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RELATIONSHIPS AMONG PRESERVICE PRIMARY MATHEMATICS TEACHERS' GENDER, ACADEMIC SUCCESS AND SPATIAL ABILITY[1]

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The aim of this work is to investigate relationships among pre-service primary mathematics teachers' gender, academic success and spatial ability. The study was conducted in Izmir with 193 pre-service primary mathematics teachers of Dokuz Eylül University. In the work, spatial ability test, which consists of two main sub-tests measuring spatial orientation and spatial visualization abilities, is used. In order to analyze the obtained data, descriptive statistics, Pearson product moment correlation coefficient and Mann-Whitney U test are used. The results indicated that pre-service primary mathematics teachers' spatial ability level is low; there is a positive relationship between spatial ability and academic success; there is no significant difference between spatial ability and gender and the abilities of spatial orientation and spatial visualization are positively correlated. Some important research questions are also proposed.

Key Words: spatial visualization, spatial orientation, spatial ability, mathematics education, academic success

INTRODUCTION

In an arbitrary textbook of mathematics education, one can see the phrase "We teach mathematics to develop students' important abilities which are used to understand and solve real world problems". The reader may ask "To what do the mentioned abilities refer?" One can think that the principal ability is problem solving skill for other related science areas such as physics and

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chemistry. With this aim, to get more success in mathematics and therefore in other areas, teaching programs are usually updated. According to a framework about programs expressed by National Council of Teachers of Mathematics [NCTM] (2000, p. 280), all mathematics programs should enable students to

- create and use representations to organize, record, and communicate mathematical ideas;
- select, apply, and translate among mathematical representations to solve problems;
- use representations to model and interpret physical, social, and mathematical phenomena.

Thus we see that the ability of representations and development process of it is important for mathematics education. NCTM (2000) emphasizes the importance of the connection between an understanding of the concept of area, perimeter and volume, on the one hand, and spatial ability on the other (Ives, 2003, p. 4). Besides, NCTM (2000, p. 43) states "one aspect of spatial visualization involves moving between two-and-three dimensional shapes and their representations. So, the ability of visual thinking is an important way to understand the geometry and mathematics. Additionally, according to July (2001, p. 22), spatial ability is also very important for work in various fields such as computer graphics, engineering, architecture, and cartography. And, recent studies imply that spatial ability is not only related to mathematics but also physics and chemistry (Alkan and Erdem, 2011; Delialioğlu, 1996; Delialioğlu and Aşkar, 1999). Therefore, the study of both two-dimensional and three-dimensional objects is prevalent throughout the study of mathematics in such areas like geometry, trigonometry, calculus and algebra, and an intuitive understanding of space and the objects in the environment would seem to be a necessity for anyone studying these or related topics (King, 2002, p. 12). In the light of the existing literature, we think that the investigation of pre-service primary mathematics teachers' spatial ability and their gender and academic success is important and it has two main subjects. The first one is to determine their level of spatial ability, because they will soon begin to teach mathematics somewhere and in this teaching process they will use spatial activities as well. The second one is to investigate the gender differences and academic success. We think that our results will be important for mathematics educators at university. They may develop some activities and update their courses for pre-service primary mathematics teacher program from the viewpoint of the spatial ability.

Theoretical Background

Definitions of Spatial Ability and Its Components

In the existing literature, the terms spatial ability, spatial skills, visualization ability, visual-spatial ability, spatial perception, spatial conceptual ability, three dimensional visualization, visual cognition and ability of visualization are used interchangeably (Cantürk-Günhan et al., 2009, p. 152). Due to this, there are different definitions of spatial ability. One of the first definitions of spatial ability is given by Linn and Peterson (1985, p. 1482) (by the name of spatial reasoning) as "it refers to the skill in representing, transforming, generating and recalling symbolic nonlinguistic information". Spatial reasoning is concerned with the representation and use of objects and their relationships within a world conceived of both topologically and geometrically in two and three dimensions, with or without time as a fourth dimension (Williams et al. 2010, p. 2). Tartre (1990) refers to the term of spatial skill and according to her spatial skills are considered to be concerned with understanding, manipulating, reorganizing or interpreting relationships visually. A more comprehensive definition is expressed by Lohman (1993, p. 20) that spatial ability may be defined as the ability to generate, retain, retrieve and transform well-structured visual images. According to Kayhan (2005), spatial ability is the ability to manipulate, reorganize or interpret relationships visually.

