The Effects of Dynamic Geometry Software and Physical Manipulatives on Pre-Service Primary Teachers' Van Hiele Levels and Spatial Abilities

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Abstract: The purpose of the study was to compare the influence of dynamic geometry software activities and influence of the physical manipulatives and drawing activities on the spatial ability and van Hiele levels of pre-service primary school teachers in a geometry course. A quasi-experimental statistical design was used in the study. The participants were 61 pre-service primary teachers in the second year of their undergraduate program in the Department of Elementary Education at Afyon Kocatepe University. A total of 32 pre-service teachers (computer group) were trained in the dynamic geometry based activities and 29 pre-service teachers (physical-drawing group) were trained in the physical manipulative and drawing based activities. In order to determine the two groups of the pre-service teachers' geometric thinking levels, the van Hiele Geometry Test and in order to determine the two groups of the pre-service teachers' spatial ability, The Purdue Spatial Visualization Test was used as the pre-test and post-test. The results of the study showed that there was no difference on the post-test of the two groups related to the van Hiele levels and spatial abilities. Moreover, both groups have significantly higher achievement on the post-test compared to the pre-test.

Keywords: van Hiele levels, spatial abilities, pre-service teacher

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1. Introduction

Many studies state that many students at all levels have misconceptions about geometric concepts (e.g. Burger & Shaughnessy, 1986; Erşen & Karakuş, 2013; Marchis, 2012; Pickreign, 2007). The reasons for this may be dense geometry teaching programs (Toluk, 2005), teaching methods used in teaching geometry (Lim & Hwa, 2007), teachers ignoring spatial relations (Olkun & Aydoğdu, 2003) and ineffective textbooks (Hershkowitz, 1987). To solve these problems, researchers focused on students' thinking in geometry and the learning process in geometry (Pegg & Davey, 1998). In this context, van Hiele geometry thinking levels is one of the most popular theorical frameworks to understand students' learning process. The most important characteristic of the van Hiele model is that it divides the ways of understanding spatial visualization into five hierarchical levels (see Table 1) which are visualization, analysis, informal deduction, deduction and rigor (van de Walle, Karp & Bay-Williams, 2007).

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Table 1. van Hiele levels of geometric understanding

Levels	Characteristics
Level 1 (Visualisation)	Students recognize figures by their appearance. They make decision based on intuition not reasoning.
Level 2 (Analysis)	Students recognize figures by their properties. They can analyze and name properties of figures, but they cannot make relationships between these properties.
Level 3 (Informal deduction)	Students can distinguish between necessary and sufficient conditions for a concept. They can form meaningful definitions and give informal arguments to justify their reasoning.
Level 4 (Deduction)	Students can contruct theorems within an axiomatic system. They know the meaning of necessary and sufficient conditions of a theorem.
Level 5 (Rigor)	Students understand the relationship between various systems of geometry. They can compare, analyze and create proofs under different geometric systems

Each of these five levels explains thinking processes used in geometry. The levels describe the different geometric thinking types and how to consider them, rather than how much knowledge should be obtained. Clements and Battista (1990) also recommend the existence of level 0 which they call pre-cognition. In this level, students initially perceive geometric shapes, but have an inability to distinguish between figures. For example students may recognize the difference between triangles and rectangles, but may not be able to distinguish between a rhombus and a square. The van Hiele levels were originally defined from 0 to 4. Yet, studies (e.g. Burger & Shaughnessy, 1986; Duatepe, 2000; Halat, 2007, Tutak, 2008) have been changed to the levels from 1 to 5. This scheme allows the researchers to use pre-cognition level for students who cannot be assigned in the visual level that is the first of the van Hiele levels. So, in this study the 1-5 scheme was used for the levels. The main aim of the van Hiele method is to improve students' geometric thinking between levels by arranging learning environment according to their levels (Pegg & Davey, 1998; van de Walle et al., 2007). In the van Hiele theory, students' movement among thinking levels depends on their education rather than their age or their biological maturity (Crowley, 1987). In suitable learning environments, students can move from one van Hiele level to another.

The usefulness of the van Hiele model to describe students' geometric thinking is shown in many studies (Clements & Battista, 1992; Halat, 2007). Studies can be classified in four groups: the effects of textbook, the effects of concrete materials and manipulatives, the effects of computer software and the effects of different teaching methods.

According to the results of the studies (e.g. Fuys, Geddes & Tischler, 1988; Soon, 1989), focusing on the effects of textbooks on students' van Hiele levels, textbooks do not support students' higher level thinking and generally include activities for level 1 and level

2. However, Halat (2007) states that textbooks designed according to van Hiele levels are effective in improving the students' geometric thinking levels.

Studies examining concrete materials and manipulatives show that using these materials in teaching geometry increases students' geometric thinking levels (e.g. Mistretta, 1996; Siew & Abdullah, 2013; Siew, Chang & Abdullah, 2013). For example, Mistretta (1996) developed a supplementary geometry unit to improve 8th grade students' geometric thinking. In this unit, he claimed that, at the end of the teaching activity with concrete material and hands on activity, students' van Hiele levels improved. Similarly, Siew and Abdullah (2013) stated that at the end of the lesson in which tangram activities were used, university students' van Hiele levels improved. Similarly, Siew, Chang and Abdullah (2013) concluded that teaching with tangrams in primary schools improved van Hiele scores, especially with low ability students. However, Corley (1991) notes that traditional teaching environments are also effective to improve students' van Hiele levels.

In studies examining the effects of computer softwares on students van Hiele levels (e.g. Abdullah & Zakaria, 2013; Bell, 1998; Breen, 1999; Clements & Battista, 1990; Hoyles & Noss, 1994; Kutluca, 2013; Tutak & Birgin, 2008; Tutak, 2008) was confirmed that using these types of software in geometry teaching has a positive effect on developing students' van Hiele levels. For example, Clements and Battista (1990) claimed that teaching geometry to 4th grade students with using Logo software improved students' van Hiele levels. Similarly, Breen (1999) found that computer-based geometry teaching in 8th grade has positive effects on students' van Hiele geometry understanding levels and understanding of geometric concepts. Morever, Kutluca (2013) determined that activities in which Geogebra dynamic geometry software is used are more effective for 11th grade van Hiele thinking levels compared to traditional teaching methods. Tutak (2008) examined the effects of both concrete materials and dynamic geometry software on students' van Hiele levels in 4th grade and found that both of them have positive effects, but teaching with concrete material is more effective. On the other hand, some studies (e.g. Smyser, 1994) claim that using computer software in teaching has no effect on developing students' van Hiele levels.

