte etki büyüklüğü değeri 0.591 olup, etkinin büyük oranlı olduğu görülmüştür. Çalışma, geometri öğretiminde kuvvetli bir destek sağlamak için farklı türde etkinliklerin sunulmasının olumlu etkilerini vurgulamaktadır.

Anahtar kelimeler: Geometri, van hiele geometrik düşünme düzeyi, uzamsal yetenek, kuvvetli destek

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INTRODUCTION

According to NCTM (2000), the principles that characterize high-quality mathematics education are equality, curriculum, teaching, learning, assessment, and technology. Of these principles, the equality principle states that high expectations and strong support are required for all students in mathematics education (NCTM, 2000). In other words, students at all levels of education should have equal opportunities to learn mathematics and be able to reach mathematical competence as a result (MoNE, 2018). Many countries have learning standards indicative of this mathematical competence, and learners are expected to reach these standards (NCTM, 2000; MoNE, 2018). However, various obstacles can prevent learners from reaching the standards required. Allexsaht-Snider and Hart (2001) define the requirements of equality in mathematics education as

- equal distribution of resources to schools, students, and teachers,
- equal education quality
- and obtaining fair results for students,

and stated that equality for learners can be achieved if these requirements are met. Allexsaht-Snider and Hart (2001) indicate that one of the important elements in meeting these requirements is classroom activities. According to researchers, these activities that the teacher will offer not only increase the learner's belonging to the class, but also offer them equal learning opportunities (Allexsaht-Snider & Hart, 2001, Gutstein, 2002). Therefore, considering the interests and needs of students, interventions with different activities that will strengthen them mathematically should be designed and implemented (Gutstein, 2002; 2003; Martin 2003). This situation leads us to the concept of "strong support", which NCTM also states. "Strong support" refers to a well-designed curriculum that will provoke learning, providing the necessary resources for learning and environments containing information and communication technologies, and employing different teaching methods in order to ensure equality in mathematics education (Croom,1997; Furner, Yahya, & Duffy, 2005; Hart & Allexsaht-Snider,1996; NCTM,2000).

On the other hand, especially considering geometry, which is one of the sub-learning areas in the mathematics curriculum, Paksu (2009) states that many students cannot learn geometry as much as they need or expect to learn. In addition, Duatepe (2004) states that in standard mathematics classrooms, students are expected to perform paper-pencil and calculation tasks related to geometry. However, geometry learning, by its very nature, requires geometric experiences (Battista & Clements, 1988; Jones & Mooney, 2003). Battista and Clements (1988) state that learning geometry begins with physical shapes and working on these shapes, and in this way, learners gain intuition and knowledge about their spatial environment. These experiences become formal by analysing them in the context of geometric concepts and relations over time (Battista, 2007). It has been determined that the learners get geometric experiences through the use of methods such as concrete material, information and communication technologies, argumentation, cooperative learning, and creative drama, and because of these experiences, it was determined that an increase in the geometry achievement and attitudes of the learners towards geometry (Battista, 2007; Chrysanthou, 2008; Chua, Tengah, Shahrill, Tan, & Leong, 2017; Clements, 2003; Duatepe-Paksu, & Ubuz, 2009; Heid, 2005; Hohenwarter & Jones, 2007; Kariadinata, Yaniawati, Susilawati, & Banoraswatii, 2017; Klemer & Rapoport, 2020; Manizade & Mason, 2010; Olkun, 2003; Paksu, 2009; Prigge, 1978; Tutkun & Ozturk, 2013). With the studies in the literature, it is thought that a strong support can be created for learners by transferring the activities in which these methods are used to formal learning environments.

In this context, it is thought that two elements that shape geometry learning are important in the design and presentation of learning experiences that will provide learners with strong support: Van Hiele Geometric Thinking Levels and spatial ability. While Van Hiele Geometric Thinking Levels is an indicator of the learners' forming a systematic structure in their minds about geometry and the establishment of relationships between shapes and shape classes (Van Hiele, 1986), spatial ability reveals how learners perform geometric actions (such as rotation, manipulation, orientation) in geometry learning and their level of ability to do so (Carroll, 1993). In this regard, these two elements are important in mathematics teaching, especially in the planning of teaching geometry, in the creation of the teaching content, and in the measurement of the proficiency levels of the learners. Van Hiele Geometric Thinking Levels present the structure and criteria for the order, boundaries, and measurement of the content that learners will learn in geometry teaching, while spatial ability provides indicators with the fulfilment of the actions as well as defining the actions taken in this structure (Van de Walle, Karp, & Bay-Williams, 2010). According to many researchers, these two elements cannot be separated from geometry teaching and their effect on geometry achievement is obvious (Clements & Battista, 1992; Saad & Davis, 1997). In order to provide strong support to learners with a holistic perspective, the measurement and development of Van Hiele Geometric

Thinking Levels and spatial abilities, which affect every stage of teaching, are necessary for effective mathematics teaching and effective geometry learning (Clements & Battista, 1992; 1996; Gutierrez, 1992; Usiskin, 1982).

Considering all these, Van Hiele Geometric Thinking Levels and spatial ability should be taken into account in the design, presentation, and evaluation of learning activities that will provide strong support in mathematics teaching for students. In this study, the effect of geometry instruction enriched with various activities that will strong support in learning mathematics and contribute to the learners' learning of geometry, on the Van Hiele Geometric Thinking Levels and spatial abilities of the students was examined.

Research Question

In the present study, the research questions sought to be answered in the context of this aim are as follows:

1.Does strong supported geometry instruction enriched with various activities affect students' Van Hiele Geometric Thinking Levels?

2.Does strong supported geometry instruction enriched with various activities affect students' spatial abilities?