The existence of these differences on the definitions of spatial ability led to different definitions of components (factors) of the spatial ability. The factor structure of spatial ability has been an area of study since the mid-1940s; however, those studies did not provide a clear picture of the underlying factors of the subject (Yılmaz, 2009). First, Ekstrom et al. (1976) identified two components of spatial ability: "spatial orientation" and "spatial visualization". According to them, spatial orientation involves the ability to perceive spatial patterns or to maintain orientation with respect to objects in space. And spatial visualization involves the ability to manipulate or transform the image of spatial patterns into other arrangements (which requires that a figure be mentally restructured into components for manipulation) or the mental rotation of a spatial configuration in short-term memory and the performing of serial operations. McGee (1979) also expressed similar definitions of spatial orientation and spatial visualization. According to McGee (1979), spatial orientation involves the comprehension of the arrangement of elements within a visual stimulus pattern, the aptitude for remaining unconfused by chancing orientations in which a configuration may be presented, and the ability to determine spatial relations in which the body orientation of the observer is an essential part of the problem; spatial visualization is an ability to mentally manipulate, rotate, twist or invert pictorially presented spatial visual stimuli. The underlying ability appears to involve a process of recognition, retention, and recall of a configuration in which there is a movement among the internal parts of the configuration, or of an object manipulated in three-dimensional space, or the folding and unfolding of flat patterns. Linn and Petersen (1985, p. 1484), in a meta-analysis article, maintain three categories; “spatial perception”, “spatial rotation” and “spatial visualization”. According to them, spatial perception is a kind of spatial ability that requires a subject to determine spatial relationships with respect to the orientation of their own bodies, in spite of distracting information; spatial rotation is a kind of ability that requires a subject to rotate a two-dimensional or three dimensional figure rapidly and accurately; spatial visualization is a kind of spatial ability that requires the subject to demonstrate an ability that involves complicated, multi-step manipulations of spatially presented information. Although the components above exist, in a recent research, Contero et al. (2005) used three factors of spatial ability which are spatial relations, spatial visualization and spatial orientation. In this article, we don’t give their definitions, because they are based on the researchers’ findings. We finally emphasize the components of the spatial ability in Table 1. In this work, we used the definitions of Ekstrom et al. (1976) and McGee (1979).

Table 1: Researchers’ definitions on components of the spatial ability

	Researcher(s)			
The Component	*Ekstrom et al. (1976)*	*McGee (1979)*	*Linn and Petersen (1985)*	*Contero et al. (2005)*
Spatial Perception			√	
Spatial Orientation	√	√	√	√
Spatial Visualization	√	√	√	√
Spatial Relations				√

One can see from definitions above, the spatial ability is strongly linked to rotation and visualization abilities. Therefore, the idea of measuring spatial ability is related to rotation and visualization tasks. In the related literature, there are many tests measure spatial ability. Some of them only focus on spatial visualization and some focus only on rotation. These differences are due to different definitions of the components of the spatial ability. For instance, Purdue spatial Visualization Test, D’Costa Paper Folding Test, MGMP Spatial Visualization Test, ETS Surface Development Test, Minnesota Paper Form Board. Olkun (2003), Sorby (2007) and Williams et al. (2010) give a brief classification about mentioned tests and express some examples of the standard tests.

