Relationship between Gender, Spatial Visualization, Spatial Orientation, Flexibility of Closure Abilities and Performance related to Plane Geometry Subject among Sixth Grade Students

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Abstract

The plane geometry subject includes concepts as points, lines, planes, space and their relations. Representations of three-dimensional objects by means of two-dimensional diagrams bring the difficulties of identification of their properties. Three subfactors of spatial ability were identified as the main variables in the performances of students related to plane geometry subject. The purpose of this study is to investigate the relationship between gender, spatial visualization, spatial orientation, flexibility or speed of closure abilities and the performances related to the plane geometry subject of the sixth grade students. The sample of the study consisted of 120 sixth grade students. In the first part of the study, the reliability and the validity studies of the representative tests were carried out. In the second part, correlation analyses were carried out. Significant correlations were found between each factor except gender. For clarifying the relationships between more than one factor multiple regression analyses were used. The results showed that the three predictor variables explained the 35 per cent of the variance in plane geometry test scores. However, degree of contribution of each factor differed. The relative impact of spatial orientation ability (B=. 41) was higher than the spatial visualization ability (B=. 26) followed by the flexibility of closure ability (B=. 05). As a result of correlation analysis, gender was not taken into the regression analyses. The plane geometry subjects in the National curriculum were analyzed and related suggestions were carried out in line with the research findings.

Key Words: Spatial ability, spatial visualization, spatial orientation, flexibility or speed of closure ability, plane geometry.

Introduction

Geometry is a mathematics subject concerned with positions or locations in space. Historically, scientific geometry began with Euclidean metric geometry; then came projective geometry, and finally topology. Geometry as presented in primary grades mostly involves activities such as connecting points with line segments and recognizing figures such as triangles, squares and rectangles. Such activities involve properties of Euclidean geometry. However, genetically, during the development of child's conception of space, topology constitutes a general foundation from which both projective space and the general metrics from which Euclidean metrics proceeds can be derived (Copeland, 1979). Hart and Moore (1973) identified five developmental levels as a result of the research studies on ontogenetic development of spatial cognition: which are types of spatial relations (topological, projective and Euclidean), modes of representation (enactive, iconic and symbolic), systems of reference (egocentric, fixed and coordinated), types of topographical representations (survey and route).

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Hamley (McGee, 1979) states that mathematical ability is composed of general intelligence, visual imagery and ability to perceive number and space configurations as mental patterns. Abilities of visual imagery and ability to perceive space configurations are very important for geometry courses. In geometry, there are defined terms as triangle, angle, and circle as well as undefined terms as point, plane, line etc. They are considered undefined terms since the representations of these identities are distinct from their geometric definitions. Everybody knows the meaning of a point and a line, but it is very difficult to put them into words. For example, a point is represented on a paper by a dot, though the dot is not a geometric point since it has some size. However, a point, in geometry, has no length, breadth or thickness that has, no size. The same problem arises with the representation of a plane. The paper or the blackboard upon which we write and draw is a portion of plane, but its representation is a rectangle seen obliquely. Because of above mentioned reasons, the representation of plane and space geometry shapes may bring the difficulties of identification of their properties and ambiguity for decoding the drawn shapes. Students may have these kinds of difficulties especially in geometry lessons. These difficulties may arise from the arrangements of subjects in mathematics curriculum as well as a specific ability related to geometry lessons, namely spatial ability.

Eliot (1999) stated in his database that the study of spatial intelligence has had more than 60 years of long and complicated history and this history can be described in three phases. In the first phase (1904-1938), researchers investigated the evidence for and against the existence of a spatial factor over and above a general factor of intelligence. In the second phase (1938-1961), they attempted to ascertain the extent to which spatial factors were differed one from another. The most recent phase (1961-1995), researchers have attempted to designate the status of spatial abilities within the complex interrelationship of other abilities, and to examine a number of sources of variance which affect performance on spatial tests. For each step, different tests were designed in order to measure different aspects of spatial abilities.

There are various research studies about spatial abilities. They can be categorized as factorial studies, correlational studies, dimensional differences, testing differences, gender differences, age differences, processing and strategy differences, social and physical differences, practice and training differences (Eliot, 1983). The main point of interest in the present study is on the factorial, correlational studies related to spatial abilities. The importance of spatial abilities was greatly emphasized by many researchers. One of the reasons for this emphasizes is the importance of these abilities in the fields such as natural sciences, geometry, engineering and architecture (Kali and Orion, 1996). The existence of learning difficulties have been found in geometry (Ben-Haim *et al.*, 1985; Cooper, 1992), science, chemistry, biology, astronomy and engineering graphics (Kali and Orion, 1996). *Cassier's Theory of Symbolic Forms and Space*, *Werner's Organismic-Developmental Theory of Space*, *Piaget's Equilibration Theory of the Development of the Child's Conception of Space* and *The Van Hiele Model of Geometric Thought* are all models or theories developed for explaining the development of spatial abilities. In the present study firstly short review will be presented about spatial ability and its connections with mathematics and geometry lesson.

Review of Related Literature

Spatial Ability

According to Pellegrino and Glaser, one way of analyses of performance, in order to study the nature of intelligence is called cognitive components approach (Sternberg, 1982). Spatial ability is one of these components. In the history different names were assigned to this concept as spatial ability (Johnson and Meade, 1987, Linn and Peterson, 1985), spatial skills (Caplan et *al*., 1985; Melancon, 1994), spatial aptitude (Sternberg, 1982), spatial intelligence (Gardner, 1983), visual-spatial intelligence (Keith, 1997), visual-spatial ability (Maccoby and Jacklin, 1974) and spatial thinking (D'Zmura, 1995). Spatial ability may be accepted as an ill-defined concept, since there isn't much agreement about the exact definition. In a broader sense, spatial abilities can be defined as "the ability to perceive environment through senses, to learn environment and the relationship between objects" or "the awareness of things and our ability to use this awareness to solve spatial problems. Focus is upon the structure of figural, object and large scale environment" (Eliot, 1999). Still another definition is "the associations between oneself and environment or between two or more objects outside of oneself" (Stockdale and Passin, 1998). The last definition emphasize the quantities of spatial abilities as size, distance, volume, order and time which are not only limited to objects and figures, and in line with the definition of Eliot. In a specific way, spatial abilities were defined interms of the tasks which are determined to be important; in terms of the test items which are developed in measurement instrument or in terms of the categorization of spatial abilities. From this perspective spatial abilities can be defined as "the abilities as to perceive the visual world accurately, encode visual stimuli and to perform transformations and modifications upon one's initial perceptions, mental manipulations, to recreate aspects of visual experiences, even in the absence of relevant physical stimuli." (Maersa, 1998) or "the ability to generate, retain and transform abstract visual images" (Linn & Petersen, 1985). Following the developmental approach of spatial cognition, researchers started to identify the abilities, which composed the spatial ability. First they investigated the evidence for and against the existence of spatial factors over and above a general factor of intelligence, and then they tried to separate these factors from each other. The most important categorization of spatial abilities is in terms of the necessary abilities to perform spatial task or the strategies to be developed. McGee (1979) summarized these findings in his article and McGee (1979) in his article mentioned about the existence of two distinct spatial abilities as visualization and orientation. Following his classification Richmond (1980) mentioned about three subfactors as visualization, orientation and flexibility of closure. Summary of these factors analytic studies are given in Table 1 which is adapted from the studies of McGee (1979) and Richmond (1980). The first of these factors is S_1, the ability to visualize a rigid configuration when it was moved into different positions. Marker tests for this factor are *Figures, Flags* and *Cards (*Richmond, 1980). The second factor is S_2, the ability to imagine movement of internal displacement among the parts of a total configuration. Marker tests for this factor are *Surface Development, Paper*