Van Hiele Geometric Thinking Levels and Spatial Ability

Van Hiele Geometric Thinking Levels is a geometric thinking model and explains how learners perceive geometry and divide these perceptions of learners into various levels (Van Hiele, 1986). According to Van Hiele (1986), the levels in the model have a sequential and hierarchical structure, therefore, to be at one level, one must be successful at the previous level. Progress between levels depends on teaching and geometry experience, not on age and gender. If the level of teaching does not include language and examples suitable for the learner's level, learning does not take place and progress between levels does not occur (Duatepe-Paksu, 2016). According to Van Hiele (1986), the levels in the model and the requirements of these levels are as follows:

Level 1 - The Visual Level: Students initially perceive the shapes as a whole. They cannot perceive the elements and properties of shapes. By approaching shapes holistically, students focus on whether they resemble shapes they have seen before, not their features. In their minds, shapes are in discrete classes, and this classification is based on similarity to their prototype.

Level 2 - The Descriptive Level: The student realizes that shapes are composed of elements and that these elements have properties. The classifications made are based on the properties of the shapes but students cannot link these classifications. Similarly, the relationship between the properties of shapes cannot be established. Therefore, students at this level cannot make a definition that includes necessary and sufficient conditions. The definitions made are in the form of listing the features of the shape.

Level 3 - The Theoretical Level/ The Informal Deduction Level: At this level, the student establishes the relationship between shape classes and understands the hierarchy between these classes. In addition, they can establish the relationship between the properties of shapes, and as a result, they can make a definition that includes necessary and sufficient conditions. The student can make logical inferences based on features such as “If shape A has … properties, it is shape B.”.

Level 4 - Formal Logic Level: Students can reason, make inferences and proofs within a mathematical system. Inferences made at this level are more formal than those made at Level 3. At this level, the system of formal inferences is reached through axioms, theorems, and proofs.

Level 5 - Systematic Thinking Level / The Nature of Logical Laws: At this stage, students notice various axiomatic systems, reflect on these systems, and understand the similarities and differences between different axiomatic systems. In this period, he can work on non-Euclidean systems and interpret any shape, definition, or feature according to these systems.

In Table 1 below, Van de Walle et al. (2010) expressed what is expected from primary and secondary school students in the geometry dimension in the context of the Van Hiele Geometric Thinking Model. Elementary and secondary school geometry teaching content was examined in 4 dimensions as shapes and properties, transformation, location, and visualization. In each of these dimensions, what is expected from the students is classified in the visual level, the descriptive level, and the informal deduction level from the Van Hiele Geometric Thinking Levels.

Table 1. According to Van de Walle et al. (2010), Van Hiele Geometric Thinking Levels and What is Expected from Primary and Secondary School Students in Various Dimensions of the Geometry Field

	Level 1 The Visual Level	Level 2 The Descriptive Level	Level 3 The Informal Deduction Level
Shapes and Properties	- Separating and classifying using simulation - Combining shapes and breaking them into parts - Recognizing patterns and creating a whole with shapes	- Identifying special categories of 2D shapes (based on a specified property) - Identifying special categories of 3D shapes (based on a specified property) - Property-based making separation and classification - Property-based creating and/or drawing shapes	- Making assumptions and examining informal inferential arguments when relating to specific categories of figures - Making definitions with necessary and sufficient properties for shapes
Transformation	- Determining the effects of scrolling, flipping, and rotating actions on simple shapes - Defining images of shapes and objects under straight and rotational symmetry	- Running resultant transformations on shapes and objects - Determining similarity and proportional relationships between shapes - Making decorations using regular shapes or complex structures	- Doing complex activities using transformation and symmetry
Location	- Using the expressions above, below, near, far, between, left and right - Using simple coordinate systems	- Analyzing the results of transformations in the coordinate system as analytical	- Determining the results of actions performed on the coordinate system by binding them to a rule - Determine the slope of a line
Visualization	- Determining all shapes that can be created from a certain number of simple tiles - Examining solid objects with the help of their faces and edges - Opening 3D objects - Matching the faces of 3D shapes	- Identifying and drawing two-dimensional views of 3D shapes - Creating 3D structure from 2D view - Identifying surfaces formed when a solid body is cut into two parts	- Explaining the results of actions taken at Level 2 with justifications and making inferences - Creating and describing Platonic objects

As seen in Table 1, Van de Walle et al. (2010) present the content of geometry teaching by associating it with Van Hiele Levels of Geometric Thinking, this presentation reveals a theoretical and intended structure. However, the fulfilment of these expectations by the learners in all dimensions of geometry teaching and the progress of their geometric thinking levels depend on geometric experiences (Clements & Battista, 1992; Van Hiele, 1986). These experiences, on the other hand, are related to spatial ability because of the actions they involve. Spatial ability is defined as imagining, perceiving, manipulating, rearranging, and re-acquiring visual images of objects or forms (Carroll, 1993). In addition, Tartre (1990) stated that spatial ability includes understanding and using the relationships between objects in addition to the specified operations. When the literature is examined, it is seen that spatial ability is a mental process and requires being able to perform various activities on 2 or 3-dimensional objects determined in space (Zeybek, 2016).

In literature, researchers have examined spatial ability under various components. For instance, McGee (1979), Lohman (1979), Clements (2004), and Tartre (1990) discuss the components of spatial ability under two headings as spatial visualization and spatial orientation. While Linn and Petersen (1985) and Okagaki and Frensch (1994) make a distinction between spatial visualization, spatial perception, and mental rotation. In addition to that, Olkun and Altun (2003) and Contero, Naya, Company, Saorín, and Conesa (2005) emphasize the spatial relations component in addition to spatial visualization and spatial orientation. Moreover, Maier (1996) argues that these components are examined in a general framework within five components: spatial perception, visualization, mental rotation, spatial relations, and spatial orientation. As it is seen, although there are no agreed spatial ability components in the literature, almost all researchers have emphasized the spatial visualization and spatial orientation components of spatial ability.