Spatial Ability and Mathematics Education

Albert Einstein points out that verbal processes seemed not to play a role in his creative thought; rather he claimed to achieve insights by means of thought experiments on visualized systems of waves and physical bodies in states of relative motion (Lohman, 1993). Albert Einstein's description of visualization was right. Because a good number of researchers indicate that spatial ability is positively related to mathematics achievement (Battista, 1990; Fennema and Sherman, 1977; Kayhan, 2005; Turgut, 2007) and also physics and science (Delialioğlu 1996; Delialioğlu and Aşkar, 1999). Guay and McDaniel (1977) have also found that among elementary school children, high mathematics achievers have greater spatial ability than low mathematics achievers (p. 214). Besides, Tartre (1990) observed that the ninth-grade students who possessed higher spatial skills were able to analyze mathematical problems, organize their thinking and relate new problems with previous knowledge. After the observations of Tartre (1990), it is safe to report that, spatial ability is also important in the process of mathematical problem solving development. Another work dealt with by Battista et al. (1989) investigated the relationship among strategies used by pre-service elementary teachers in geometric problem solving, the spatial visualization and formal reasoning. The researchers found that spatial visualization, formal reasoning and problem solving performance were significantly related to geometry course grade, and that spatial visualization and formal reasoning were significantly related to problem solving performance. As explained, development of the spatial ability is a very important task because we have to understand and develop the geometry knowledge of the students in the unity of the theoretical knowledge and spatial abilities (Nagy-Kondor, 2007). Here, one can ask a question on whether this ability can be improved or not. Several studies have appeared in the literature. However, inconsistent results are found on the development of spatial ability. For instance, Ferrini-Mundy (1987) investigated the effects of spatial training upon calculus achievement, spatial visualization ability, and the use of visualization in solving problems on solids of revolution. The findings indicated that the spatial training program was not statistically significant in improving spatial ability scores. However, the research indicated that spatial training program was effective in improving the scores o the solid problems. On the other hand, in another work, Ben-Chaim et al. (1988) conducted a research on middle school students to determine the effect of building and drawing activities with small cubes. After instruction, the students had significant gains from the training. Rafi et al. (2005) conducted an experimental study using a Web-based Virtual Environment in Computer-Aided-Design (CAD) course with 98 pre-service teachers. Subjects of the study were pre-tested at the beginning of the semester with spatial tests focusing on mental rotation and spatial visualization to provide the baseline measurement. After five weeks applications in CAD course, post-testing of spatial tests revealed significantly the overall spatial ability improvements as measured by the test scores. In a recent study Yolcu and Kurtuluş (2010) also accomplished development of elementary school students' spatial ability by the help of isometric drawings. In another work, Kurtuluş (2011) investigated the effect of computer-aided perspective drawings on eighth grade primary school students' achievement in spatial orientation and perspective drawing. In the lessons of the experimental group students, on the other hand, perspective drawing applications were carried out using computer-aided teaching method for two and a half weeks (10 class hours). It was determined that there was a statistically significant difference between the Spatial Orientation test rank-score means and the Perspective Drawing test rank-score means of the experimental group students and the control group students. Kurtuluş and Uygan (2010) aimed to determine effects of Sketchup based geometry activities and projects on spatial visualization ability of students mathematics teachers. In instruction of experimental group, problem based activities being related to solid objects were solved and a project designed in Sketchup environment. There was a significant difference between two groups in favour of experimental group. By the aid of the recent results educators agree on the use of drawing and building activities in the process of mathematics teaching (Olkun, 2003).

Gender Differences in Spatial Ability

The researchers investigated the possibility of a gender difference in spatial ability. Some studies have shown that males perform better than females on spatial visualization tests (Battista, 1990; Ben-Chaim et al. 1988; Tartre, 1990). There is a great deal of evidence to suggest that spatial skills of women lag significantly behind those of their male counterparts (Sorby, 2007, p.2). Since, this gender difference in spatial visualization has been widely accepted, some researchers have proposed that this difference has resulted in fewer females in certain careers, such as engineering and architecture than males (Strong, 1999). Pietsch and Jansen (2012) investigated the effect of long-term physical and musical activity on spatial cognitive performance, measured by mental rotation performance in detail. In the work well known gender difference favoring males was found for both sports and education students but not for music students. In contrast to these results, Manger and Eikeland (1998) addressed in their study which was conducted among 724 Norwegian sixth-grade students that there were no significant sex difference in spatial visualization. Due to these conflicting results the educators are still interested in gender difference in case of spatial ability.