Apart from these studies, there are some other studies examining the effects of using different methods on students' van Hiele levels. Duatepe (2004) found that using drama-based geometry teaching in 7th grades is more effective than traditional teaching on students' van Hiele geometry levels. Studies using different material or methods, mainly aimed to describe the effect of only one material. However, there are a few studies (e.g. Tutak, 2008) in which a few different materials or methods are used together in order to compare their effects. These studies mainly focus on activities for primary and secondary school levels (i.e. for lower van Hiele levels). In this context, there is a need to investigate the effect of dynamic geometry software and concrete materials on van Hiele levels in teacher education.

On the other hand, the spatial ability is another important concept to understand the students' geometric thinking and learning process. NCTM (2000) noted that in geometric thinking, spatial ability is important and includes 2D and 3D objects' mental representation and manipulation with the perception of different perspectives of the objects. Spatial ability is assumed as one of the most important components of mental ability (Linn & Petersen, 1985). Although, there is no consensus on the definition of spatial ability, many studies (e.g. Clements, 1998; Del Grande, 1990; Linn & Petersen, 1985; Maccoby & Jacklin, 1974; McGee, 1979) showed different components of it.

Studies agree that spatial ability is defined as the abilities related to the use of space (Linn & Petersen, 1985; Olkun, 2003). Moreover, research has shown that general spatial ability can be thought of as being composed of two primary factors: spatial relations and spatial visualization. Olkun (2003) defined spatial relations as "imagining the rotations of 2D and 3D objects as a whole body (p.2)" and defined spatial visualization as "imagining the rotations of objects and their parts in 3D space in a holistic as well piece by piece fashion (p.2)".

Spatial ability is closely related to teaching many subjects in mathematics and geometry (Hoffer, 1981; Kurtuluş, 2013). A positive relationship between success in mathematics/geometry and spatial ability is often emphasized (e.g. Battista, 1980; Battista, 1994; Fennema & Sherman, 1977; Guay & McDaniel, 1977; Gunderson, Ramirez, G., Beilock & Levine, 2012; Kayhan, 2005). Moreover, spatial abilities are also related to mathematical problem solving (e.g. Grattoni, 2007; Markey, 2009; Tartre, 1990; Van Garderen & Montague, 2003).

Although there are some studies that ask whether spatial ability and spatial visualization can be improved with teaching (e.g. Hoong & Khoh, 2003) or not most studies showed significant change in students' spatial abilities by using different instruction methods and materials (Akasah & Alias, 2010; Arici & Aslan-Tutak, 2013; Baki, Kösa & Güven, 2011; Chaim, Lappan & Houang, 1988; Çakmak, 2009; Erkoç, Gecü & Erkoç, 2013; Güven & Kösa, 2008; Kayhan, 2005; Kurtuluş, 2013; Olkun, 2003; Risma, Putri & Hartono, 2013; Toptaş, Çelik & Karaca, 2012; Yıldız 2009; Yolcu & Kurtuluş, 2010; Yurt & Sünbül, 2012). However, Boakes (2009) found that there is no significant effect of instruction on spatial ability. We can classify these studies in three groups: (i) studies examining only the effects of computer-based activities, (ii) the effects of physical manipulatives, and (iii) the effects of both computer-based and physical manipulative activities.

Among the studies in the first group, Güven and Kösa (2008) showed that a geometry teaching environment prepared with the dynamic geometry software Cabri 3D improved pre-service teachers' spatial ability. Toptaş et al. (2012) determined that the 3D modeling program GoogleSketchup has a positive effect on 8th grade students' spatial ability. Similarly, Erkoç et al. (2013) examined the effect of the GoogleSketchup program on 8th grade students' mental rotation skills. The group in which GoogleSketchup was used had higher test scores compare to the control group, but there was no statistically significant difference. In addition, Kurtulus (2013) examined the effect of using 3D web-based interactive virtual environment on pre-service teachers' spatial skills. He used Purdue

Spatial Visualisation test for determining pre-service teachers' spatial skills. The best development was seen in the developments section, the second highest development was seen in the rotation section and the least development was seen in the views section.

Among the studies in the second group, examing the use of concrete materials, Chaim et al. (1988) studied the effect of a geometry unit designed with concrete activities, building and drawing solids made of cubes on students' spatial visualization from 5th grade to 8th grade. According to the results, at first there was a meaningful difference between girls' and boys' spatial visualization. At the end of teaching, students' spatial ability changed positively and, despite gender differences, girls and boys had similar gains. Akasah and Alias (2010) claimed that engineering drawing studies improved spatial skills. Similarly Olkun (2003) also stated that spatial ability can be improved with engineering drawing activities. Risma et al. (2013) examined the effect of building block activities on 3rd grade students' spatial visualization, and concluded that these kinds of activities improve students' spatial visualization. Arıcı and Aslan-Tutak (2015) claim that origami based geometry instruction has statistically significant effect on 10th grade students' spatial visualization.

Finally, among the studies examining the effects of both computer-based programs and concrete materials, Yıldız (2009) found that a 3-D computer program and concrete manipulatives improved 5th grade students' spatial visualization and mental rotation skills. Yolcu and Kurtuluş (2010) designed a teaching program using both unit cubes and a web site. The program aimed to help students form 3D shapes. According to the results, both have positive effects on students' spatial ability. Baki et al. (2011) compared the effects of dynamic geometry programs and the use of physical manipulatives on students' spatial ability. According to the results, using physical manipulatives and computer based-learning is more effective on spatial ability than traditional methods. Similarly, Yurt and Sünbül (2012) examined the effect of an environment in which virtual objects and concrete objects are used on 6th grade students' spatial thinking and mental rotation skills. According to the results, students studying with concrete objects had the highest score. Students studying in virtual learning environments had the second highest score. The lowest scores belonged to the students following only the teaching program. Moreover, students studying in virtual learning environments had the highest scores in mental rotation skills. Studies comparing the effects of using more than one material (both computer program and concrete material) are seen mostly in primary school and there are a few studies for upper grades. In this context, there is a need to investigate the effect of using computer-based and physical-drawing based instructions on spatial ability in teacher education.