Spatial visualization can be expressed as the creation of an image in the mind and its manipulation (Karaman, 2000; Linn & Petersen, 1985; Okagaki & Frensch, 1994). Although the expression manipulation in this definition has a meaning as intervening and performing a series of actions, it needs to define the actions it will involve. In this context, when the spatial visualization definitions in the literature are examined, McGee (1979) emphasizes the rotation and opening-closing operations on the object in his definition, while Lohman (1979) emphasizes the paper folding and unfolding operations and the unfolding of 3D objects. Tartre (1990) and Maier (1996) consider spatial visualization through moving the object and stated that this movement could be in the form of moving the whole or a part of the object. As a result, spatial visualization can be expressed as imagining an object in the mind, performing a series of operations such as rotating, opening-closing, folding-unfolding mentioned above on these objects or parts of objects, and the whole process of imagining the result of these operations. Spatial orientation, on the other hand, is defined as the individual's ability to determine the order, patterns, and appearances of objects according to their position (McGee, 1979). While Lohman (1979) defines spatial orientation as determining how the given objects will appear from different angles, Maier (1996) defines the position of the object's parts relative to each other and the object relative to other objects, establishing relationships and being able to determine them according to one's position.

Considering the studies revealing that spatial ability is an important factor in geometry teaching (e.g., Clements & Battista, 1996; Maier, 1996; Olkun & Altun, 2003, Tartre, 1990), it is of great importance how this ability is reflected in the curriculum and what the contents are in which students should use these abilities. Considering the NCTM (2000) standards, it is seen that spatial relations, transformations, visualization, and spatial reasoning are emphasized in the field of geometry learning. In this context, concerning spatial ability, learners are expected to operate on 2 and 3-Dimensional shapes, determine their parts and relations with other shapes, draw 3-Dimensional shapes from different directions in 2 dimensions, create a 2-Dimensional representation in 3-dimensional, and make transformations on shapes. In the Mathematics Curriculum in Turkey (MoNE, 2018), the relationship between spatial ability and geometry was revealed under the title of spatial relations in the primary school curriculum (1-4 grades), through the examination of place, direction, and position relations and geometric shapes. In the middle school program (5-8 grades), a relationship between spatial ability and geometry has been established through acquisitions that include activities such as determining, creating, and expanding the basic elements of 3D shapes, drawing views of structures from different sides, rotating, and shifting given 2 and/or 3-dimensional shapes.

It is seen that while spatial ability expresses the actions of individuals on shapes and objects, Van Hiele Geometric Thinking Levels focuses on how individuals perceive geometry, which includes shapes and objects, in the context of levels. It is thought that it is essential for an individual who is at any of the Van Hiele Geometric Thinking Levels to use their spatial abilities, due to the nature of geometry. In other words, to fulfil the tasks required by the levels, the individual must employ her/his spatial ability. For this reason, carrying out activities to address, evaluate and develop these two interrelated issues will contribute to the development of learners' geometry learning (Gutierrez, 1992; Naraine, 1989; Uzun, 2019).

METHOD

Within the scope of the research, pre-test and post-test were performed and a training process was conducted between the two test applications. However, the participants involved in the process were chosen for a purpose, not by chance. Therefore, in this study, a weak experimental design with single group and pre-test and post-test models was adopted (Fraenkel, & Wallen, 2006). Before the training process, all data collection tools were used as pre-test within the scope of the study. Then the training process was carried out and after the completion of the training process, the same tests were given as post-test.

Population and Sample

Due to the purpose of the study, the population was determined as the students who will start seventh grade in schools located in the disadvantaged regions of a mid-sized province in the Central Anatolia region and have high academic achievement. According to Fraenkel and Wallen (2006), the purposive sampling method is used if the researchers are going to determine the participants to be included in the sample. For the purpose of this study, a purposeful sampling method was adopted as the participants with high academic achievement were selected from the students who will start seventh grade in schools located in the disadvantaged regions of a mid-sized province in the Central Anatolia region.

The reason why the seventh-grade students were determined as the population of the study was that the most comprehensive content of geometry learning area in the mathematics curriculum of MoNE (2018) is in the seventh grade. For this reason, the study was planned to be carried out with students who were not acquainted with the geometry learning area in detail yet, but who was studying at a grade level with some prior knowledge. When the objectives in the mathematics learning program were taken into consideration, it was decided that the best grade level that could meet this expectation was the level that finished sixth grade and started seventh grade. In addition, another preference reason is that the students at the end of the sixth grade have not received any prior instruction on some of the geometry contents that they will encounter for the first time in the seventh grade and are therefore less likely to have a prejudice, anxiety, or attitude towards geometry. Finally, the reason why the participants were selected among the students with high academic achievement in schools in disadvantaged regions is that despite their disadvantages and inadequacies, they could change this situation positively and keep their academic achievement high. The reason why the population is limited to a province is that the training process to be carried out is implemented within the boundaries of that province.

In this context, lists of schools in disadvantaged regions were obtained from the Provincial Directorate of National Education to determine the sample. There are five schools on the list. The purpose of the study was explained by interviewing the mathematics teachers at the schools one by one and for this purpose, three to five t students were identified in each school, proportional to the size of the school. In this context, a total of 24 students, 13 females and 11 males from five schools were selected to be included in the sample. Approval forms were obtained from the parents of the students for their participation in the study. Then, two male students who did not participate in the training process were excluded from the sample and the study was completed with 22 students, 13 females and 9 males.