Research Significance

Investigating spatial visualization is important because of correlational and logical-intuitive support for its relationship to most technical-scientific occupations and especially to the study of mathematics, science, art and engineering (Ben-Chaim et al., 1988). On the other hand, geometry is an important subject in the primary mathematics program. Spatial ability of have been widely studied and are known to be fundamental to higher-level thinking, reasoning and creative process (Sorby, 2007, p.1). Additionally, in a recent study, by Turgut et al. (2009), it has been observed that pre-service primary mathematics teachers who will teach mathematics soon do not have adequate proficiency in spatial ability components and how to develop this ability. And Cantürk-Günhan et al. (2009) addressed that a graduate student working as a teacher has low spatial ability. These are important problems for learning and teaching mathematics in primary schools. In light of the existing literature, we explore the relationships among academic success, gender and spatial ability which may open doors to new research on the development of spatial ability at university level. This work posed the following questions:

1. What is pre-service primary mathematics teachers' spatial ability level?
2. Is there a significant relationship between pre-service primary mathematics teachers' academic success and their spatial ability?
3. Is there a significant relationship between pre-service primary mathematics teachers' gender and their spatial ability?
4. Is there a significant relationship between pre-service primary mathematics teachers' spatial orientation and spatial visualization abilities?

METHOD

The purpose of the study is to determine relationships among pre-service primary mathematics teachers' gender, academic success and spatial ability. Hence, this is a correlational study. The subjects of the study are 193 pre-service primary mathematics teacher students (sophomore and senior level) consisting of 111 women and 82 men.

Measurement Instruments

In this work, we use spatial ability test developed by Ekstrom et al. (1976) consisting of two main sub-tests. The first one is the Spatial Orientation Ability Test (SOAT) (Kayhan, 2005). It also consists of two sub-tests: Card Rotation Test (CRT) and Cube Comparison Test (CCT). CRT is developed to measure the ability to see the differences between the shapes and true-false items. In CRT, there are 160 items. CCT is developed to measure the ability of mental rotation. In CCT, there are cubes that have six faces with different numbers, figures or letters on each surface and one decides whether the given cubes are the same or not. It consists of 42 questions. The score of the SOAT is the summation of the scores obtained by CRT and CCT sub-tests.

The second test is Spatial Visualization Test (SVAT) (Kayhan, 2005). It also consists of two sub-tests. Paper Folding Test (PFT) and Surface Development Test (SDT). PFT test consists of multiple choice items that require imagining folding and unfolding a piece of paper. There are 20 questions. In SDT test there are 60 questions. SDT requires imagining the development of different objects by folding a piece of paper, and consists of matching items. In Appendix-A, sample questions of SAT are given directly from Kayhan (2005). In Table 2, reliability coefficients and total scores of tests are expressed.

Table 2: Reliability Coefficients, Number of the questions and Total Scores of the Spatial Ability Test

Test		*Reliability*	*Number of Questions*	*Total Scores*
SOAT	CRT	0.80	160	160
	CCT	0.84	42	42
SVAT	PFT	0.84	20	20
	SDT	0.82	60	60

Procedure

Before the tests were administered, the necessary permissions were obtained from the department of primary education. The Turkish version of the Spatial Ability Test translated and administered by Delialioğlu (1996) is used. Permission from Ö. Delialioğlu is also taken via e-mail. For all tests, 40 minutes were given to students to complete the whole test.