Gutierrez (1992) claims that the van Hiele model of thinking can be used to understand the 3D geometry learning process and analyze whether there is a relation between students' van Hiele geometry thinking levels and spatial abilities. In the literature a few studies (e.g. Karrass, 2012; Naraine, 1989; Smyser, 1994) showed the relationship between van Hiele levels and spatial ability. Naraine (1989) states that van Hiele levels were significantly correlated with spatial visualization ability. According to the results, the higher-level van Hiele had better spatial visualization ability than the lower-level van Hiele levels. Similarly, Karrass (2012) found a positive relationship between pre-service high school teachers' spatial abilities and their van Hiele levels, but she also stated that the results had lower reliability because the sample was narrow. However, Smyser (1994) did not find any relationship between van Hiele level and spatial visualization. In these three studies with different results, it is clear that the relationship between spatial ability and van Hiele level is still open for discussion.

The purpose and research problems of the study

The purpose of the study was to compare the influence of dynamic geometry software (DGS) based instruction and influence of the physical manipulatives and drawing activities on the spatial ability and van Hiele levels of pre-service primary school teachers in a geometry course. The following research questions were addressed:

1. What differences exist between pre-service teachers instructed with DGS-based activities and pre-service teachers instructed with physical manipulatives and drawing activities in reference to the van Hiele levels in geometry?
2. What differences exist between pre-service teachers instructed with DGS-based activities and pre-service teachers instructed with physical manipulatives and drawing activities in reference to gains in spatial ability?
3. What relationship exists between the van Hiele levels and the spatial ability of the groups?

2. Method

A quasi-experimental statistical design was used in the study. The researchers employed a control group to compare with the experimental group, but participants were not randomly selected or assigned to the groups (Cohen, Manion & Morrison, 2007; Creswell, 2012). In this study, while the experimental group included students who were instructed with DGS-based activities, the control group was comprised of students who were instructed with physical manipulatives and drawing activities. The researchers chose the experimental research method because it allows researchers to establish possible cause and effect between their independent and dependent variables (Creswell, 2012). The researchers investigated the influences of doing both DGS-based activities and physical manipulatives and drawing activities on the pre-service teachers' levels in geometry and spatial ability. Moreover, the relationship between students' van Hiele levels and spatial ability was investigated in the study. Therefore, this experimental approach enabled the researchers to evaluate the effectiveness and relationship of both DGS-based instruction and physical manipulative and drawing-based instruction in a geometry course.

2.1. Sample of Research

The participants were 61 pre-service primary teachers in the second year of their undergraduate program in the Department of Elementary Education at Afyon Kocatepe University. Each participant had already been assigned to one of two classes by the university. All participants took the geometry course during the 2012-2013 academic years. Each of the two classes was assigned at random to one of the two treatments. A total of 32 pre-service teachers (20 girls and 12 boys) comprised the DGS-based instruction group (computer group) and 29 pre-service teachers (16 girls and 13 boys) comprised the physical manipulative and drawing activity based instruction group (physical-drawing group).

2.2. Instruments

Van Hiele Geometry Test (VHGT)

In order to determine pre-service teachers' geometric thinking levels, the van Hiele Geometry Test (VHGT) was administered to the pre-service teachers as the pre-test and post-test during a single class period. The test consists of 25-multiple choice questions representing five van Hiele levels, developed by Usiskin (1982). In the test, the first five items represent level 1; the second five items represent level 2 and so on for all five levels. This test was translated into Turkish by Duatepe (2000) and in this study, Cronbach Aplha reliability measures were found as .82, .51, .70, .72, .59, for each section of test, respectively.

The questions in the first level were related to identifying triangles, rectangles, squares and parallelograms. In this level, figures were judged by their appearance. The questions in the second level analyzed figures (such as squares, rectangles, rhombuses, isosceles triangles and circles) in terms of their components and relationships. The questions in the third level included logically ordering properties of figures, and understanding relationship between squares, rectangles and parallelograms. The questions in the fourth level were related to the significance of deduction and the roles of postulates, theorems and proof. The questions in the fifth level were about understanding non-euclidean geometry, a necessity component of making abstract deductions.

Purdue Spatial Visualization Test (PSVT)

The Purdue Spatial Visualization Test (PSVT) was used as the pre-test and post-test. This test was developed by Guay (1977) with three subscales: developments, rotations and views. Each subscale has 12 multiple-choice questions. A description of each subscale of the test is presented below.

Developments

The questions in this section were designed to describe how students visualize the folding of developments into three dimensional objects. Students were asked to choose the correct answer from five possible shapes. A sample item from this subscale is given in Figure 1.

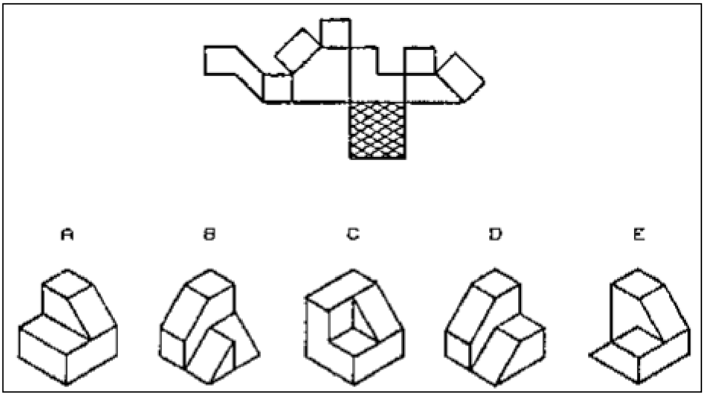

Figure 1. A sample item of Development Part

Rotations

The questions in this section are designed to see how students can visualize the rotation of three-dimensional objects. In each question there is an object in two different positions. The object on the left shows the starting position and same object on the right has been rotated on the X, Y and Z axes. Students were first asked to find the pattern of rotation and then to select the representation of the object whose position represents the next rotation in the pattern. A sample item from this subscale is given in Figure 2.