Training Process

Within the scope of the training offered to the participants, activities related to the geometry learning area were carried out. After obtaining the necessary permissions and completing the official correspondence, the training process, involving nine activities related to the seventh-grade geometry learning area in the mathematics curriculum of the MoNE (2018), continued for five days. Each activity was prepared and carried out by experts in the field and presented with approximately 150 minutes of practice.

Since the participants from different schools were involved in the process, firstly an introductory activity that used creative drama and geometry concepts was conducted. Then, with the second activity accommodating geometry and the digital world, students were enabled to use technology effectively. In the third activity, a process in which origami was employed was realized for students to form some geometric shapes. In the fourth activity, a study on how geometric shapes were constructed with the help of a ruler and a compass was carried out. The following fifth and sixth activities were planned to combine geometry and technology again. In the fifth activity, each student made a polygon drawing with the GeoGebra software under the guidance of the instructor, and in the sixth activity, the geometric structures were examined with the GeoCadabra® and SketchUp® software to activate the spatial thinking process. In the seventh activity, students played games about geometry and designed a box game. After the eighth activity, which was taught coding for geometric shapes with the help of Small Basic software, the training process was completed with the final stage of the activity that brings geometry and the digital world together.

Data Collection Tools

Two data collection tools, Van Hiele Geometry Test and Spatial Ability Test were used. The Van Hiele Geometry Test was developed by Usiskin (1982) and adapted into Turkish by Duatepe (2000). It consists of 25 multiple-choice items and a total of five levels, five items per level. The first level (visual) included items 1.-5. of the test, was related to the visual properties and the definition of geometric shapes. The second level (analysis) included items 6.-10. of the test and rather than visual features, this level was related to the properties of geometric shapes such as square, rectangle, rhombus, isosceles triangle, and the radius and tangent of a circle. In the third level (informal deduction), items 11.-15. of the test were included and in addition to sorting and comparing the properties of geometric shapes, this level evaluated the hierarchy between these shapes, simple inferences. 16.-20. Items of the test which were in the fourth level (formal deduction) contained axioms, postulates, and theorems related to geometric shapes, and in the fifth level (rigor) included the last five items of the test, contain high-level geometric thinking process.

Usiskin (1982), who developed the data collection tool, calculated the reliability values for each level of the test as .39, .55, .56, .30, and 0.26, respectively. The reliability values of Duatepe (2000), who adapted the data collection tool into Turkish, determined those values as .82, .51, .70, .72, and .59 respectively. On the other hand, Şener-Akbay (2012) found that the related values as .45, .40, .50, .36, and .24; and .72 for the whole test. Within the scope of this study, the KR-20 reliability coefficient calculated for the overall test was calculated as .53 for the whole test, but it was observed that the reliability values obtained for the levels were lower. The low reliability value of the levels was since there were five items in each level and five items were insufficient to obtain high-reliability coefficients (Şener-Akbay, 2012). In addition, Kehoe (1995) stated that the KR-20 value should be around .50 in multiple-choice tests with a number of items of 10-15 and that value should be around .80 in multiple-choice tests with a number of items greater than 50. As there are 25 multiple-choice items in the data collection tool, the reliability values obtained in this study were considered to be sufficient.

The other data collection tool, Spatial Ability Test, was developed by Ekstrom (1976) and adapted to Turkish by Delialioğlu and Aşkar (1999). The test consists of four sub-tests, paper folding (20 items), surface development (60 items), cube comparison (42 items), and card rotation (160 items), and a total of 282 items. The paper folding sub-test was aimed to make the participants think of the paper after folding a paper and punching it from several points. Items in the surface development sub-test included matching the numbers and letters given to the sides of a geometric shape, in open and closed forms. Finally, the items in the cube comparison sub-test were required to decide whether the cubes with different letters on the surfaces were the same, while the items in the card rotation sub-test aimed to make participants find the differences and similarities between the geometric shapes.

Delialioğlu and Aşkar (1999) calculated the reliability of the paper folding sub-test as .84; surface development sub-test as .82 at the surface formation size; cube comparison sub-test as .84 and .80 for the card rotation sub-test, in their study with high school students. On the other hand, Bayrak (2008) conducted with secondary school students, and calculated the reliability value for paper folding sub-test as .79; .74 for surface development sub-test; and .80 for the card rotation sub-test and .80 for the cube comparison sub-test. In this study, the calculated reliability values were .59 for paper folding size; .86 for surface development sub-test; .31 for the cube comparison sub-test; .96 for card rotation sub-test, and .95 for the whole test. The obtained values were high enough for the sub-tests other than the cube comparison, and it was estimated that the reliability of the cube comparison sub-test was low because the participants cannot answer all the items in the given time.

Data Analysis

The data collection tools were applied to a single group as pre-test and post-test. The Van Hiele Geometry Test, one of the data collection tools, with five multiple-choice items at each level and a total of 25 multiple-choice items in five levels. For this reason, 1 point was given for the correct answer that the participants answered in the test and 0 points were given for each wrong and empty answer. In this context, the highest score could be obtained from the test was 25 and the lowest score was 0. To determine the data analysis method, the distribution of the scores related to the pre-test and post-test applications was examined. In these distributions, skewness and kurtosis values were between 2 and -2 for both pre-test and post-test, and Shapiro-Wilk values for normality tests were not statistically significant ($p_{pre\text{-}test} = 0.21 > 0.05$; $p_{post\text{-}test} = 0.80 > 0.05$). In other words, since the sample showed similar characteristics with the population, the paired samples t-test of parametric methods was used to determine whether there was a significant difference between the pre-test and post-test mean scores.