Analysis of the Data

To analyze the obtained data descriptive statistics, the Mann-Whitney U test and the Pearson Product Moment Correlation Coefficient were used with the aid of the SPSS 13.0 program.

RESULTS

Results of the Research Question 1

To examine pre-service primary mathematics teachers' spatial ability level, we used descriptive statistics. The results are given in Table 3.

Table 3: Descriptive results of spatial ability, its components and gender

Gender	*N*	*SOAT*		*SVAT*		*Total-SAT*	
		$\bar{x}$	*S.d.*	$\bar{x}$	*S.d.*	$\bar{x}$	*S.d.*
Girl	111	175.52	25.72	39.50	18.73	214.64	37.64
Boy	82	174.09	20.63	38.35	17.79	212.32	33.06
Total	193	174.80	23.17	38.92	18.26	213.48	35.35

It is seen from Table 3 that students' mean on SAT is $\bar{x} = 213.48$ with $Sd = 35.35$. The means of sub-factors of the spatial ability are obtained as for SOAT, $\bar{x} = 174.80$ with $Sd = 23.17$, and for SVAT, $\bar{x} = 38.92$ with $Sd = 18.26$. Comparing maximum scored of the SAT 282 with pre-service primary mathematics teachers' mean, it can be said that their spatial ability was roughly low.

Results of the Research Question 2

To examine the difference between pre-service primary mathematics teachers' academic success and spatial ability, we used the Pearson Product Moment Correlation Coefficient. We present the results in the Table 4. When Table 4 is examined, a statistically significant correlation is seen between the spatial ability and academic success of pre-service primary mathematics teachers (r=.36, p< .01). Also, it can be concluded from the results that the spatial orientation ability and academic success were significantly correlated (r=.29, p< .01), but not as strongly as spatial visualization ability and academic success (r=.32, p< .01).

Table 4: Pearson product moment correlation coefficients of pre-service primary mathematics teachers' academic level and spatial ability

	Correlation Coefficient
SAT-AS	0.36* p= .00
SOAT-AS	0.29* p=.00
SVAT-AS	0.32* p=.00

*Significance Level is .01

Results of the Research Question 3

To determine the difference between pre-service primary mathematics teachers' gender and spatial ability, first we investigate the distribution character of the spatial ability scores. Kolmogorov-Smirnov normality analysis results are given in the Table 5.

Table 5: Results of kolmogorov-smirnov normality test on measuring spatial ability

Measurement		*Kolmogorov-Smirnov*		
		Statistics	df	p
SAT	Women	0.102	111	0.006
	Men	0.107	82	0.022

In the Table 5, we observe that distribution of the scores with respect to gender does not have the characterization of normality ($p< .05$). Therefore, to compare the means, we use a non-parametric test the Mann-Whitney U test. We express the results in the Table 6.

Table 6: Results of Mann-Whitney U test of spatial ability with respect to gender

Gender	N	Mean Rank	Sum of Ranks	U	p
Woman	111	99.28	11020.50	4297.50	.509
Man	82	93.91	7700.50		

The results indicate that there is no statistically significant difference between pre-service primary mathematics teachers' scores of spatial ability and gender ($U=4297.5$, $p> .05$). It can be said that there is no difference between women's and men's spatial ability.

Results of the Research Question 4

We used one more Pearson Product Moment Correlation coefficient to determine the relation between spatial orientation and spatial visualization ability. The results are given in the Table 7.

Table 7: Pearson product moment correlation coefficients of pre-service primary mathematics teachers' spatial orientation and spatial visualization abilities

	Correlation Coefficient
SOAT-SVAT	.42*
	p=.00

*Significance Level is .01

It has been observed that spatial orientation and spatial visualization ability of pre-service primary mathematics teachers are positively correlated ($r=.42$, $p<.01$).