Folding and tests of mechanical comprehension (Richmond, 1980). The third factor is S_3 (spatial relations), the ability to think about those spatial relations in which the body orientation of the observer is an essential part of the problem. Following the studies of Thurstone, in 1951, French identified a visualization factor (V_i) as the ability to mentally manipulate three-dimensional objects, and orientation factor (SO) as the ability to remain unconfused by the varying orientations in which a spatial pattern may be presented. Ekstrom *et al*., in the manual for *Kit of Factor-Referenced Cognitive Tests*, made a distinction between spatial visualization and spatial orientation ability (McGee, 1979). They suggested that visualization ability (V_z) require the mental reconstruction of figures into components for manipulation, whereas in spatial orientation the whole figure is manipulated. Both spatial orientation and visualization require short-term visual memory. Orientation requires only mental rotation of the configuration; however, visualization requires both rotation and the performance of serial operations. These identifications support the distinction between Thurstone's S_1 (spatial visualization) and S_2 (spatial orientation) factors. Richmond (1980) related these classifications to the Guilford's Structure of Intellect Model. In this model, a space factor CFS-V (Cognition of Figural Systems) resembles to Thurstone's S_1 factor and Guilford's factor CFT (Cognition of Figural Transformations) resembles to Thurstone's factor S_2 and Michael *et al*. Factor V_z. He also added a third factor to this classification which is the Thurstone's factor C_2 called as Thurstone flexibility of closure and defined as the ability to keep in mind a configuration against distraction. He emphasized the similarities between this factor and Guilford's factor NFT. Marker tests for this factor include *Copying, Gottschaldt Figures, Surface Development* and *Paper Folding* tests (Richmond, 1980). Following the classification of Richmond , researchers suggested that the notion of "spatial ability" can be extended beyond the classic spatial orientation and visualization factors with an inclusion of the factors traditionally called as closure speed and closure flexibility (Caplan *et al*., 1985), which support the addition of C_2 factor to the classification by Richmond.

From a different point of view Maccoby and Jacklin (1974) classified spatial abilities into two groups as visual-analytic and visual non-analytic. Visual analytic tests require the disembedding of a portion of visual stimulus while visual non-analytic tests require mental rotation or the visualization of a stimulus from a different perspective. Another recent but similar classification of is by Linn and Petersen (1985), such that they categorized spatial abilities into three groups as spatial perception, mental rotations and spatial orientation. These are very similar to the categorization of Lohman, as the spatial orientation, spatial relations and spatial visualization. Another theory for the categorization of spatial ability is the Sub-Factor Theory. In Sub-Factors Theory, spatial ability has been broken down into five contributing subfactors. They are organized in ascending order according to factor-of-difficulty (Maersa, 1998).

Table 1. Summary of spatial visualization and spatial orientation and flexibility of closure factors - symbols and descriptions

Investigator	Spatial Visualization Factor Symbol Description	Spatial Orientation Factor Symbol Description	Flexibility of Closure
Guilford and Lacey (1947)	V_z the ability to imagine the rotation of depicted objects, the folding or unfolding of flat patterns, the relative change of position of objects in space, or the motion of machinery. This visualization is strongest in tests that present a stimulus pictorially and in which some manipulation or transformation to another visual arrangement is involved.	SR An ability to determine relationship between different spatially arranged stimuli and responses and the comprehension of arrangement of elements within a visual stimulus pattern.	
Thurstone (1950)	S_2 the ability to visualize a rigid configuration when it was moved into different positions.	S_1 An the ability to recognize the identity of an object when it was seen from different angles and the ability to visualize a rigid configuration when it was moved into different positions S_3 An ability to think about those spatial relations in which the body orientation of the observer is essential part of the problem.	C_2 The ability to keep in mind a configuration against distraction.
French (1951)	V_i An ability to comprehend imagery movements in three-dimensional space or the ability to manipulate objects in the imagination.	S An ability to perceive spatial patterns accurately and to compare them with each other. SO An ability to remain unconfused by the varying orientations in which a spatial pattern may be presented. Dimensionality is less important to the factor than the rotational position of presentations.	
Ekstrom, French Harman	VZ An ability to manipulate or transform the image of spatial patterns into other arrangements; Requires either the mental restructuring of a figure into components for manipulation or the mental rotation of a spatial configuration in short term memory, and it requires performance of serial operations, perhaps involving an analytic strategy.	S An ability to perceive spatial patterns or to maintain orientation with respect to objects in space; requires that a figure be perceived as a whole.	NFT The ability to recognize familiar figures that have been
Guilford	CFS-V The ability to perceive a	CFT The ability to transform	

(1967)	figure in space no matter where you are in relation to the figure itself.	figures, that is to recognize a figure when it is rotated into a new orientation.	partially obscured.

The Relationship between Spatial and Mathematical Abilities

Spatial ability is an important component of mathematical ability. Research studies showed that performances of the students in geometry subjects of mathematics lessons were strongly related to their spatial abilities. The extent to which spatial abilities enter into mathematical ability is the main problem in lots of researches. Spatial tests had relatively high correlations with mathematics course performance compared to verbal and reasoning tests. Bennett's (McGee, 1979) *Space Subtest of DAT Battery* is found to be predictive of success in school geometry and quantitative thinking. Shawal (1999) investigated the relationship between spatial ability and mathematics learning for elementary Yemeni students. Results emphasized the use of imagery facilitates in doing mathematics.

