SPATIAL VISUALIZATION SKILLS OF HUNGARIAN AND TURKISH PROSPECTIVE MATHEMATICS TEACHERS

Melih Turgut [1]

Eskişehir Osmangazi University, Faculty of Education, Meşelik Campus, Eskişehir-Turkey

Rita Nagy-Kondor[2]

University of Debrecen, Faculty of Engineering, Debrecen-Hungary

ABSTRACT

This report investigated spatial visualization skills of two samples of junior level prospective elementary mathematics teachers from Hungary (n=78) and Turkey (n=81) who were enrolled to elementary mathematics teacher training departments. This work was a correlational study and in the work a reduced version of Heinrich spatial visualization test (HSVT), which is a paper-pencil test consists of 25 items of spatial visualization problems related to synthesis and decomposition of pieces, was used. According to results, there was a significant difference between Hungarian and Turkish prospective mathematics teachers' scores of HSVT in favor of Hungarian sample and there was no gender difference for each and overall groups. Moreover, we finally give descriptive results of the least and the most items marked correctly in HSVT in a brief way.

Keywords: Spatial ability, spatial visualization, prospective mathematics teachers.

[1] mturgut@ogu.edu.tr
[2] rita@eng.unideb.hu

INTRODUCTION AND THEORETICAL BACKGROUND

Because spatial ability has received much attention in recent years, it can be expressed that development of this ability is important for each area of science, technology, engineering and mathematics (STEM) fields (Cohen & Hegarty, 2012; Wai, Lubinski & Benbow, 2009). For instance, National Council of Teachers of Mathematics [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 (cited in Ives, 2003, p. 4). Studies on spatial ability not only arise in the field of mathematics & geometry education (Battista, 1990; Bosnyak & Nagy-Kondor, 2008; Bulut & Köroğlu, 2000; Guay & McDaniel, 1977; Kalogirou & Gagatsis, 2011; Kurtuluş & Uygan, 2010; Olkun, 2003; Turgut, 2007; Turgut, 2010; Turgut & Yenilmez, 2012) or engineering education (Nagy-Kondor, 2007; Sorby 2007; Sorby, 2009; Williams, Gero, Lee & Paretti, 2010) but also in chemistry, physics education (Alkan & Erdem, 2011; Delialioğlu & Aşkar, 1999) and psychology & psychology education (Burin, Delgado & Prieto, 2000; Kyttala & Lehto, 2008). According to results of these studies, it can be said that researchers agree that spatial thinking is necessary for the development of visual reasoning, scientific thought, ability to think and imagine the manipulation of stimuli treatments particularly in mathematics and geometry applications. Because spatial thinking is important in the education of STEM fields, at this point, one question may come to mind: Is there a comprehensive definition of spatial ability? In the existing literature, there are definitions of spatial ability by the names of spatial reasoning, spatial visualization or spatial skills (Cantürk, Yılmaz & Turgut, 2009). According to Linn and Petersen (1985, p. 1982), spatial reasoning refers to “the skill in representing, transforming, generating and recalling symbolic nonlinguistic information”. Another definition about spatial reasoning expressed by Williams et al. (2010) as “the ability 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” (p. 2). Lohman (1993) stated that spatial ability may be defined as “the ability to generate, retain, retrieve and transform well-structured visual images” (p. 20). And according to Alkan and Erdem (2011), “spatial abilities are described as the combination of the skills such as creating mental pictures of objects in the universe, recognizing in different ways and budging these objects as a whole or in pieces individually" (p. 3446). The existence of these differences on the definitions of spatial ability led to different definitions of components (factors) of the spatial ability (Turgut & Yılmaz, 2012). For instance, Ekstrom et al. (1976) defined two principal components of spatial ability as the *spatial visualization* and *spatial orientation*. Ekstrom et al. (1976) expressed that "*spatial orientation* involves the ability to perceive spatial patterns or to maintain orientation with respect to objects in space". And according to Ekstrom et al. (1976) *spatial visualization* involves the ability to manipulate or transform the image of spatial patterns into other arrangements or the *mental rotation* of a three dimensional stimuli. 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. Linn and Petersen (1985, p. 1484), in a meta-analysis article, maintain spatial ability into three categories; *spatial perception, spatial-mental rotation* and *spatial visualization*. According to them, *spatial perception* is a kind of spatial ability that requires to determine spatial relationships with respect to the orientation of their own bodies; *mental 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.

Several studies have indicated that there are various factors effecting spatial ability. One of well – known factor is gender. According to Yılmaz (2009), "in general, boys have a higher spatial ability than girls which may be caused by biological and/or environmental factors" (p. 93). And the related literature shows that there is a significant male advantage on mental rotation tasks at every age (Linn & Petersen, 1985; Pietsch & Jansen, 2012; Voyer, Voyer & Bryden, 1995). These results were derived by the aid of the interesting test of Vanderberg and Kuse (1978) and its original version developed by Shepard and Metzler (1971). According to Linn and Petersen (1985) and Voyer et al. (1995) the factor of spatial visualization also shows a male advantage. There are conflicting results in the reviewed literature about this fact. For instance, while Turgut and Yenilmez (2012) concluded that there was not a significant difference between male and female groups’ scores in spatial visualization, Dursun, Işıksal and Çakıroğlu (2010) observed a significant difference. Related to this fact, Turgut and Yılmaz (2012) stated that “due to these conflicting results the educators are still interested in gender difference in case of spatial ability” (p. 10).