CONCLUSIONS AND DISCUSSION

Researchers pointed out the importance of spatial ability in the process of teaching and learning mathematics. So, thereafter educators have studied its relationships with other abilities or gender and achievements in science. The aim of these works was to develop this important ability by the help of the existing relationships. For instance, we know that spatial ability is positively correlated to mathematics achievement (Battista, 1990; Fennema and Sherman, 1977; Turgut, 2007), since recent works recommend considering spatial ability and the use of some building activities and isometric drawings in teaching mathematics. The mentioned recommendations were for primary and secondary school students. The problem is to develop adults' spatial ability which is still an open problem.

In the existing literature, we observe that the researchers focus on primary and secondary school students more than on adults. In this work, we were interested in adults as well as pre-service primary mathematics teachers' spatial ability and its relationships with gender and academic success. We found that their spatial ability level was low. While they were completing the spatial test, they said that it was really hard and the process of the imagination of the pieces was not easy for them. However, the subjects of the study were sophomore and senior students of primary mathematics teacher department who took geometry and linear algebra courses. So they see and manipulate different versions of lines and planes in three-dimensional space. Therefore, we think that the determination of the effect of geometry course on students' spatial ability is important and an open problem. Besides, what kind of activities should be used? In the light of the obtained results, we think that the geometry course should be updated in terms of the spatial ability. Nagy-Kondor's (2010) activities developed by GeoGebra and Cinderalla may be added to syllabus of the geometry course.

We found that academic success was positively related to spatial ability. This result supported previous findings of (Battista, 1980; Fennema and Sherman, 1977; Kayhan, 2005; Turgut, 2007). We also observed that there was no significant difference between spatial ability and gender. This result supported the findings of Manger and Eikeland (1998). However, the subjects of the study were restricted to 111 women and 82 men. For a further research it can be dealt with the same aim on equal subjects.

Finally, we found that the abilities of spatial orientation and spatial visualization are positively correlated, but not strongly ($r=.42$, $p<.01$). This result supported the distinction of the two major abilities of the spatial ability as stated by Ekstrom et al. (1976) and McGee (1979). So, it can be said that they are different abilities.

Now, we stress the importance of our study at university level according to spatial ability and propose the following questions for the researchers.

1. How we can adapt some of spatial activities to pre-service primary mathematics teachers' program?
2. Do the courses analytic geometry or differential geometry effect students' spatial ability?
3. What are the relationships of spatial ability with other lessons? For instance, is there a significant relationship between calculus or algebra achievement with spatial ability?

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REFERENCES

Alkan, F. & Erdem, E. (2011). A study on developing candidate teachers' spatial visualization and graphing abilities, *Procedia Social and Behavioral Sciences* 15, 3446–3450.

Battista, M.T. (1990). Spatial Visualization and Gender Differences in High School Geometry. *Journal for Research in Mathematics Education*, 21 (3), 47-60.

Battista, M.T. et al. (1982). The Importance of Spatial Visuaization and Cognitive Development for Geometry Learning in Preservice Elemantary Teachers. *Journal for Research in Mathematics Education*, 13 (5), 332-340.

Ben-Chaim, D. et al. (1988). The Effect of Instruction on Spatial Visualization Skills of Middle School Boys and Girls. *American Educational Research Journal*, 25 (1), 51-71.

Cantürk-Günhan, B. et al. (2009). Spatial Ability of a Mathematics Teacher: The Case of Oya, *IBSU Scientific Journal*, 3 (1), 151-158.

Contero, M. et al. (2005). Improving Visualization Skills in Engineering Education. *Computer Graphics in Education*, Sep/Oct, 24-31.

Delialioğlu, Ö. (1996). *Contribution of students' Logical Thinking Ability, Mathematical Skills and Spatial Ability on Achievement in Secondary School Physics.* Dissertation, Ankara: Middle East Technical University.

Delialioğlu, Ö. & Aşkar, P. (1999). Contribution of Students' Mathematical Skills and Spatial Ability in Secondary School Physics, *Journal of Hacettepe Faculty of Education*, 16-17, 34-39.