The study of Hadfield *et al*. (1992) showed that, in predicting mathematics achievement and mathematics anxiety of Navajo Middle School students, spatial (r = .214, p = .0001), categorical (r = .146, p = .01) and sequential skills (r = .256, p = .0001) were identified as the best predictors of mathematics achievement. There can also be found connections between the spatial abilities and the geometry parts of mathematics lessons. The ability to mentally rotate and manipulate figures seems to be the skill most directly related to success in geometry. Even in the most abstract geometrical thinking students must find links with spatial intuition. According to Bronowski (1947; in Melancon, 1994) many mathematicians believed that beyond the level of simple computation all mathematical thought was based on geometrical concepts. Smith even described mathematics as a visual rather than verbal language. Supporting this idea lots of mathematical concepts were introduced visually and geometrically, i.e., number lines and graphing. Although materials designed for instruction in mathematics courses took account the spatial components, formal curricula offered little to foster spatial skill acquisition (McGee, 1979). Spatially minded students won't be able to develop their abilities in an environment where there is a less emphasize to their spatial abilities. This may affect their success in future math proficiency.

It is known that there is necessarily a loss of information when moving from a geometrical object to its drawing. But students while reading a drawing they tended to regard the properties of the drawing as the properties of the object itself. Research on 6th grade students showed that it is necessary to make the rules for drawing space geometrical figures explicit, even in the high school level. Most of the visual mathematical materials represented to the students are two dimensional, (e.g. textbook). Bishop (1980) said that the representation of a three dimensional object by means of two dimensional diagram demanded considerable conventionalizing which was by no means immediately recognizable by those from non-western culture. Research results indicated that students' work mainly based on the properties of the represented shape. So transformation from two-dimensional plane to three-dimensional space is very important concept for mathematics and especially for geometry.

One of the aspects of spatial perception is the perception and representation of depth. The sources of pictorial dept information were usually considered to be occlusion, size, height in the picture plane (as a function of horizon), linear perspective and texture gradient (Braine et *al*., 1993). Children's drawings showed that they don't draw what they see from a particular point in space, but rather, they draw their knowledge of the scene. Light and Foot (Braine *et al*., 1993) suggested that young children draw the spatial relations among objects from the view that best enables the children to present their knowledge (regardless of the child's actual view). In 1977, Willats analyzing children's drawing systems used by children (in a Western culture) saw that they developed drawing skills as onthographic in the early school years, then vertical oblique, oblique, naive perspective and correct perspective in adolescence. In another study by Butler (1982), about predicting the three-dimensional objects from the geometrical information in drawing, Hochberg and Brooks stated that perceived dimensionality of an object increases with the complexity of the drawing. Thus, a viewer is presented with a very complex drawing of a simple three-dimensional object, and then the minimum principle will force the viewer toward the simpler, three-dimensional interpretation. On the other hand, if a viewer is presented with an extremely simple two-dimensional representation of the same object, the minimum principle will draw the viewer towards the two-dimensional interpretation. In general the more complex the drawing, the greater the tendency to interpret the picture as three-dimensional.

In order to test the hypothesis of Hochberg and Brooks, in Butler's (1982) research, three different experiments were conducted. Subjects were supposed to judge the dimensionality of drawings of first wire objects and second solid objects (in the form of both transparent, nontransparent objects) and third interpretation of drawings in the previous two cases. The overall analysis suggested that when trying to prepare a three-dimensional drawing of an object, it was better to use relatively complex drawings, since otherwise drawings may appear too flat or ambiguous. As a result of the difficulties of the perception of three-dimensional figures and their properties, students encounter with problems such as the visualization of the invisible parts of the objects. In a study by Ben-Haim *et al*. (1985), students determined the number of cubes. Students who missed the items were employing incorrect counting strategies. Some of them only deal with two dimensions rather than three dimensions and others missing the hidden portion of the figure. The level of the performance for the fifth, sixth, seventh and eight graders were 25 per cent, 40 per cent, 45 per cent and 50 per cent respectively. Results showed and improvement as a result of maturity and experience. The results of the similar items in other studies also showed low frequencies; about half of the students in the middle grades cannot answer correctly this type of questions.

Cooper (1992) identified another factor in geometry lessons as the concept of symmetry. The perceived horizontal and vertical have a very powerful influence on the procedures students follow when determining images of symmetry in three dimensions. In the areas of trigonometry and co-ordinate geometry, and in works that involves the interpretation or construction of plans and solid structures, the notion of symmetry is present. Therefore the curriculum makers and instructors must be aware of the problems that some students encounter.

Delialioglu and Askar (1999) investigated the contribution of mathematical skill and spatial ability related to the achievement in secondary school physics.

Correlation analysis showed that the correlation coefficient for mathematical skills and achievement in physics was .46 and for spatial ability and physic achievement was .45. Multiple regression analyses showed that spatial abilities account for 9.6 per cent of the variance in physics achievement and the combined contribution of spatial ability and mathematical skills is 30.66.

Gender Differences

Differences between the performances of males and females in spatial ability were widely accepted, but the magnitude of this difference, the age of arousal and its sources are open to discussion (Hyde, 1981; Liben *et al.*, 1981; Linn and Petersen, 1985; Maccoby and Jacklin, 1974; McGee, 1979). Explanations of gender differences in spatial ability depend, to some extent, on when these differences first occur or more directly as stated by Johnson and Meade (1987), age of emergence of male advantage.

Many researchers agree that spatial abilities of males are more highly developed than those of the females (Kali and Orion, 1996, Caplan *et al*., 1985). Maccoby and Jacklin (1974) concluded that the male advantage emerges in adolescence and is maintained in adulthood.

In order to analyze the developmental nature of spatial ability in both boys and girls, Johnson and Meade (1987) applied a battery of 7 spatial tests (*Flags, Mental Rotations, Cubes, Hands, Blocks, Hidden Figures, Spatial Relations Tests)* to 1800 students ranging from 6 to 18 years of age. Results showed that a male advantage in spatial performance appeared by the age 10, that the magnitude of the advantage remained constant through age 18. In early years language skills may mask a male advantage in spatial ability during the primary school years. Richmond (1980) stated that gender differences in spatial ability may emerge before adolescence for certain type of spatial factors but not all and they were not necessarily generalized at that time.