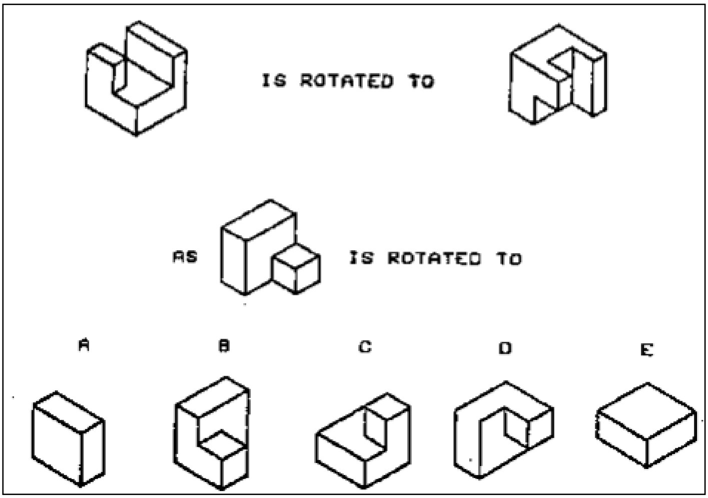

Figure 2. A sample of Rotations Part

Views

The questions in this section are designed to describe how students can visualize how three-dimensional objects look from various viewing positions. An object is placed in the middle of a transparent cube and one of the corners of the cube is marked by a black dot. Students are asked to imagine themselves moving around the cube until the black dot is located directly between them and object and guess in their mind how the object in the cube will look. A sample item from this subscale is given in Figure 3.

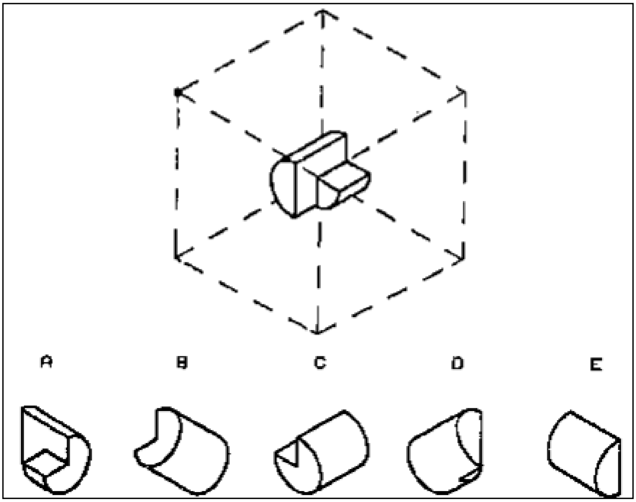

Figure 3. A sample of Views Part

The PSVT has been shown to be a valid and reliable instrument. Guay (1980) used the PSVT test with 217 high school students, 51 skilled machinists, and 101 university students and reported an internal consistency coefficient of 0.87; 0.89 and 0.92, respectively. Sevimli (2009) used PSVT on 110 pre-service teachers and found internal consistency coefficients of 0.91 for developments; 0.77 for rotations; 0.85 for views and 0.84 for the entire test. This test was used in many other studies (e.g. Sevimli, 2009; Baki et al., 2011; Kurtuluş, 2013) examining spatial skills.

2.3. Procedure

Treatment of the Computer Group

At the beginning of the study, the pre-service teachers were administered the VHGT and PSVT tests as the pre-test. Before the treatment, pre-service teachers in the computer group were trained on how to use GeoGebra and Cabri 3D software as the programs were new for them. Pre-service teachers learned the functions of the menu such as how to draw a line or a segment, how to drag and construct bisectors, and how to measure lengths, areas and angles for GeoGebra, and how to draw points, lines, planes or spheres, how to construct prism, cylinders, and cones and how to rotate or open-close them for Cabri 3D software. The pre-service teachers spent four class hours (two of them for GeoGebra and others for Cabri 3D) learning both GeoGebra and Cabri 3D software. During this four hour period, no application within the scope of the course content was made with the pre-service teachers. The pre-service teachers in this group used the features of GeoGebra and Cabri 3D software to study the worksheets. They first used the GeoGebra software 2 hours a week for six weeks and then used Cabri 3D 2 hours a week for six weeks. The content of the course is presented in Table 2.

Table 2. Contents of the course

Week	Course Content
1 st week	Angle measures and inequalities in a triangle
2 nd week	Bisectors, medians and altitudes of a triangle
3 rd week	Perimeter and area of a triangle
4 th week	Angle measures in polygons
5 th week	Properties of polygons
6 th week	Free exercises
7 th week	Points, lines and planes in space and relations among them according to each other
8 th week	Properties of prisms and open and closed status of it
9 th week	Properties of pyramids and open and closed status of it
10 th week	Cylinders and cones
11 th week	Properties of sphere
12 th week	Free exercises

During the course, the teacher's role was not an authority and source of the knowledge. Pre-service teachers studied DGS environment, constructed the structure, explored the relations and wrote the obtained results in the related places on the worksheets. The course was carried out in the computer laboratory and a computer was given to each two pre-service teachers. In this process, the teacher had a role like a maestro and organized the classroom discussions in the line of the obtained results. Two examples of the worksheets for the computer group are in Appendix A and Appendix B.

Treatment of the Physical-drawings Group

The physical-drawing groups' activities were parallel to the computer groups' activities, but pre-service teachers in the physical-drawing group used drawing and concrete materials while doing activities. Two examples of the worksheets for the physical-drawing group are in Appendix C and Appendix D. Both computer group and physical-drawing group, courses were given by the same teacher. During the course, direct information was not given by the teacher. Pre-service teachers studied physical manipulatives and drawing activities, constructed the structure, explored the relations and wrote the obtained results in the related places on the worksheets. The teacher's role was to guide the instruction process and results were discussed at the end of the course as a whole class discussion. The teacher was qualified to use both DGS software and physical and drawing activities as he had relevant courses in his education.