Ekstrom, R.B. et al. (1976), *Manual for Kit of Factor Referenced Cognitive Tests*. Princeton, NJ: Educational Testing Service.

Fennema, E. & Sherman, J.A. (1977). Sex-Related Differences in Mathematics Achievement and Related Factors: A Further Study, *Journal for Research in Mathematics Education*, 7 (3), 189-203.

Ferrini-Mundy, J. (1987). Spatial Training for Calculus Students: Sex Differences in Achievement and in Visualization Ability, *Journal for Research in Mathematics Education*, 18 (2), 126-140.

Guay, R. & McDaniel, E. (1977). The relationship between mathematics achievement and spatial abilities among elementary school children. *Journal for Research in Mathematics Education,* 8 (3), 211-215.

Ives, D.L. (2003). *The Development of Seventh Graders' Conceptual Understanding of Geometry and Spatial Visualization Abilities Using Mathematical Representations With Dynamic Models.* Dissertation, The Graduate School of Montclair State University.

July, R.A. (2001). *Thinking in Three Dimensions: Exploring Students' Geometric Thinking and Spatial Ability with The Geometer's Sketchpad.* Dissertation, Florida International University, College of Education.

Kayhan, E.B. (2005). *Investigation of High School Students' Spatial Ability*. Dissertation, Ankara: Middle East Technical University.

King, J.M. (1992). *A Study of The Use of Spatial Skills in a Three-Dimensional Logo Envoirement*. Dissertation, Florida State University College of Education.

Kurtuluş, A. & Uygan, C. (2010). The Effects of Google Sketchup Based Geometry Activities and Projects on Spatial Visualization Ability of Student Mathematics Teachers, *Procedia Social and Behavioral Sciences,* 9, 384-389.

Kurtuluş, A. (2011). Effect Of Computer-Aided Perspective Drawings On Spatial Orientation And Perspective Drawing Achievement, *TOJET: The Turkish Online Journal of Educational Technology,* 10 (4), 138-147.

Linn, M.C. & Petersen, A.C. (1985). Emergence and Characterization of Sex Differences in Spatial Ability: A-Meta Analysis, *Child Development*, 56, 1479-1498.

Lohman, D.F. (1993). *Spatial Ability and G.* Paper presented at the First Spearman Seminar, University of Plymouth, July 21, 1993.

Manger, T. & Eikeland, O.J. (1998). The Effects of Spatial Visualization and students' Sex on Mathematical Achivement, *British Journal of Psychology*, 89, 17-25.

McGee, M.G. (1979). Human spatial abilities: psychometric studies and environmental , genetic, hormonal and influences. *Psychological Bulletin,* 86 (5), 889-918.

Nagy-Kondor, R. (2007). Spatial Ability of Engineering Students, *Annales Mathematicae et Informaticae,* 34, 113-122.

Nagy-Kondor, R. (2010). Spatial Ability, Descriptive Geometry and Dynamic Geometry Systems, *Annales Mathematicae et Informaticae,* 37, 199-210.

National Council of Teachers of Mathematics. (2000). *Principles and Standarts for School Mathematics*. Reston, Va.: National Council of Teachers of Mathematics.

Olkun, S., (2003). Making Connections: Improving Spatial Abilities with Engineering Drawing Activities, *International Journal of Mathematics Teaching and Learning,* Retrieved on 17 October 2009 at http://www.ex.uk/cimt/ijmt1/ijabout.htm.

Pietsch, S. & Jansen, P. (2012). Different Mental Rotation Performance in Students of Music, Sport and Education, *Learning and Individual Differences,* 22, 159-163.

Rafi, A. et al. (2005). Improving Spatial Ability Using a Web-based Virtual Environment (WbVE), *Automation in Construction*, 14, 707-715.

Sorby, S.A. (2007). Developing 3D Spatial Skills for Engineering Students, *Australasian Journal of Engineering Education,* 13 (1), 1-10.