Linn and Petersen (1985) explained the emergence of gender differences in two ways. Differences in early adolescence were explained by pubertal change (Weber, 1976) but the differences prior to adolescence were explained by biologically as based on genetic factors (Witting and Petersen, 1979) or prenatal hormonal influences (Linn and Petersen, 1985). Similarly Connor *et al*. (1978) identified the influence of three factors on the development of spatial abilities for boys and girls. These factors are genetic, environmental and polygenic factors. According to them genetic or biological differences were due to the X-chromosome. Harris suggested that spatial ability was recessive and carried on X-chromosome (Caplan *et al*., 1985). Environmental factors were explained by different cultural sex-role patterns. These patterns may result in sexually differential childhood experiences, which affect the development of spatial abilities. It appeared that, gender differences on tasks with large spatial components were more likely to be found in cultures having rigidly defined sex roles. The third factor took account the effect of both genetic and environmental factors, which was called as polygenetic factor by Fain (Connor et *al.*, 1978). The lower level of ability observed in females could be accounted for by a deficit in certain environmental events during development, which were necessary to permit the full expression of one's genetic endowment. Following this classification, McGee (1979) reviewed the individual differences in spatial abilities in four categories, environmental, genetic, hormonal and neurological. The additional categories in this classification were hormonal and neurological factors. Hormonal effect was the result of the balance of estrogen and androgen. High body of androgenization was associated with low spatial scores among males and with high spatial scores among females. The other factor was the neurological effect. The development of gender differences in spatial skills were likely related to gender differences in the development of hemisphere specialization. Recent work in hemisphere specialization demonstrated that the right cerebral hemisphere was specialized for spatial processing.

As it can be seen from these explanations, it is commonly believed that males' spatial abilities were superior to those of females (Caplan et *al.,* 1985). The lack of consensus in defining "spatial ability", inconsistencies in data, small sample sizes and overgeneralization decreased the reliability of these findings. Moreover, tests used for the identification of spatial ability may be limited in nature and can have different loadings on factors other than spatial abilities. This ambiguity led the researcher to factor analytic techniques of spatial ability. But, from a factor analytic point of view, tests of spatial ability did not display a simple and singular pattern of relationship (Richmond, 1980).

Spatial visualization is one of the factors of spatial abilities it has found to be more related to math performances for girls than for boys (Sherman, 1980). Despite findings that males were superior to females in spatial ability (Maccoby and Jacklin, 1974; Sherman, 1980). Sherman and Moses have found that genetic factors were not the cause of these differences. With proper instruction females can perform as well as males at creative visual thinking and problems requiring spatial ability. It had been found that spatial abilities of both males and females improve as they become more involved with such tasks as model building, working with three-dimensional objects, and solving spatial visualization problems (Melancon, 1994).

The other important factor of spatial abilities is the spatial orientation. Spatial orientation ability was found to be related to the field dependence, field independence, Piagetian and maze tasks. In these areas gender difference were found. Sherman (1967) argued that the gender difference in field dependence was the result of the gender differences in space perception. Factor analytic studies showed that gender differences in field dependence were eliminated after removing differences in spatial abilities (Hyde et *al.,* 1975). Liben and Golbeck (1980) investigated the sex difference in Piagetian horizontality and verticality tasks, which had loading on spatial factors. Results showed significant performance differences in physical and nonphysical contexts favoring nonphysical one in both sexes. Females were better when physical phenomena were irrelevant but it was also true for males, so the results can not be accounted for overall gender differences.

Linn and Petersen (1985) in order to clarify the linkage between gender differences in spatial ability and other differences between males and females conducted a meta-analysis. They categorized the spatial abilities into three groups as spatial perception, mental rotations and spatial visualization. Result of the meta-analysis suggested that gender differences arise for some type of spatial abilities but not others, large gender differences were found only on measures of mental rotation, smaller gender differences were found on measures of spatial perception.

Method

Sample

Sample of this study is composed of 120 sixth grade students who are attending co-educational private school in İstanbul. Students who were participated in the sample selected from five different classes randomly out of the ten sixth grade classes. For the reliability and validity studies of Composite_Gestalt Completion Test and Siccar Point Preview Test data were collected from 520 primary school children (166 fifth graders, 97 sixth graders and 257 seventh graders) from the same school who do not take place in the sample of the study.

Procedure & Instruments

All plane geometry subject in mathematics curriculum were identified in order to develop an instrument related to the subject. Secondly three representative tests of spatial ability were selected and validity and reliability studies of these tests were carried out by using a sample of 520 students. All four instruments were administered to a group of 120 sixth grade students.

As it is mentioned previously four instruments were used in the study.

Plane Geometry Test: This test was developed by the researcher and includes items on two and three-dimensional geometric figures parallel two the objectives of sixth grade national mathematics curriculum. Plane Geometry Test contains 28 items, from which 11 of them are multiple-choice and 17 of them are essay types of items. Duration of the test was 40 minutes. Results of this test were compared with the results of another test which was prepared according to the same objectives and test-parallel test reliability result of this study was calculated as .75.

Siccar Point Preview Test: This instrument was used inorder to measure spatial visualization ability of students (http://www.cogsci/ed/ac/uk/~paulus/Work/Geospreports/forma.htm). Test consists of the 32 odd items of the Revisted Minnesota Paper Form Board Test. The individual's task is to select the completed figure that can be constructed from the set of randomly arranged pieces. The test is a speed test with duration of 10 minutes. Experts opinions were taken for the construct validity. The test was administered to 520 fifth, sixth and seventh grade students (116 were fifth graders, 97 sixth graders and 257 seventh graders). There were totally 239 girls ($\overline{X}$ =15.12) and

281 boys ($\bar{x}$ =13.91) in the group. The item analysis results showed reliability coefficient of $\propto$ =.78 ($\bar{x}$ =14.50, and SD=4.94).

Structure of Intellect-Learning Abilities Test (SOI-LA): This test was used to measure the spatial orientation ability of students. Test was designed by Meeker, Meeker & Roid (1985), according to the factors of Guilford's Structure of Intellect. For each factor a representative subtest was designed, so the test has separate tests for each subfactor as *Evaluation of Figural Units (EFU), Cognition of Figural Classes (CFC), Divergent Production of Semantic Units (DMU)*. Related to the spatial orientation ability Cognition of Figural Systems (CFS) subtest was used. 26 items were included in the instrument test and the duration of it was 5 minutes. Reliability and validity analyses has been conducted for each subtest as well as for an overall test and the original alternative form correlation of this subtest is .69 and the test-retest correlation of Form A and Form B is .69 and .71 respectively. Studies of content representativeness, empirical data on criterion relatedness, including concurrent and predictive validity and construct validity studies were conducted (Meeker, Meeker & Roid in 1985). The adaptation and translation studies were conducted by Ardaç and Erktin (1996) in Turkey. The researchers administered the test to a sample of 70 Turkish seventh and eight grade students and calculated alpha coefficient for reliability as .95.

Composite Gestalt Completion Test: This instrument used to measure flexibility of closure ability which was prepared by John Eliot and Mark Czarnolewski (1999). Test was composed of 21 items drawn from large pool of items of Thurstone and Jeffrey's Speed of Closure Test, Street's Gestalt Completion Test, Harshman and Harshman's Figures Test and the ETS Gestalt Completion Test. The instrument includes identification of objects given in an incomplete form. Reliability study for Turkish sample carried out by 520 fifth, sixth and seventh grade students. There were 238 girls and 282 boys in the group. As a results of item analysis reliability coefficient Cronbach alpha was found to be .73 compared to the original alpha of .82 ($\bar{x}$ is 8.59 and SD 3.53). As a result of this adaptation study an alternative answer was accepted for two questions. Two experts' opinions were also taken for evidence related to construct validity. As it is mentioned above items were including ill structured problems so objectivity of scoring checked and inter rater reliability of the adapted instrument was calculated as .91.