2.4. Data analysis

The van Hiele geometry thinking test (VHGT) consists of 25 multiple choice questions. For every correct answer, one point was given and for every wrong or blank answer, no point was given. All pre-service teachers' answer sheets from VHGT were read and scored independently by two researchers (both of the authors). All pre-service teachers received a score for each van Hiele level according to Usiskin's (1982) grading system. The criterion for success at any given level was four out of five correct responses. Usiskin's (1982) grading system was as follows:

- 1 point for meeting the criterion on items 1-5 (Level-1)
- 2 points for meeting the criterion on items 6-10 (Level-II)
- 4 points for meeting the criterion on items 11-15 (Level-III)
- 8 points for meeting the criterion on items 16-20 (Level-IV)
- 16 points for meeting the criterion on items 21-25 (Level-V)

To determine the normal distribution of the data, the coefficients of skewness and kurtosis were examined. The coefficient of skewness of PSVT was .383 and standard error of skewness was .360; the coefficient of kurtosis of PSVT was -.179 and standard error of kurtosis was .604. The coefficient of skewness of VHGT was .306 and standard error of skewness was .411; the coefficient of kurtosis of VHGT was.540 and standard error of kurtosis was .614. If the ratio of the coefficient of skewness (kurtosis) to the coefficient of the standard error of skewness (kurtosis) is staying between -1,96 and +1.96, the distribution of the data is considered normal (Can, 2014; Hinton, 2004). For that reason data was analyzed by using parametric tests.

When analyzing the data, the researchers first conducted the independent sample t-test statistical procedure with $\propto = .05$ on the pre-service teachers' VHGT pre-test scores to determine differences in terms of performance between the computer and physical-drawing groups. Then the post-test scores from the VHGT were compared using one-way analysis of covariance (ANCOVA) with $\propto = .05$. Finally, the paired sample t-test with $\propto = .05$ was used to determine the mean differences between pre-test and post-test scores of pre-service teachers in each group separately based on the VHGT.

On the PSVT, one point was given for every correct answer, and no point was given for every wrong or blank answer.The researchers conducted the independent sample t-test statistical procedure with $\propto = .05$ on the pre-service teachers' PSVT pre-test scores to determine any differences in terms of performance between the computer and physical-drawing groups. Then, the post-test scores from the PSVT were compared using one-way analysis of covariance (ANCOVA) with $\propto = .05$. Finally, the paired sample t-test with

$\propto = .05$ was used to determine the mean differences between pre-test and post-test scores of pre-service teachers in each group separately based on the PSVT.

In order to find the relationship between van Hiele levels and PSVT scores, Spearman's rank correlation was calculated and value of the correlation coefficient was evaluated as Cohen (1988) suggested.

The internal validity and external validity are very important in the experimental designs. Fraenkel, Wallen and Hyun (2012) define respectively internal and external validity as internal validity means that observed differences on the dependent variable are directly related to the independent variable, and not due to some other unintended variable and external validity means that the extent which results of a study can be generalized to the world at a large. In this study we tried to minimize the threats to internal and external validity as follows:

- To minimize the subject characterictics threat and maturation threat, we constituded a group of participants with similar characteristics such as age, ability, grade level, maturity. Moreover, in this group, we randomly assigned to experimental and control groups.
- The validity and reliability of the data collection instruments used in this study have been justified in many other studies. Moreover, we prepared instructions for using these instruments. Thus, we tried to minimize the instrument threat.
- To control the data collector threat, both experimental and computer groups, courses were given by the same teacher who is one of the researchers of this study. Furthermore, the data collection instuments were applied by the same teacher.
- The interaction between taking a pre-test and the treatment itself may effect the results of the experimental group. However, because of the implementation time is not too short, the interaction of the test threat was reduced.

3. Findings

1. *What differences exist between pre-service teachers instructed with DGS-based activities and pre-service teachers instructed with physical-drawing activities regarding the acquisition of the van Hiele levels in geometry?*

Table 3 presents the values of the mean and standard deviation of the scores of computer and physical-drawing groups obtained from the VHGT and the results of the independent t-test related to the VHGT.

Table 3. Descriptive statistics and independent t-test of the pre-service teachers' VHGT scores before the intervention

Groups	Computer group			Physical-drawing group					
Measures	N	Mean	SD	N	Mean	SD	df	t	p
VHGT pre-test scores	32	3.75	2.53	29	4.31	3.04	59	-.79	.44

As seen in Table 3, the results of the independent t-test showed no statistically significant difference in pre-test VHGT scores between the computer group (M=3.75, SD=2.53) and the physical-drawing group (M=4.31, SD=3.04) [t(59)=-.79, p>.05]. This shows that groups were at the same level in all concepts prior to implementation and thus exhibited comparable characteristics.

The pre-service teachers took the same VHGT test again, after the treatment. The descriptive statistics for the data obtained from the VHGT after the treatment is presented in Table 4.

Table 4. Descriptive statistics of pre-service teachers' VHGT scores after the intervention

Groups	Computer group			Physical-drawing group		
Measures	N	Mean	SD	N	Mean	SD
VHGT post-test scores	32	5.63	2.89	29	5.89	2.91

In order to determine if the differences in the averages of scores obtained from each group were statistically significant, a paired sample t-test was applied to the data obtained from the entire test at a significant level of 0.05. Table 5 summarizes the results of the paired sample t-test analysis for the pre- and post-test.

Table 5. Paired sample t-test results of pre- and post- test scores within groups

Groups	Computer group			Physical-drawing group		
Measures	df	t	p	df	t	p
	31	-3.35	.01	28	-2.61	.01

According to the results in Table 5, there is a significant difference in the pre-service teachers' van Hiele levels in the both computer group and physical-drawing group. Based on these statistical results, one would say that the activities of both the computer and physical-drawing groups have positive effects on the pre-service teachers' acquisition of the van Hiele levels in geometry. The eta squared statistic (.27 for VHGT of Computer Group and .20 for Physical-drawing group) indicated a large effect size.

In order to determine if there is any significant difference in the post-test VHGT scores for computer group and physical-drawing group, while controlling for their pre-test scores on this test, analysis of covariance (ANCOVA) was performed. Table 6 presents the results of ANCOVA related to the VHGT.

Table 6. Covariance analysis results of VHGT for groups

Measures	df	f	p
VH Post-test Scores	1	.01	.93

According to Table 6, there is no statistically significant difference in the gain scores of pre-service teachers in the computer group and physical-drawing group with respect to the van Hiele levels (F[1, 61]=.01, p= .93), where the van Hiele levels scores of the pre-test was used as covariate.