Another data total tool, Spatial Ability Test, consists of four sub-tests and a total of 282 items. Some of the items were multiple choice and some of them are short answers. In the surface development subtest, which requires short answers, the participants who wrote the correct letter were given 1 point for this part and 0 points for the students who gave the wrong answer and left blank. The lowest score that can be obtained from the whole test was 0 and the highest score was 282. To analyse the data obtained within the scope of the research, firstly the distribution of points related to the applications was examined again. As a result, it was observed that the skewness and kurtosis values for pre-test and post-test applications were in the range of 2 and -2, and Shapiro-Wilk values related to normality tests were not statistically significant ($p_{pre\text{-}test} = 0.09 > 0.05$; $p_{post\text{-}test} = 0.52 > 0.05$). That's why the paired samples t-test of parametric methods was used to determine whether there was a significant difference between the pre-test and post-test mean scores.

Research Ethics

Since the present study is an experimental study, various precautions had to be taken to protect the participants. Within the scope of the study, the necessary permissions were obtained in three stages. In the first stage, the author, who worked at the university in the province where the study was conducted, received approval for the study from the human research ethics committee of the relevant university. With the approval from the university, the researchers obtained the necessary permissions from the provincial directorate of national education in the province where the study would be conducted. Finally, necessary permissions were obtained from the parents' of students who participated in the study with the parent consent form. Dates and numbers of ethics committee permissions are given at the end of the article.

FINDINGS

The pre-test and post-test scores obtained in the study, which examined the effect of geometry instruction enriched with various activities on the Van Hiele Geometric Thinking Levels and spatial abilities of the students, were examined. With the parametric tests applied, it was determined whether there was a significant difference between the mean scores of the Van Hiele Geometry Test and Spatial Ability Test pre-test and post-test scores. To determine this difference, paired samples t-test was applied between pre-test and post-test. Results were shown in Table 2.

Table 2. Paired-Samples T-Test Results of Van Hiele Geometry Test

Test		n	$\bar{X}$	sd	t	p
Van Hiele Geometric Thinking Test	Pre-test	22	8.14	2.731	-.407	.688
	Post-test	22	8.36	2.381		

As seen in Table 2, according to the results of the analysis, it was determined that there was no significant difference between the pre-test and post-test mean scores in the scores obtained from the Van Hiele Geometry Test. (pre-test = 8.14; post-test =8.36; p=0.68>0.05). However, when the number of students who answered the test items correctly is examined, it is seen that the number of students who answered correctly to 9 items decreased, the number of students who answered correctly to 10 items increased, and the number of students who answered correctly to 6 items did not change. While the highest decrease in the number of students responding to the items was 4, it was observed that the maximum increase was 6.

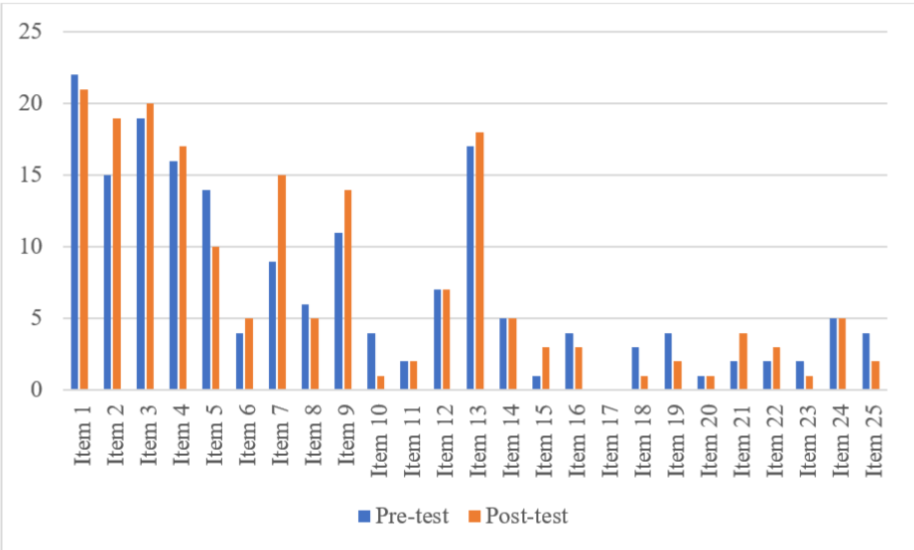
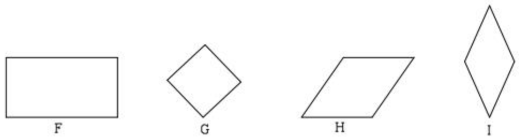


Figure 1. *The items in the Van Hiele Geometry Test and the number of students who answered these items correctly*

When Figure 1 is examined, the number of students who answered correctly to item 4 (Figure 2) decreased by 4, while the number of students who answered correctly to item 10 decreased by 3 students. The number of students who answered correctly to items 1,8,16,18,23 and 25 decreased by 1 or 2 students. It was determined that the majority of the items in which the number of students who answered correctly in the test decreased or did not differ, were in the last 15 items of the test. It is seen that these items are items for measuring the Informal Deduction Level (items 11-15), the Formal Logic Level (items 16-20), and the Systematic Thinking Level (items 21-25) from the Van Hiele Geometric Thinking Levels in the test. Item 4, which is the item with the highest decrease in the number of students who answered correctly, is presented in Figure 2.