Statistical Analysis

Multiple Regression Analysis was used for clarifying the relationship between more than one factors First the contribution of each factor to the performances of the students' in plane geometry subject was identified by Simple Regression Analysis. Secondly, the contribution each two subfactors were identified on the performances of the students in plane geometry subject and at last total contribution of all the factors were identified. In order to analyze the difference between the performances of the sixth grade male and female students on plane geometry subject t-test for independent samples was used.

Results

Plane Geometry Test, Siccar Point Preview Test, Structure of Intellect-Learning Abilities Test (SOI-LA) and Composite Gestalt Completion Test were administered to 120 sixth grade students. Descriptive statistic related to these instruments were shown in Table 2.

Table 2. Descriptive statistic of spatial ability sub-tests and plane geometry test

	Gender	N	$\overline{X}$	SD	Max.	Min.
Siccar Point Preview Test	Male	60	14.28	4.73	25	4
	Female	60	14.37	4.32	26	2
	Total	120	14.33	4.51	26	2
Cognition of Figural Systems Test	Male	60	15.70	7.57	26	1
	Female	60	15.63	6.45	25	3
	Total	120	15.67	7.00	26	1
Composite Gestalt Completion Test	Male	60	8.33	3.77	15	0
	Female	60	7.37	3.23	19	1
	Total	120	7,85	3.53	19	0
Plane Geometry Test	Male	60	51.62	17.18	81.50	17.00
	Female	60	47.15	12.55	65.00	12.50
	Total	120	49.38	15.14	81.50	12.50

Multiple regression is used more often in social sciences because combining two or more variables often leads to more accurate predictions of a dependent variable (Grimm, 1993). In this study the dependent variable is the performance of students related to plane geometry subject and the independent variables are the gender and subfactors of spatial ability - which are spatial visualization, spatial orientation and flexibility of closure abilities -. For linear regression to be of use, the two variables must be linearly related (correlated). So the first step is to investigate the correlation between these variables. Table 3 shows the results of correlation analysis.

Table 3. Correlation analysis of dependent and independent variables

	Plane geometry	Spatial visualization	Spatial orientation	Flexibility of closure	Gender
Pearson correlation sig. (2-tailed)					
Plane geometry		.45** p= .00	.54** p= .00	.25** p= .01	.15 p= .11
Spatial visualization	.45** p= .00		.44** p= .00	.24** p= .01	-.01 p= .92
Spatial orientation	.54** p= .00	.44** p= .00	.	.36** p= .00	.01 p= .96
Flexibility of closure	.25** p= .01	24** p= .01	.36** p= .00		.14 p= .13
Gender	.15 p= .11	-.01 p= .92	.01 p= .96	.14 p= .13	

**Correlation is significant at the .01 level (2-tailed)

The results of the correlation analysis of sample data show significant correlations between dependent and independent variables except one factor. Gender as an independent variable shows no significant correlation with the dependent and other independent variables. Therefore gender won't be taken as an independent variable to the regression analysis. Correlation coefficients between sub factors are significant and also not too high to indicate the measure of the same content.

Following the calculation of correlations (see results in Table 3) regression analyses were carried out and results are summarized in Table 4 and 5.

Table 4. Model summary

Model	Variable sets included in model[a]	Variable sets eliminated from model	R	R^2	Adjusted R^2	Std. error of the estimate
Model 1	1	2	.45	.21	.20	13.55
Model 2	2	2	.54	.29	.29	12.80
Model 3	3	2	.25[a]	.07	.06	14.70
Model 4	1,3	1	.48[a]	.23	.22	13.41
Model 5	2,3	1	.54[a]	.30	.28	12.82
Model 6	1,2	1	.59[a]	.35	.34	12.32
Model 7	1,2,3	0	.59[a]	.35	.33	12.36

a. Predictors: 1= Spatial visualization; 2 = Spatial orientation; 3 = Flexibility of Closure
b. Dependent variable: Plane geometry

As a result of this model summary independent analyses were conducted for each model and the following regression equations were developed.

Regression equation for Model 1 is
Plane Geometry = 27.55 + (1.52 x Spatial Visualization).
Beta value .45 shows the relative impact of the variable which is considerably high and spatial visualization ability is responsible from 21 percent of the variance in plane geometry scores.

Regression equation for Model 2 is
Plane Geometry = 31.11 + (1.17 x Spatial Orientation).
Beta value .54 shows the relative impact of the variable which is considerably high and spatial orientation ability is responsible from 29 % of the variance in plane geometry scores.

Regression equation for Model 3 is
Plane Geometry = 40.82 + (1.09 x Flexibility of Closure).
Beta value .25 shows the relative impact of the variable which is moderate and flexibility of closure ability is responsible only from 7 % of the variance in plane geometry scores.

Regression equation for Model 4 is Plane Geometry = 24.191 + (1.399 x Spatial Visualization) + (.656 x Flexibility of Closure).
Beta value .42 compared to the beta value of .15 shows that the relative impact of spatial visualization is higher than the impact of flexibility of closure ability on the plane geometry scores and both flexibility of closure and spatial visualization abilities are responsible from 23 percent of the variance in plane geometry scores. The impact of spatial visualization is significant while the impact of flexibility of closure is not significant.
Regression equation for Model 5 is
Plane Geometry= 29.59+(1.11 x Spatial Orientation) + (.30 x Flexibility of Closure).
Beta value .51 compared to the beta value of .07 shows that the relative impact of spatial visualization is much higher than the impact of spatial orientation on the plane geometry scores and both flexibility of closure and spatial orientation abilities are responsible from 30 percent of the variance in plane geometry scores. The impact of spatial orientation is significant while the impact of flexibility of closure is not significant.
Regression equation for Model 6 is
Plane Geometry = 22.23 + (.90 x Spatial Visualization) + (.91 x Spatial Orientation).
Beta value .42 compared to beta value of .27 shows that the relative impact of spatial orientation is higher than the impact of spatial visualization on the plane geometry scores and both spatial orientation and spatial visualization is responsible

from 35 % of the variance in Plane Geometry scores. The impact of both spatial visualization and spatial orientation abilities are significant.

Table 5. shows the multiple regression analysis between the dependent variable performances of students in plane geometry and the independent variables flexibility of closure, spatial orientation and spatial visualization abilities (Full Model).