***2.** What differences exist between pre-service teachers instructed with DGS-based activities and pre-service teachers instructed with physical-drawing activities regarding spatial abilities?*

Table 7 presents the values of the mean and standard deviation of the scores of computer and physical-drawing groups that were obtained from the PSVT and the results of independent t-test related to the test.

Table 7. Descriptive statistics and independent t-test of the pre-service teachers' PSVT scores before the intervention

Groups	Computer Group			Physical-drawing Group					
Measures	N	Mean	SD	N	Mean	SD	df	t	p
Developments	32	5.28	2.32	29	5.93	2.88	59	-.98	.33
Rotations		5.03	2.07		5.38	2.91		-.54	.59
Views		4.50	1.88		4.79	2.21		-.56	.58
Total		14.81	4.67		16.10	6.52		-.90	.37

Table 7 demonstrates that for the pre-test, the t-test results show no significant difference in the mean scores between groups for the development section of the PSVT [t(59)=-.98, p>.05], the rotations section of PSVT [t(59)=-.54, p>.05], the views section of PSVT [t(59)=-.56, p>.05] and the overall PSVT [t(59)=-.90, p>.05]. This shows that there were no statistically significant differences between the spatial abilities of pre-service teachers in the computer and physical-drawing groups at the beginning of the course.

The pre-service teachers took the same PSVT test again, after the intervention the descriptive statistics for the data obtained from the PSVT after the intervention is presented in Table 8.

Table 8. Descriptive statistics of students' PSVT scores after the intervention

Groups	Computer Group			Physical-drawing Group		
Measures	N	Mean	SD	N	Mean	SD
Developments	32	6.66	2.72	29	6.97	2.61
Rotations		7.25	1.78		6.24	2.82
Views		5.97	2.60		5.79	2.34
Total		19.88	5.60		19.00	6.22

Table 8 demonstrates that the mean of the pre-service teachers' test scores increased in the post-test.

In order to determine whether differences in the averages scores of each group were statistically significant or not, a paired sample t-test was applied to the data obtained from the entire test at a significance level of 0.05. Table 9 summarizes the results of the paired sample t-test analysis for the pre- and post-test.

Table 9. Paired sample t-test results of pre- and post- test scores within groups

Pair	Groups	Computer Group			Physical-drawing Group		
	Measures	df	t	p	df	t	p
1 st	Developments	31	-3.81	.00	28	-2.80	.01
2 nd	Rotations	31	-7.01	.00	28	-2.42	.02
3 rd	Views	31	-3.78	.00	28	-2.39	.02
4 th	Total PSVT	31	-8.20	.00	28	-4.22	.00

According to the results in Table 9, there is a significant difference in the pre-service teachers' spatial abilities in both computer group and the physical-drawing group. These differences were observed with respect not only to the test results taken as a whole, but also to each section of the test results ($p<.05$) for two groups. Based on these statistical results, it is clear that both DGS-based and physical-drawing activities have positive effects on the pre-service teachers' acquisition of spatial abilities. The eta squared statistics were .42 for the developments section, .61 for the rotations section, .32 for the views section, and .69 for the total PSVT of the computer group. The same measurements were .22 for the developments section, .17 for the rotations section, .17 for the views section and .39 for the total PSVT of physical-drawing group. The guidelines proposed by Cohen (1988, pp. 284-7) for interpreting this value are: .01 small effects, .06 moderate effect and .14 large effects. Given our eta squared values for both groups, we can conclude that there was a large effect in the each section of PSVT scores obtained before and after the intervention.

In order to determine if there is a significant difference in the post-test PSVT scores for the computer group and the physical-drawing group, while controlling for their pre-test scores on this test, an analysis of covariance (ANCOVA) was performed. Table 10 presents the results of the ANCOVA related to the subsections of PSVT and the whole PSVT.

Table 10. Covariance analysis results for each section of PSVT scores for groups

Measures	Group	df	f	p	Partial Eta Squared
Developments Post-test scores	Computer Physical-drawing	1	.11	.74	.00
Rotations Post-test scores	Computer Physical-drawing	1	8.41	.01	.13
Views Post-test scores	Computer Physical-drawing	1	.45	.51	.01
Total PSVT Post-test scores	Computer Physical-drawing	1	4.71	.03	.08

The ANCOVA results showed that there is no significant mean difference in the gain scores of pre-service teachers in the computer group and physical-drawing group with respect to both the developments section of the PSVT (F[1. 61]=.11, p=.74) and the views section of the PSVT (F[1.61]=.45), where the developments section and views section of pre-test were used as covariate. There is a significant mean difference in the gain scores of pre-service teachers in the computer group and physical-drawing group with respect to the rotations section of PSVT (F[1. 61]=8.41, p=.01), where the rotations section of the pre-test was used as covariate. The comparison of the mean scores revealed that the computer group's gain scores (M=7.25, SD=1.78) were significantly higher than those of the physical-drawing group (M=6.24, SD=2.82) with a moderate effect size (eta squared is .13). In other words, the pre-service teachers in the computer group with DGS-based activities outscored the ones who did physical-drawing activities in the rotation section of PSVT. There is a significant mean difference in the gain scores of pre-service teachers in the computer group and physical-drawing group with respect to the total PSVT (F[1. 61]=4.71, p=.03), where the pre-test scores of the total PSVT was used as covariate. The comparison of the mean scores revealed that the computer group's gain scores (M=19.88, SD=5.60) were significantly higher than those of the physical-drawing group (M=19.00, SD=6.22) with a moderate effect size (eta squared is .08).

3. *What is the relationship between the van Hiele levels and spatial abilities of the groups?*

The relationship between the VHGT scores and the PSVT scores of pre-service teachers was investigated using the Spearman rank correlation coefficient (r_s). Table 11 shows a correlation between VHGT and PSVT scores for the entire groups.

Table 11. Correlation between subject variables VHGT and PSVT scores.

		PSVT
VHL	r_s	-.09
	p	.48
	N	61

According to Table 11, van Hiele levels were not significantly correlated with spatial abilities. The guidelines proposed by Cohen (1988, pp. 79-81) to interpret the value of the correlation coefficient are: r=.10 to .29 small, r=.30 to .49 medium, and r=.50 to 1.0 large. Table 11 shows that there is a negligible correlation between two variables. Knowing the subject's score on one test gives little or no indication of the subject's score on the other test.