4. Which of these are squares?



(A) None of these are squares.
(B) G only
(C) F and G only
(D) G and I only
(E) All are squares

Figure 2. *Van Hiele Geometry Test Item 4 - The item with the highest decline in the number of students who answered correctly*

If Figure 1 is examined again, the number of students who answered item 7 correctly increased by 6, while there was an increase of 4 students in item 2, and 3 students in item 9. The number of students who answered items 3, 4, 6, 13, 15, 21, and 22 correctly increased by 1 or 2 students. It was determined that the number of students who answered correctly in the test increased mainly in items 2,3,4,6,7, and 9. When the structure of the Van Hiele Geometry Test was examined, it was seen that these items were aimed at measuring the Visualization Level and the Descriptive Level from the Van Hiele Geometric Thinking Levels. Item 7, in which the highest increase in the number of students who gave correct answers was observed, is given in Figure 3.

7. In the rectangle GHJK, GJ and HK are the diagonals.

Which of the (A) – (D) is not true in every rectangle?

(A) There are four right angles.
(B) There are four sides
(C) The diagonals have the same length.
(D) The opposite sides have the same length.
(E) All of (A) – (D) are true in every rectangle.

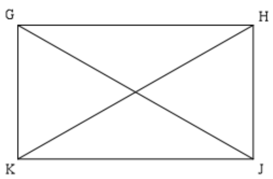


Figure 3. *Van Hiele Geometry Test Item 7 - The item with the highest increase in the number of students who answered correctly*

When the scores obtained from the Spatial Ability Test, which is another measurement tool in the study, were examined, it was determined that there was a significant difference between the pre-test and the post-test (pre-test = 119.41; post-test = 156.68; t =-5.511; p=0.00<0.05). Results were shown in Table 3. The mean of the scores obtained from the Spatial Ability Test increased by 37.27 points from the pre-test to the post-test. The eta squared value is 0.591, and it is seen that the effect is large.

Table 3. Paired-Samples T-Test Results of Spatial Ability Test

Test		n	$\bar{X}$	sd	t	p
Spatial Ability Test	Pre-test	22	119.41	25.367	-5.511	.000
	Post-test	22	156.68	31.087		

However, when the Spatial Ability Test is examined, it is seen that this test contains four separate subtests that include different tasks related to spatial ability. These subtests are the Paper Folding Test, the Surface Development Test, the Cube Comparison Test, and the Card Rotation Test, and the results of the scores obtained from the tests are given in the Table 4 below.

Table 4. Paired-Samples T-Test Results of Sub-Test of Spatial Ability Test

Test		n	$\bar{X}$	sd	t	p
the Paper Folding Test	Pre-test	22	5.91	1.998	-6.340	.000
	Post-test	22	8.73	2.815		
the Surface Development Test	Pre-test	22	17.45	5.974	-2.622	.016
	Post-test	22	21.64	8.894		
the Cube Comparison Test	Pre-test	22	18.09	4.105	-.128	.899
	Post-test	22	18.27	3.453		
the Card Rotation Test	Pre-test	22	77.95	22.967	-5.175	.000
	Post-test	22	108.05	25.417		

According to Table 4, it was determined that there were significant differences in favor of the post-test scores between the pre-test and post-test scores of the Paper Folding Test ($\bar{X}_{\text{pre-test}} = 5.91$; $\bar{X}_{\text{post-test}} = 8.73$; $t=-6.340$; $p=0.00<0.05$), the Surface Development Test ($\bar{X}_{\text{pre-test}} = 17.45$; $\bar{X}_{\text{post-test}} = 21.64$; $t=-2.622$; $p=0.016<0.05$), and the Card Rotation test ($\bar{X}_{\text{pre-test}} = 77.95$; $\bar{X}_{\text{post-test}} = 108.05$; $t=-5.175$; $p=0.00<0.05$). The eta square values of the differences obtained in the aforementioned subtests were .656, .246 and .560, respectively, and it was determined that the effect was large. However, when the scores obtained from the Cube Comparison Test were examined, it was determined that there was no significant difference between the pre-test and post-test scores ($\bar{X}_{\text{pre-test}}= 18.09$; $\bar{X}_{\text{post-test}} = 18.27$; $t =-.128$, $p=.899>0.05$).

In all the items in the Paper Folding Test, which has a significant increase in the scores of the students, it is requested that a square-shaped paper be folded and punched from one point and then the position of the holes formed on the paper when opened. According to the findings, when the correct answers to the items in this subtest were examined, it was observed that there was an increase in favor of the post-test for each item. It was determined that item 10 had the highest increase with 10 students who answered correctly (Figure 4).

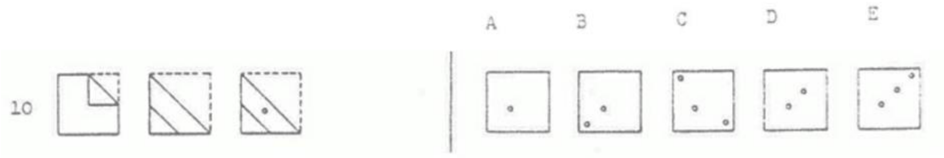


Figure 4. *Paper folding test item 10*

The items in the Surface Development Test, which significantly increased the scores of the students, include the open and closed view of an object. It is expected that the numbers given to the sides in the open view of the object and the letters given in the closed view are correctly matched. In this test, 12 objects were given, and it was asked to match the specified edges on the open and closed views of the 5 edges determined in each of these objects. When the items in this test were examined, it was determined that the highest increase in the number of students who gave correct answers was item 6. This item is given below.