We know that development of geometrical and spatial reasoning is very important in the training process of prospective mathematics teachers. Besides, Sorby (2007) stated that “spatial ability of have been widely studied and are known to be fundamental to higher – level thinking, reasoning and creative process” (p. 1). In the light of these statements, we investigate and compare Heinrich spatial visualization test performances of two samples of junior level prospective elementary mathematics teachers from teachers from Hungary (n=78) and Turkey (n=81) enrolled to mathematics teacher training departments with respect to variable of gender. So, this work posed the following questions:

1. What are prospective Hungarian and Turkish elementary mathematics teachers’ spatial visualization ability levels?
2. Is there a significant relationship between prospective Hungarian and Turkish mathematics teachers’ gender and their spatial visualization ability?
3. What is prospective Hungarian and Turkish elementary mathematics teachers’ correct response rates of each item of Heinrich spatial visualization test?

METHOD

Subjects

The total subjects were 78 (53 females, 25 males; age range 19 to 21 years) junior level of prospective elementary mathematics teachers from Hungary, and 81

(57 females, 24 males; age range 19 to 20 years) junior level of prospective elementary mathematics teachers from Turkey. Subjects of the study are volunteered to participate and confidential feedbacks were given to those participants who are interested in. The Turkish junior level prospective elementary mathematics teachers were recruited from a government university located in the western Turkey and the Hungarian sample recruited from a government university located in the eastern of Hungary.

Instruments

One of paper-and-pencil test was selected to measure spatial visualization ability of junior level prospective elementary mathematics teachers: a reduced version of Heinrich Spatial Visualization Test (HSVT). This test was developed by Heinrich (1989) to examine the spatial abilities of engineering graphics students. The original HSVT includes two major expert skills in spatial visualization: synthesis and decomposition. At this point, Chen (1995) stated that “for each two basic skills she hypothesized that when mental rotation was added to these tasks at three hierarchical levels of complexity, this would render the spatial problem solving progressively more difficult” (p.2). The original HSVT consists of 48 items divided into 6 scales: (1) synthesis without rotation; (2) decomposition without rotation; (3) synthesis with one-step rotation; (4) decomposition with one-step rotation; (5) synthesis with two-step rotation; (6) decomposition with two-step rotation. Kuder-Richardson 20 (n=177) reliability of 0.94 was reported by Heinrich (1989). In this work, following theoretical aspects of the HSVT, we used 25 items of it due to administering to the junior level prospective elementary mathematics teachers. Example items of the test are given in the following figures[3].

[3] Similar items used in the reduced test are given in the light of the examples of Chen (1995).

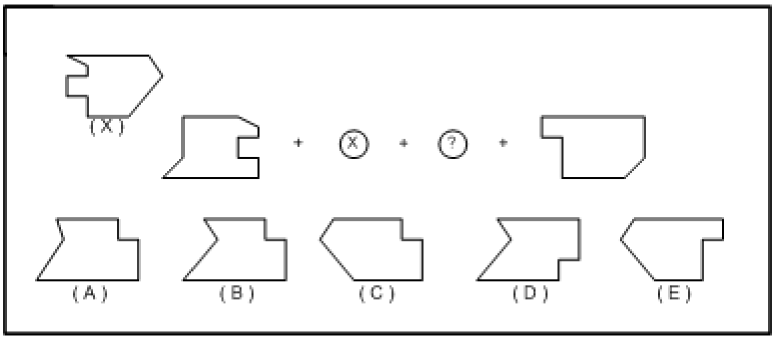

Figure 1. Example item for Synthesis section

Figure 1 expresses an example about the part of “Synthesis”. Synthesize four pieces, adjusting Probe X to fit piece # and selecting one of 5 options A, B, C, D, E to replace the question mark (Chen, 1995, p. 3).

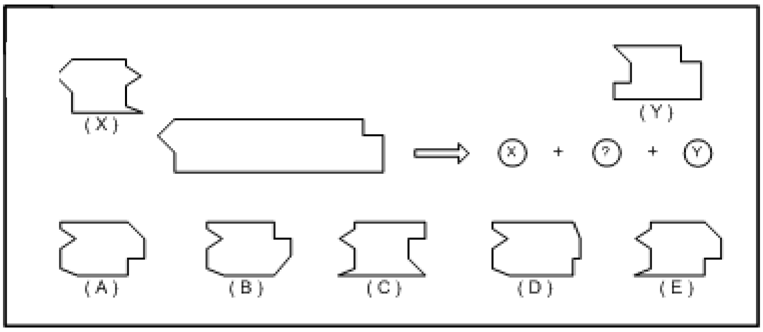

Figure 2. Example item for Decomposition section

In the Figure 2, decompose given pattern three pieces, X+?+Y, where probes X,Y may need to be adjusted, and after selecting one of 5 options, A, B, C, D, E to replace the question mark (a.g.e). The reduced test includes 15 items for the part of “synthesis”, and 10 items for the part of “decomposition”. We also used a personal information form for gathering data on gender and age.