4. Discussion and Conclusions

The paired sample t-test results show that the VHGT scores of the pre-service teachers in the computer group were significantly higher at the end of the course than at the begining. Many studies (Abdullah & Zaharia, 2013; Bell, 1998; Breen, 1999; Clements & Battista, 1990; Hoyles & Noss, 1994; Kutluca, 2013; Tutak & Birgin, 2008; Tutak, 2008) show that VHGT levels are developed in computer based environments. In this context, the results of this study have parallels with existing literature. Additionally, some studies' results indicate that using concrete materials and hands-on activities improved students' VHGT levels (Mistretta, 1996; Siew & Abdullah, 2013; Siew et al., 2013). According to the results of this study, the scores of physical-drawing group in which concrete materials and drawing activities were used were significantly higher at the end of the course than at the beginning. This result also showed that using both DGS and concrete materials and drawing activities affect pre-service teachers' VHGT levels.

The results of ANCOVA showed that there was not a statistically significant difference between the computer and the physical-drawing group in terms of VHGT post-test scores. This means that both teaching methods used in the groups have similar effects on pre-service teachers' VHGT levels. There were a few studies comparing the use of DGS and concrete materials and drawing activities. Tutak (2008) stated that learning environments designed by both concrete materials and 2D dynamic geometry software had positive effects on students' VHGT levels. In this context, the result is parallel with the result of Tutak's study. Yet, he claimed that using concrete materials was more effective than DGS for primary school students (grade 4-8). This shows a contrast with the results of our study. Further study comparing the effects of DGS-based environment and concrete materials and drawing activities based environment on students' VHGT levels would be useful. Moreover, in this study there were also activities for pre-service teachers' higher VHGT levels. The results of this study can point to other studies that might be carried out.

The paired sample t-test results show that the PSVT scores of the students in the computer group were significantly higher at the end of the course than at the beginning. In many studies (Baki et al., 2011; Erkoç et al., 2013; Güven & Kösa, 2008; Kurtuluş, 2013; Toptaş et al., 2012) 3D computer software was effective in improving students' spatial ability. As in this study, Güven and Kösa (2008) with Baki et al. (2011) claimed that Cabri 3D improved spatial ability. Other studies examined the effects of 3D modelling and web-based learning environment on spatial ability instead of DGS. While the environment designed in these studies prepared for students to form geometric shapes, to rotate formed shapes, or to open and close these shapes, they do not give many opportunities for students to make their own geometric shapes or to discover different features while doing these activities. The aim of the environment designed in this study as in the studies of Güven and Kösa (2008) and Baki et al. (2011) was not for developing pre-service teachers' spatial ability. The aim of this study was to use Cabri 3D software to design an environment to make pre-service teachers form their own geometric shapes with dragging and measuring activities, to make them discover different points and to make them learn solid geometry. The results of this study prove that these environments for 3D dynamic geometry software as in Baki et al. (2011) are also valid for environments including drawing and concrete materials. In many studies it was stated that concrete materials have positive effects on students' spatial abilities (Akasah & Alias, 2010; Arici & Aslan-Tutak, 2013; Chaim et al. 1988; Olkun, 2003). In this study, the scores of the physical-drawing group were significantly higher at the end of the course. Therefore, both DGS-based and concrete materials and drawing activity environments have positive effects on students' spatial ability.

When the results of ANCOVA showing that the computer group and physical-drawing groups' post-test scores were compared, there was no statistically meaningful difference in the developments and views sections. The developments section is related to spatial visualization which is one of the factors of spatial ability (Kurtuluş, 2013). In the development section, students made mental visualization of 3D objects based on their surface developments. Cabri 3D is significantly useful for many 3D objects to show their open and close appearance. Students can form different 3D shapes and they can also open and close these shapes. Moreover, since pre-service teachers in the physical-drawing group formed many solid objects by themselves in the development section, there was no statistically meaningful difference. On the other hand, in some studies (e.g. Yurt & Sünbül, 2012), it was stated that students who studied with concrete models had higher spatial thinking skills than students who studied in computer-based environments. The views section of the scale measured skills of mental visualization of rotated views of objects (Kurtuluş, 2013). In the views section, students pictured solid objects in their mind through different viewpoints. Baki et al. (2011) found statistically meaningful difference in favor of the computer group between group studied with DGS and the group studied with manipulative activities. He claimed that the reason for this was that Cabri 3D gives oppurtinity for students to see solid objects from many different points of views. However, in this study, no statistically meaningful difference was found. Similar to computer group, pre-service teachers who formed solid object models by themselves took these objects and had the opportunity to observe them from different points of views. This may be the reason for this result.

In the rotations section and in the whole PSVT total score, there was a statistically meaningful difference in favor of the computer group. The rotations section measured the participants' skills of mental rotation of geometric objects (Kurtuluş, 2013). Baki et al. (2011) did not find any statistically meaningful difference between teaching groups studying with manipulative based activities and computer-based activities for the rotations section. In this study in favor of the computer group, there was a medium level statistically meaningful difference between the computer group and physical-drawing group in the total scores of the PSVT test. It was seen that different results were obtained when the results of studies (Baki et al., 2011; Yildiz, 2009; Yolcu & Kurtuluş, 2010; Yurt & Sünbül, 2012) were compared. For example Baki et al. (2011) claimed that students' spatial ability improved with both DGS and manipulative activities. However, Yurt and Sünbül (2012) claimed that the group using concrete materials had higher spatial thinking than the group using computer activities.

The results of this study showed that there were no statistically meaningful relationship between van Hiele levels and spatial ability. There are a few studies (Karrass, 2012; Naraine, 1989; Smyser, 1994) examining the relationship between van Hiele levels and spatial ability. These studies have different results. For example Naraine (1989) and Karrass (2012) stated that there was a positive relation between VHGT and spatial ability, but Karrass (2012) added that number of sample was narrow and the results had lower reliability. On the other hand, Smyser (1994) stated that there was no relation between VHGT and spatial ability. The students in both computer group and physical-drawing group had usually lower and medium van Hiele levels related to the post-test scores. This can be a reason for being no relationship between van Hiele levels and spatial ability.