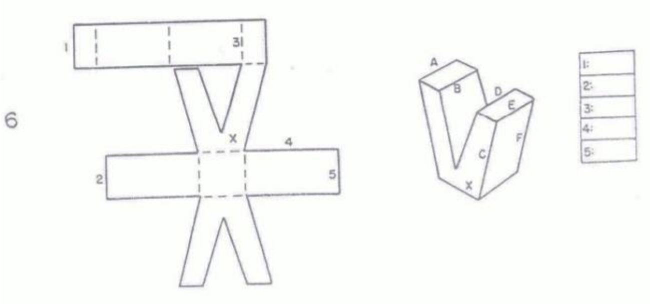


Figure 5. *Surface development test item 6*

Finally, there was a significant increase in the scores obtained from the Card Rotation Test. In this subtest, a figure is given, and it is expected to compare the eight figures to the left of this figure and to determine the figures that are the same as the given figure. While the rotated form of the figure is considered the same, its symmetrical form is not considered the same. In this test, 20 shapes were given, and they were asked to be compared with 8 shapes next to each of these 20 shapes. The answers given by the students were examined and it was determined that the highest increase in the number of students who gave correct answers was in item 17. The item with the increase is given below.

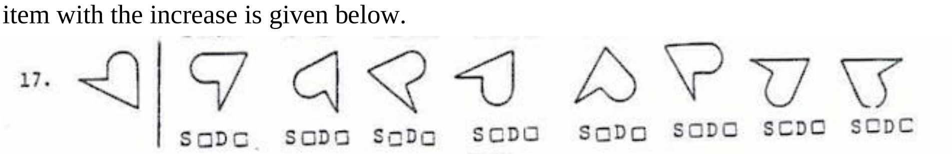


Figure 6. *Card Rotation Test Item 17*

The only subtest in which there was no significant increase in students' scores is the Cube Comparison Test. In this subtest, it is expected to determine whether a pair of cubes with letters, numbers or figures can be the same as each other. In the test, 42 pairs of cubes with three visible sides are given and it is necessary to determine whether each of these pairs is the same. Although there is no statistically significant difference between the pre-test and post-test, when the answers of the students are examined, it was observed that the highest increase in the number of students who gave correct answers was experienced in item 18 and the highest decrease in item 5. These items can be seen below.

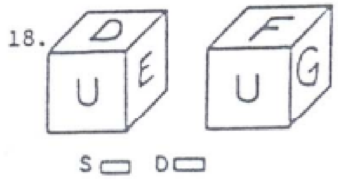


Figure 7. *Cube Comparison Test Item 18*

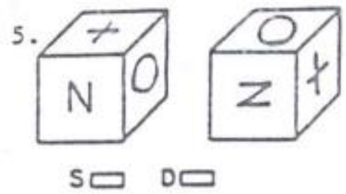


Figure 8. *Cube Comparison Test Item 5*

DISCUSSION & CONCLUSION

In this study, we investigated how geometry instruction, enriched with various activities that provide strong support had an impact on students' Van Hiele Geometric Thinking Levels and spatial abilities. According to the findings of the study, there was no statistically significant difference between the pre-test and post-test results of students' Van Hiele Geometric Thinking Levels. On the other hand, there is a positive and statistically significant difference in favor of the post-test results of students' spatial abilities. In line with these results, it can be said that geometry instruction, which includes various activities given to the students between the pre-test and the post-test, contributes to the spatial abilities of the students.

Although there was no statistically significant increase in the scores of the students in the Van Hiele Geometry Test, it is seen that the increase in the correct answers of the students in the test was mostly in the first 10 items. In the test, the first five items (items 1-5) are related to the visual level and the next five items (items 6-10) are related to the descriptive level, which is the second level. Van de Walle (2013) stated that students at the visual level should have experiences with shapes in order to change and develop their perceptions, and therefore, students should play with objects in geometric shapes and make observations. It is thought that simulating geometric shapes with directions such as "What geometric shape does this shape we have created resembles that we know?", "Which geometric shapes do you think this product contains?" on the products created in the origami activity during the application process and making comments on the products may have contributed to the students' correct answers to the questions about the visual level in the test.

At the descriptive level, it is stated that activities such as working on elements such as edges, angles, and diagonals, distorting shapes and creating shapes from pieces should be presented so that students can realize the properties of shapes (Duatepe-Paksu, 2016). It is thought that the discussion on polygons and the properties of polygons with GeoGebra and geometric construction activities, and the discussion of the edge and angle elements in the drawing of a geometric figure in the coding activity done with Small Basic software may have contributed to the students' level of noticing the properties of shapes and contributed to giving correct answers to the questions on the descriptive level. Duatepe-Paksu (2016) states that learners may appear at a certain level of geometric thinking with memorized expressions but may not have this thought. In this sense, besides the increase in correct answers to the questions about measuring the visual level and the descriptive level, it is thought that learners can actually provide the features required by that level with the experiences gained as a result of differentiated activities. Moreover, since the levels are sequential, the learner will belong to the level of geometric thinking s/he is said to be in and will be able to fulfill her requirements and then have the necessary infrastructure to move on to the next level.

On the other hand, it can be said that the reason for the lack of a significant increase in the Van Hiele Geometric Thinking Levels of the students is that the activity process is as short as five days. Van Hiele (1986) states that progress between levels depends on teaching and geometric experience. Although the geometric experiences presented in the study vary, giving each activity in a limited time of 150 minutes may not be enough to increase the Van Hiele Geometric Thinking Levels of the students. Considering that most of the participants of the study were at the descriptive level at the beginning and end of the study, students need to gain experience to progress at their current level and reach the next level, which is the informal deduction level. The amount of experience gained in this limited time can be characterized as not allowing the establishment of the relationship and hierarchy between the shape classes, which are the requirements of the informal deduction level.