Table 5. Coefficients[b] of multiple regression analysis for flexibility of closure, spatial orientation and visualization

***Model 7* (Full Model)**	***Unstandardized* coefficients**		**Standardized coefficients beta**	**t**	**p**
	B	*Std. error*			
(Constant)	21.42	4.18		5.13	.000
Spatial visualization	.88	.28	.26	.26	.002
Flexibility of closure	.19	.35	.05	.56	.578
Spatial orientation	.88	.19	.41	4.68	.000

a Predictors: Flexibility of closure, spatial orientation and spatial visualization
b Dependent variable: Plane geometry

Regression equation for Model 7 is

Plane Geometry = 21.42 + (.88 x Spatial Orientation) + (.19 x Flexibility of Closure) + (.88 x Spatial Visualization).

Beta value .41 shows the relative impact of spatial orientation is higher than the impact of spatial visualization followed by the impact of flexibility of closure on the plane geometry scores. Table 5 shows that flexibility of closure, spatial orientation and spatial visualization together is responsible from 35% of the variance in plane geometry scores. The impact of both spatial visualization and spatial orientation abilities are significant while the impact of flexibility of closure is not significant. Results support the hypothesis that there is a significant positive relationship between the sixth grade students’ interaction of spatial visualization, spatial orientation, flexibility of closure abilities and the performances in plane geometry subject as measured by The Plane Geometry Test.

Conclusion and Implications

The purpose of this study was to investigate the relationship between the three components of spatial abilities as spatial visualization, spatial orientation, flexibility or speed of closure abilities of the sixth grade students and their performances in plane geometry subject. In order to find an answer, simple and multiple regression analyses were conducted. First of all, the relationships between each of the sub factors of spatial ability and the performances of the sixth grade students in plane geometry subject were determined. Secondly, total contribution of the independent variables to the performances of the sixth grade students in plane geometry subject was determined.

As it can be seen in review of literature part, most of the researchers conducted their studies without making a distinction between the sub factors of spatial ability and taking it as a compound but single ability. Shawal (1999) stated that in order to foster mathematical thinking, reasoning and problem solving abilities, it would be necessary for the students to have greater opportunities to engage in spatial abilities. Hadfield *et al*. (1992) also emphasized the importance of spatial abilities. They have found the spatial factor to be the one of the best predictors of mathematics achievement. Another approach for the analysis of the relations between spatial ability and mathematics performance, as in the present study, was to divide the spatial ability into its sub factors.

Spatial visualization ability is one of the sub factors of the spatial ability. Findings of the present study showed that there was a significant relationship between spatial visualization ability and the performances on plane geometry subject. Spatial visualization ability explained 21 per cent of the variance in plane geometry test scores of the sixth grade students. Moreover, beta coefficient of .45 showed the relative impact of the variable, which was considerably high. Spatial visualization had been shown to be related to mathematics performance (Sherman, 1979). Sherman also mentioned about the concurrent improvement of spatial visualization and mathematics ability. Nutall *et al*. (1985) have found consistent relationships between mental rotation skills which is one of the components of spatial visualization and mathematics aptitude. The result of the present study support the previous results stating that there is a significant positive relationship between the spatial visualization abilities and the performances in plane geometry subject of the sixth grade students.

The second sub factor was spatial orientation ability. Results of the data analyses of the present study showed that there was a significant relationship between students' spatial orientation abilities and performances in plane geometry subject. The spatial orientation ability explained 29 percent of the variance in plane geometry test scores of the sixth grade students. Beta coefficient of .54 showed the relative impact of the variable, which was considerably high. The results of the present study were consistent with the findings of Hill (McGee, 1979) who administered two different test representing the spatial visualization and spatial orientation factors. Results showed that the two tests had high correlations with mathematics course performance. There are also other factors as space perception, depth perception which are the components of spatial orientation ability were shown to be positively related to mathematics performance.

The third component of spatial ability was flexibility of closure ability. Results of the data analyses of the present study showed a positive relationship and that the flexibility of closure ability explained 7 per cent of the variance in plane geometry test scores. Beta coefficient of .25 showed the relative contribution of this factor, which was moderate. As it can be seen, although the relationship of this factor was at a significant level, the contribution of this factor was not as much as the contribution of other factors of spatial ability to the performances of sixth grade students in plane geometry subject. In the literature review, relations of this factor with the plane geometry subject were not directly identified. Because of that reason, this factor was not included in lots of previous categorization studies of spatial abilities. But, Richmond (1980) and Harshamn *et al*. (1983; in Caplan *et al*., 1985), included this factor in their classification of spatial abilities. Research results for the categorizations of spatial abilities were explained in Table 1 in detail. In the present study this categorization was selected by the researcher, in order to investigate the total contribution further.

After the investigation on the contribution of each spatial ability sub factor, total contribution of these factors on the performance in plane geometry subjects of the sixth grade students were investigated. Total contribution of these factors to the plane geometry test scores was found to be at 35 per cent, which was higher than the contribution of each factor as expected. However the degree of contribution of each factor differs. The relative impact of spatial orientation ability (beta coefficient of .41) was higher than the impact of the spatial visualization ability (beta coefficient of .26) followed by the flexibility of closure ability (beta coefficient of .05). Although the contribution of spatial orientation and spatial visualization abilities were at significant level, the contribution of flexibility of closure ability was not at significant level. The differences mainly arise from the different nature and content of these abilities.

Ekstrom *et al*. (1963; in McGee, 1979) made a distinction between spatial visualization and spatial orientation ability. They suggested that visualization ability required the mental reconstruction of figures into components for manipulation, whereas in spatial orientation the whole figure is manipulated. Both spatial orientation and visualization required short-term memory. Orientation required only mental rotations of configurations; however, visualization required both rotation and the performance of serial operations. Linn and Peterson (1985) categorized spatial abilities into three groups as space perception, mental rotation and spatial visualization, while others categorized them as spatial visualization, spatial relations and spatial orientation. However later authors suggested that mental rotations are a specific type of manipulation included in spatial visualization category (Kali and Orion, 1996).

Myers suggested that spatial visualization test items were usually more difficult than spatial orientation items and Zimmerman supports these suggestions (McGee, 1979). Research results of the present study may help to explain the differences in the contribution of sub factors of spatial abilities to the plane geometry subject. Flexibility or speed of closure factor on the other hand represents a different set of abilities. It was not included in the first classification. However, in later years Richmond (1980), in his article included the flexibility of closure ability as a sub factor of spatial ability. Following him Harshman *et al*. (1983; in Caplan *et al*., 1985) suggested that the notion of spatial ability could be extended beyond the classic spatial orientation and spatial visualization factor with an inclusion of another factor traditionally called as closure speed or closure flexibility. Richmond in his research tried to identify the common requirements of these abilities. He stated that there might be a considerable spillage of loading among S1 (spatial visualization), S_2 (spatial orientation) and C_2 (flexibility or speed of closure). Often S_1 and S_2 overlap, as do S_2 and C_2. On the other hand, S_1 and C_2 were usually separated, and it can be said that the tests, which mark out these factors, were sampling different ability domains. Factor S1 was marked by tests of a nondisembedding sort, while factor C_2 was marked by the tests associated with disembedding ability (Richmond, 1980).