Strong, S.D. (1999). *The Development of a Computerized Version of Vandenberg's Mental Rotation Test and the Effect of Visuo-Spatial Working Memory Loading*. Dissertation, Iowa State University.

Tartre, L.A. (1990). Spatial Orientation Skill and Mathematical Problem Solving, *Journal for Research in Mathematics Education*, 21, 216-229.

Turgut, M. (2007). *Investigation of 6., 7. and 8. Grade Students' Spatial Ability*. Dissertation, Izmir: Dokuz Eylül University.

Turgut, M. et al. (2009). An Investigation of Knowledge Level About Spatial Ability. *E-Journal of New World Sciences Academy,* 4 (2), 317-326.

Williams, C.B. et al. (2010). Exploring Spatiala Reasoning Ability and Design Cognition in Undergraduate Engineering Students, *Proceedings of the ASME 2010 International Design Engineering Technical Conference & Computers and Information in Engineering Conference,* 1-8.

Yılmaz, H.B. (2009). On the Development and Measurement of Spatial Ability, *International Electronic Journal of Elementary Education,* 1 (2), 83-96.

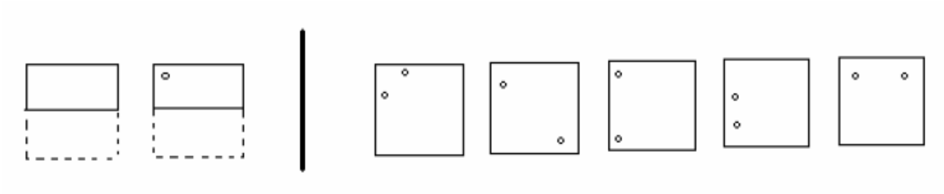
Yolcu, B., Kurtuluş, A. (2010). A Study on Developing Sixth-Grade Students' Spatial Visualization Ability, *Elementary Education Online*, 9 (1), 256-274.

APPENDIX-A

Sample Questions of Spatial Ability Test

Paper Folding Test

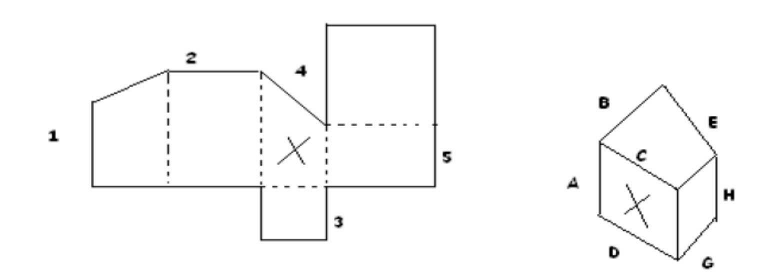
The square shaped paper on the left side on the vertical line is folded and then a hole is made. After unfolding the paper, which one of the shapes right side of the vertical line will appear?



Surface Development Test

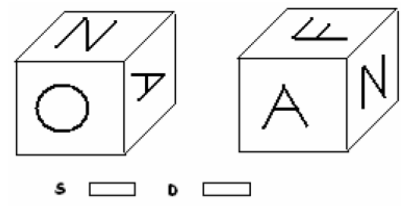
When the paper is folded from the dotted lines, the subject on the right will be formed. By imagining the folding of the paper, match the numbered edges to the letters.

p.c. the surface marked by X on unfolded paper on the left and on the subject on the right shows the same surface.



Cube Comparison Test

In the following cubes all the numbers, figures and letters appears only once on each cube, but it can be unseen position. Then, find out whether the cubes on the left and the right are the same. If the cubes are the same then mark **S** (same), otherwise mark **D** (different).



Card Rotation Test

This test requires the comparing the shape of on the left side of the vertical lines with the eight shapes on the right side of the vertical line. Find out whether the shapes on the right side can be determined by rotating the shape on the left side of the vertical line, in other words examine whether the shapes are same or different. If the shapes are the same as the shape of the left side of the vertical line, then mark **S** (same), otherwise mark **D** (different).