When the effect of the activities within the scope of the study on the spatial ability of the students was examined, a statistically significant difference emerged in favor of the post-test both in the general Spatial Ability Test and in the subtests of the Paper Folding Test, Surface Development Test, and Card Rotation Test. The Paper Folding Test measures spatial visualization, which is one of the sub-components of spatial ability. The increase in the scores of the students in this subtest in the post-test can be associated with the activities carried out during the implementation phase of the study. It is thought that the content of the origami activity in the study contributes to the students by providing experiences in folding and unfolding paper, in terms of including tasks such as unfolding, following the steps, and observing the results. Considering McGee's (1979) definition of visualization as manipulating, rotating, folding, and unfolding a visually given object in the mind, it can be said that the activity provides the experience of the unfolding process and the development of spatial ability by presenting visual pictures that can be stored in the mind. In addition, it is thought that performing step-by-step operations and seeing the results with the coding activity in which the Small Basic software used in the study helps the students to follow the steps in the Paper Folding Test, imagine the result of each step and continue the next step. This has contributed to the development of spatial ability with the same effect as origami activity.

If we look at the Surface Development Test, which is a significant difference in favor of the post-test in the scores the students received, it is necessary to determine the edges of the 3-dimensional shape that is given open and closed appearance in the test. In order to fulfill this requirement, students should use their spatial orientation skills, which include thinking about the position of their parts relative to each other and the order they create. With the “GeoCadabra®” and “SketchUp®” activities, the students experienced the appearance and construction of geometric structures from different aspects, examined the structure and properties of the shapes, and interpreted the reflections of the changes on the shapes. The students experienced focusing on the key features of the shapes through their experiences in these activities (Gluck & Fitting, 2003; Hsi, Linn & Bell, 1997; Kayhan, 2012; Schultz, 1991; Zeybek, 2016). Geometric experiences and strategies obtained by the students through the activities mentioned may have contributed to the spatial orientation abilities of the students, resulting in higher scores in the post-test.

There was also a significant increase in the scores obtained from the Card Rotation Test, which is among the subtests. This test aims to measure the spatial visualization sub-component of spatial ability and requires visualization of the object as a result of rotational movement (Eme & Marquer, 1999). One of the objectives of the study in the implementation process was for the students to experience the results of the rotation operations performed on 2D shapes in the GeoGebra activity. In the coding activity, in which Small Basic software was used, the students were provided to examine concepts such as rotation, rotation reference, rotation angle, and the image formed as a result of rotation. In these activities, the students had the opportunity to see the result of the rotation process and to examine the effects of the actions on the shape. Moreover, through these activities, they have gained the experience of rotating the whole and a certain part of the shape. When the literature is examined, rotating the whole and rotating the part are two of the spatial strategies that help to perform actions that require spatial ability (Eme & Marquer, 1999; Gluck & Fitting, 2003; Zeybek, 2016). It can be said that the activities carried out both provide visual pictures/experiences related to rotation and provide these strategies to the students, thus contributing to the development of their spatial abilities.

Considering all the results of the study, it can be concluded that both geometric thinking and spatial ability contribute to the geometric experiences presented to the students through activities. It is thought that the geometrical experiences of individuals are of great importance, especially in the development of spatial ability. It has been determined by the studies in the literature that the geometric experiences gained through both concrete materials and information and communication technologies contribute to the spatial abilities of the people (Battista, 2007; Boakes, 2009 Clements, 2003; Clements & Battista, 1992; Kösa, 2011; Lioa, Yu, & Wu, 2015; Turğut, 2010). In this context, the results of this research are parallel to the literature.

Implications

The current study, which focuses on strong support, examined the presentation of differentiated geometry activities to students located in a disadvantaged region through the students' Van Hiele Geometric Thinking Levels and spatial abilities. A partial but potential effect on Van Hiele Geometric Thinking Levels and a strong positive effect on spatial ability were obtained. For this reason, it can be said that presenting differentiated geometry activities to each student in every learning environment is necessary for geometry learning. As the literature indicates, activities should be shaped around today's needs and student interest, which include technology and materials. For this reason, it is recommended that teachers use information and communication technology tools that support visualization such as GeoGebra, Cabri3D, GeoCadabra, and SketchUp during geometry instruction, include creative drama, story writing, and educational game techniques that will increase learners' motivation and participation in their activities, and associate algorithm and coding with geometry. However, if it is considered that not all teachers have a sufficient level of knowledge in the integration of these tools and techniques into instruction, training/seminars/courses on these subjects should be offered to in-service teachers.

For pre-service teachers, the necessary information and teaching activities should be presented about Van Hiele Geometric Thinking Levels and spatial ability in the "Geometry and Measurement Teaching" course in the undergraduate curriculum called "Primary Education Mathematics Teaching Undergraduate Program" of the Council of Higher Education. In addition to the compulsory "Algorithm and Programming" and "Instructional Technologies" courses in the undergraduate curriculum, it should be ensured that the necessary knowledge and skills are acquired for the design of different activities with elective courses such as “Drama in Education”, “Computer Assisted Mathematics Education”, “Activity Development in Teaching Mathematics”, “Material Design in Teaching Mathematics”, and “Teaching Mathematics with Games”. Finally, it is recommended that middle school students be offered geometry experiences in lessons such as "Mathematics Applications" and "Mental Games" lessons, as well as differentiated geometry activities in mathematics lessons.

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Statements of publication ethics

The ethics committee permission information obtained for the conduct of this study is as follows:

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Researchers’ contribution rate

While the first of the researchers contributes to the formation of the theoretical structure, data collection, interpretation and discussion of the findings, the second researcher contributes to the collection, analysis and interpretation of the data.

Conflict of interest

The authors declare that there is no conflict of interest.

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