The interpretation of the existence of C_2 factor, which defined as the flexibility or speed of closure factor is in general open to cultural differences. In the present study contribution of this factor was less than the other factors, since the emphasis in geometry lessons may not be on the requirements of this factor. In Turkey, geometry lessons can not be covered in desired ways as a result of the curriculum deficits, time constraints, and number of students in the class and the limited use of educational technology.

In this study gender was not found as one of the factors affecting the plane geometry performances of the sixth grade students. The concept of gender differences in mathematics lessons and in subjects related to the mathematical knowledge was widely acknowledged. However, they show inconsistencies about the nature and the emergence period of these gender differences. As an example, MacKenzie (1995) emphasized that the math gap amounts to over 40 points (out of 800) on the SAT (*Scholastic Aptitude Test),* which was taken by most of the high school students and it tended to widen among the more selected populations. He also stated that the years of intense efforts to identify and remove the questions that might be biased against girls' have not made a change in the gap. In a similar study, Nutall et *al*. (1995) identified that males performed better than females in *Scholastic Aptitude Test-Math* (SAT-M) for high ability groups but not for the low ability group. Tantre and Fennema (1995) also investigated the relationship between mathematics achievement and gender. In their longitudinal study, on a group of 60 students progressing from 6^{th} to 12^{th} grade, they have found consistent gender differences in stereotyping mathematics as a male domain. They also identified no differences in spatial ability, verbal or mathematics skills and found positive correlations between achievement and confidence.

Gender differences can also be explained by biological factors. The acquisition of different cognitive and motor skills gives way to the development of different abilities. Developmental phases of males and females show differences. Mathematics ability is the combination of different abilities as computational skills, analytic thinking, problem solving, perceptual and motor skills. The developments of these different skills are depends on the age of children. In early years, because of the continuous nature of the human development, these abilities may not be sufficient to the development of mathematics ability or some parts of the mathematical performance. Through maturation and interaction with the environment, these abilities improve.

Sherman (1980) in her research identified that although there were no significant gender differences in mathematics performances of grade 8 students, significant differences were found in grade 11. Maccoby and Jacklin (1974) stated that from different cognitive skills, mathematics performance and spatial visualization have been thought to show the largest difference in favor of males; these differences were not usually evident in grade school, however they were thought to emerge during the adolescence. While there was little difference in achievement in early grades, there were significant differences in the number of advanced courses taken by males contrary to the choices of females. The findings of the present study were in the same line with the previous studies that gender differences might not always be observed in early grades. The sample of the present study was composed of sixth grade students of 12 to 13 years of age. It was natural to observe no gender differences in their performances on plane geometry subject in these early years.

It can be concluded that the spatial abilities are the important determinants of the development of the space conception, which brings the improvements in the performances of the students in plane geometry subject. Therefore, the emphasis of this topic in mathematics curriculums should be reviewed. If we investigate the programs of different educational practices, it can be seen that the spatial ability is an important part of geometry performance. Programs in USA name the subject not only as geometry but also *geometry and spatial sense*. For example, Florida Sunshine Curriculum (1997) identified geometry and spatial sense topic to be important to develop dynamic imagery, a very important concept underling much of the mathematics learning, as well as learning in general. In a similar way, The Ontario Curriculum (1997) defined the spatial ability as the intuitive awareness of one's surroundings and the objects in them. In The Ontario Curriculum spatial sense accepted as a necessity for interpreting, understanding and appreciating our inherent geometric world. Insights and intuitions about the characteristics of two-dimensional shapes and three-dimensional figures, the interrelationships of shapes and the effect of changes to the shapes were considered the aspects of spatial sense. In a different practice, New Jersey Department of Education (1996) defined the spatial sense as an intuitive feel for shape and space. The subject of geometry and spatial sense included concepts as traditional geometry, including ability to recognize, visualize, represent and transform geometric shapes but, it also involves less formal ways of looking at two and three-dimensional space, such as paper folding, transformations, tessellation and projections.

In all above mentioned practices, at the end of fourth grade students were expected to explore spatial relationships such as the direction, orientation and perspectives of the objects in space their relative shapes and sizes and relation between objects and their shadows, concepts as congruence, symmetry, similarity, properties of three and two dimensional shapes by using concrete objects, drawings, classifying shapes, geometric transformations as rotations, reflections and translations. Building upon these knowledge and skills in preceding grades, by the end of grade 8, students were expected to relate two and three dimensional geometry using shadows, perspectives, projections and maps, identifying, describing and comparing and classifying plane and lines, intersecting lines, planes and angles and the application related to the measurement part of geometric figures.

It can be said that traditionally, elementary school geometry instruction has focused on the categorization of shapes and at the secondary level, it has been thought as the prime example of the formal deductive system. While these perspectives are important, they are also limiting. In order to develop spatial sense, students should be exposed to a broader range of geometric activities at all grade levels.

The Curriculum and Evaluation Standards for School Mathematics of USA (NCTM, 1989) also included geometry and spatial sense for grades K-4 and 5-8. The emphasis of NCTM is similar to the previously mentioned programs. The objectives of the program were developed as a result of the findings of above mentioned research studies and also to the developmental levels of the students in these grades. Students were expected to acquire this topic through first-hand experiences with the geometric nature of the world in which they live. Vocabulary, which has played important role in earlier programs, must grow out of experiences and understanding.