Our study aimed to determine the both effect of dynamic geometry software activities and the physical manipulatives activities on the spatial ability and van Hiele levels of pre-service primary school teachers. We found significant differences between the pre-and post-test scores of participants in both groups. This shows that both dynamic geometry software activities and the physical manipulatives activities had a positive effect on students' spatial ability and van Hiele levels. Furthermore, the correlation result showed no statistically significant relationship between van Hiele levels and spatial abilities.

The results have two important implications for education: (i) that spatial ability and van Hiele levels can be improved through training if it involves relevant content, (ii) dynamic geometry software activities and the physical manipulatives activities can enhance students' van Hiele levels and spatial abilities. In the further researches; other factors that influence both van Hiele levels and spatial abilities in different grade schools can be investigated. Moreover, the relationship between spatial abilities and van Hiele level is still for investigation.

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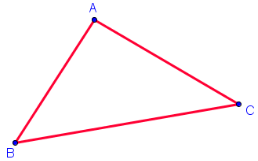
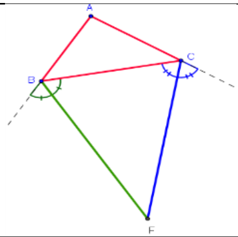
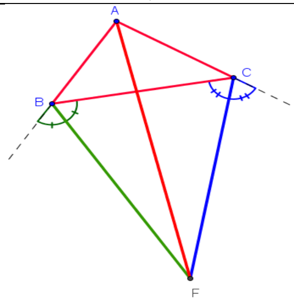
Appendix A

An example of a worksheet on plane geometry for the computer group

Subject: Angle bisector of triangles

Name: Date: / / 2012

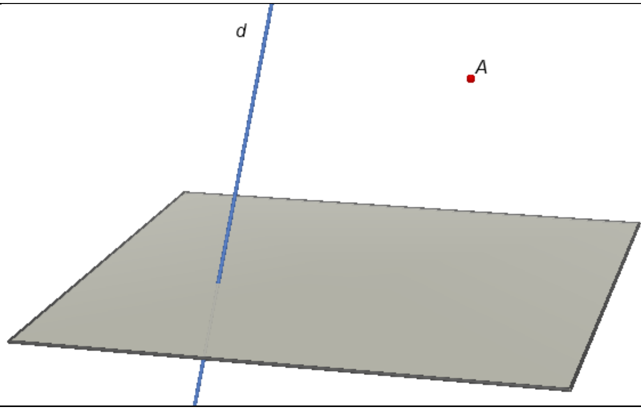
<table>
<tr><td>1. Draw an ABC triangle.</td><td>
</td></tr>
<tr><td>2. Draw the external bisector of $< ABC$ and $< ACB$. Then name the intersection point of two bisectors as “F”.</td><td>
</td></tr>
<tr><td>3. Draw a segment from the point A to the point F.</td><td>
</td></tr>
<tr><td>4. Find $< FAB$ and $< FAC$. Drag the corner points of the triangle and fill the table below.</td><td><table><tr><td>$< FAB$</td><td>$< FAC$</td></tr><tr><td></td><td></td></tr><tr><td></td><td></td></tr><tr><td></td><td></td></tr></table></td></tr>
<tr><td colspan="2">5. What results did you obtain? What can you say about the measures of the angles of $< FAB$ and $< FAC$. Write your results.</td></tr>
</table>

Appendix B

An example of a worksheet on solid geometry for the computer group

Subject: The number of planes which include a line and a point outside of the line

Name: Date: / / 2012

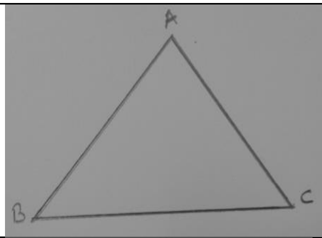
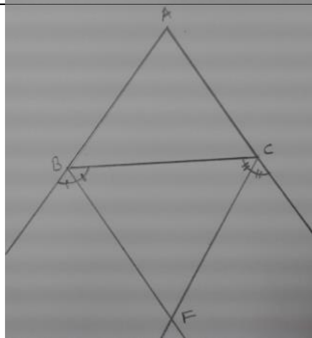
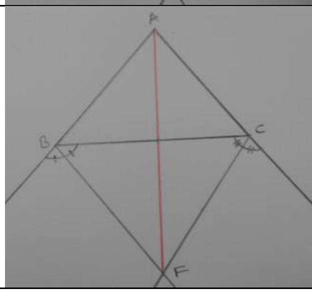
1. Draw a straight line, named d, on the ground plane and select a point named A outside of the line d as you can see on the right side image	
2. How many different planes can you create including this point and line?	
3. Try again using different points and lines. Write your results.	

Appendix C

An example of a worksheet on plane geometry for the physical-drawing group

Subject: Angle bisector of triangles

Name: Date: / / 2012

<table>
<tr><td>1. Draw an ABC triangle.</td><td>
</td></tr>
<tr><td>2. Draw the external bisector of $< ABC$ and $< ACB$. Then name the intersection point of two bisectors as “F”.</td><td>
</td></tr>
<tr><td>3. Draw a segment from the point A to the point F.</td><td>
</td></tr>
<tr><td colspan="2">4. Find $< FAB$ and $< FAC$. What can you say about the measures of $< FAB$ and $< FAC$? Write your results.</td></tr>
<tr><td colspan="2">5. Try again for different triangles (acute, right and obtuse triangle) Find $< FAB$ and $< FAC$. What can you say about the measures of the angles of $< FAB$ and $< FAC$? Write your results.</td></tr>
<tr><td colspan="2">6. What did you obtain? What can you say about the measures of the angles of $< FAB$ and $< FAC$ for different triangles? Write your results.</td></tr>
</table>

Appendix D

An example of a worksheet on solid geometry for the physical-drawing group

Subject: The number of planes which include a line and a point outside of the line

Name: Date: / / 2012

1. Draw a straight line, named d, which lies on the ground face of the transparent cube and select a point named A, outside of the line and on any side face as seen to the right.	
2. How many different planes contain this point and line?	
3. Try again using different points and lines. Write your results.	