The curriculum of Turkish educational system also underlined these kinds of expectations starting from the first grade through to grade eight, in primary level. A closer look shows the differences in topics of geometry subject. The National Curriculum of Turkish Education shows some differences from the above mentioned curriculum. As an example, in Turkish mathematics curriculum, concepts of points, lines, planes and a space constructed the early topics, with a less emphasis on the discovery of two and three dimensional shapes around the students' world. The second distinction is that Turkish mathematics curriculum has been designed according to the developmental levels of the Piaget's intellectual development of space cognition while the previously mentioned programs have been developed according to the Model of Van Hieles. Dutch researchers Pierre Van Hiele and Diana van Hiele-Geldof who identified five levels of development through which students pass when assisted by an appropriate instruction (Mason, 1998; Graham, 1999):

- Visual recognition of shapes by their appearance as a whole (level 0)
- Analysis and description of shapes in terms of their properties (level 1)
- Higher "theoretical" levels involving informal deduction (level 2)
- Formal deduction involving axioms and theorems (level 3)
- Work with abstract geometric systems (level 4)

Majority of high school geometry courses was taught at Level 3. Van Hieles also emphasized that a person must proceed through levels in order and the advancement from level to level depends more on content and mode of instruction than an age and that each level has its own vocabulary and its own system of relations. According to the Van Hieles, a student progresses from one level to the following level with an instruction that is organized into five phases of learning. In order to provide better understanding of students in this subject, following phases can be integrated into the mathematics curriculum. In phase 1 (Inquiry/Information) the teacher and the student engage in conversation and activity about the objects of the study in order to identify what students already know about a topic. Observations are made, questions are raised and level specific vocabulary is introduced. In phase 2 (Guided/directed Orientation) students explore the topic through materials that the teacher has carefully sequenced. These activities should gradually reveal the characteristics of structures to the students. Following this in phase 3 (explicitation) students describe what they have learned about the topic in their own words. Other than to assist and to introduce relevant mathematical terms, the teacher's role is minimal. It is during this phase that the levels systems of relations begin to become apparent. In phase 4 (free orientation) students apply the relationship to solve problems and investigate tasks that are more open-ended and in the last phase 5 (integration) students are able to internalize and unify relations into a new body of thought. They summarize and integrate what they have learned, developing a new network of objects and relations. The teacher can assist in the synthesis by giving "global surveys" of what students already have learned.

The Van Hiele Model indicates that effective learning takes place when students actively experience the objects of study in appropriate context, and when they engage in discussion and reflection. According to the model, using lecture and memorization as the main methods of instruction will not lead to effective learning. Teacher can assess their students' level of thought and provide instruction accordingly.

In 1960, Soviet Union changed their geometry curriculum, in line with the results of the Van Hiele research. During the 1980s; there was also a growing interest in the United States in the Van Hieles' contributions. For example, The Standards of the National Council of Teachers of Mathematics of USA (1989) have developed their programs according to the results and implications of Van Hiele model by stressing the importance of sequential learning and an activity approach and put it into application. All these explanations should not be interpreted as the integration of only one model, namely Van Hiele Model and Piaget's Theory of Space Conception, into the curriculum. The important point here is to combine the theory of Piaget's and the model of Van Hiele's and the other developmental research results in order to provide optimum opportunities for the improvement of these concepts in mathematics curriculum or preferably in an special lesson.

In order to provide a better learning environment, especially in elementary and secondary classrooms, environment can be designed to foster the abilities of many visually oriented learners. They respond well to movies, television, slides, posters, charts, diagrams, computers and color coded materials. Beside observations, learning can also be enhanced with visual tools such as computers, video cameras, signs, artistic media and building and drafting supplies. Classroom environment can be made more supportive and inviting when visual humor is part of the setting. Cartoons, posters, and humorous pictures or photographs related to the subject matter convey pleasant messages about learning to students.

In recent years visual medium has been used very extensively in books especially for pre-school children. Informal observation suggest that children learn much of their early vocabulary in response to items pointed out to them in a picture book which can be transferred to other areas as to learn speaking and listening stories. It could also be helpful to use for older children in secondary school mathematics lessons (Serpel and Deregowski, 1980). Sometimes verbal and sometimes visual cues may not be reached by all the students. A mathematical subject of plane geometry is one of them. In this study, reasons of difficulties at this subject were defined as the factors of spatial ability. The interaction of these factors were determined to be the significant relationship of spatial ability of the students' s performances in plane geometry subject and the contribution of three sub factors of spatial ability as spatial visualization, spatial orientation and flexibility of closure abilities were determined. Results of the study indicate that we need to provide students with the necessary facilities to develop their d abilities. Different instructional practices may be designed according to the academic needs of students.

But it must not be forgotten that the categorisation of spatial abilities in this study can be enlarged and different aspects of spatial abilities may be introduced. This study was conducted with the students who were enrolled in a private school and belonged to higher SES group, which may affect the generalizability of the study. *Plane*

Geometry Test items includes the knowledge of two and three-dimensional figures, their properties and also relations between these properties. Relations between figures were defined in terms of the intersection and union of figures, which brings the concept of set operations. A further research can be conducted in order to determine the contribution of mathematical knowledge related to set operations and the spatial abilities of students, emphasizing different age levels and different SES groups.

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Altıncı Sınıf Öğrencilerinin Cinsiyetlerinin, Uzaysal Görme, Uzaysal Yönelme ve Bütünleştirme Esnekliği Becerilerinin, Uzay Geometri Konusuna Yönelik Başarıları ile İlişkisi.

Özet

Uzay geometri konusunda bulunan, genelde üç boyutlu olan şekillerin iki boyutlu ortamlar üzerinden gösteriminden kaynaklanan problemler nedeni ile öğrencilerinöğrencilerin bu şekillerin özelliklerini anlamada zorlandıkları gözlemlenmektedir. Öğrencilerin uzay geometri konusuna yönelik başarılarının, uzay ilişkilerine yönelik becerileri ile şekillenebileceği düşünülmektedir. Çalışmanın amacı altıncı sınıf öğrencilerinin cinsiyetleri, uzay ilişkilerine yönelik becerilerinin alt boyutlarından uzaysal görme, uzaysal yönelme ve bütünleştirme hız ve esnekliği becerileri ile uzay geometri konusundaki performansları arasındaki ilişkileri belirlemektir. Çalışmanın örneklemini 120 kişilik bir öğrenci grubu oluşturmaktadır. Çalışmanın ilk kısmında kullanılan testlerin geçerlik ve güvenirlik çalışmaları yapılmıştır. İkinci kısımda, öncelikle değişkenler arasındaki korelasyon katsayılarına bakılmış, cinsiyet dışında anlamlı seviyede ilişkiler bulunmuştur. Daha sonra birden fazla değişken arasındaki ilişkileri belirlemek için çoklu regresyon analizi uygulanmıştır. Sonuçlar üç değişkenin uzay geometri başarısındaki değişkenliğin yüzde 35'ini açıklayabildiğini göstermiştir. Ancak değişkenlerin katkı derecelerinde farklılıklar görülmektedir. Uzaysal yönelme (B=.41) en fazla katkıya sahiptir, bunu uzaysal görme (B=.26) ve bütünleştirme hız ve esnekliği (B=.05) takip etmektedir. Korelasyon analizi sonuçlarına göre, cinsiyet, çoklu regresyon analizine bir değişken olarak alınmamıştır.

Anahtar sözcükler: Uzay geometri, uzaysal ilişkiler yönelik beceriler, uzaysal görme, uzaysal yönelme, bütünleştirme hız ve esnekliği.