Procedure

Translation

For the all measurements test stimuli were identical for the languages English, Hungarian and Turkish. To ensure comparability, first English instructions were translated into Hungarian and Turkish by the each author. Thereafter, English and translated versions are reviewed by two experienced translators. Hungarian feedbacks are discussed between the second author and the Hungarian translator, and Turkish feedbacks are dealt with by the first author. The final version of tests were administered to the samples.

Administration

All data were collected by the each author during the spring semester of 2012. The test was administered in small groups (max. 40 subjects) to explain instructions, efficiently. Standard instructions were given to two samples of junior level prospective elementary mathematics teachers from Hungary and Turkey. Thereafter they completed the three sample items. The necessary feedbacks, corrections and explanations were administered by the each author. For the entire test, 25 minutes were given to the each sample to fill the whole test.

RESULTS

Mean Scores of Each Sample and Statistical Differences

Means, standard deviations of spatial visualization ability and statistical differences of each group were analyzed in terms of descriptive statistics. The results appear in the Table 1.

Table 1. *Mean scores of HSVT of each sample and statistical differences*

Group		All	Female	Male	Sex Difference	Group Difference
	n	78	53	25		
Hungarian	M	19.57	19.41	19.92	p>.05	
	SD	3.80	4.16	2.92		p<.05**
	n	81	57	24		
Turkish	M	15.91	15.61	16.62	p>.05	
	SD	4.23	4.64	3.01		
	n	159	110	49		
Overall	M	17.71	17.44	18.30	p>.05	-
	SD	4.41	4.79	3.37		

Investigating of each sample's and all subjects' means and standard deviations, we find that Hungarian junior level prospective elementary mathematics teachers mean score of HSVT was 19.57 (SD=3.80), and mean score of Turkish sample was 15.91 (SD=4.23). According to these results, it can be said that

Hungarian and Turkish prospective elementary mathematics teachers had adequate spatial visualization ability.

Table 1 also shows that there was a significant difference (t_{157}=5.37, p<.05) between mean scores of spatial visualization of Hungarian and Turkish junior level prospective elementary mathematics teachers. Hungarian sample performed better than those Turkish did at HSVT. Examination of Table 1 also reveals that both males and females had higher HSVT scores in the Hungarian sample than those for the Turkish sample did. Besides, we observe that sex differences was not significant for each group: Hungarian (t_{76}=0.54, p>.05) and Turkish sample (t_{79}=0.98, p>.05) and for all sample (t_{157}=1.13, p>.05). Here it can be also expressed that although the difference in spatial visualization performance between female and male groups of the total sample was not significant, the data suggested that the difference was bordering on a significant level. In both Hungarian and Turkish sample, male prospective teachers performed than those female did.

Another evidence about Hungarian sample's performance which was better than Turkish sample did was the distribution of the HSVT scores. Figure 3 gives us the results with respect to distribution of the HSVT scores.

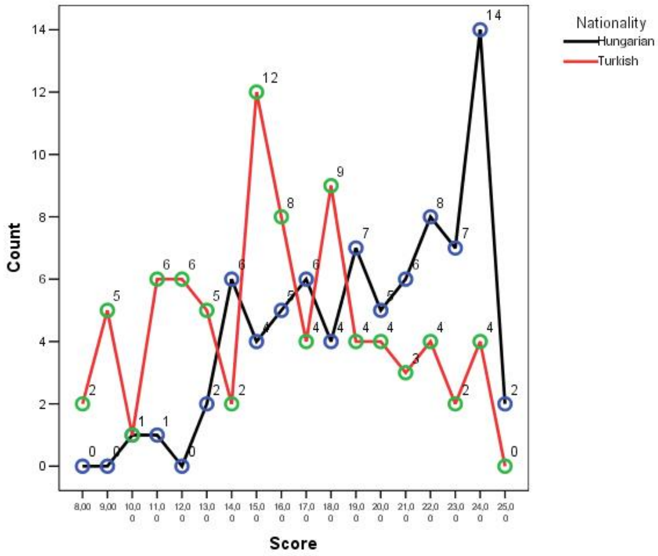

Figure 3. Distribution of the Scores of HSVT

Figure 3 shows that, while there were 49 Hungarian junior prospective elementary mathematics teachers performed 19 and greater scores from the HSVT, in Turkish sample there were 21 prospective teachers. And none of Turkish prospective teachers did give correct responses for the whole HSVT while 2 Hungarian did.

Correct Responses for Each Item of HSVT

Correct responses given to each item of HSVT was presented in the Figure 4. As it is shown, the most items were marked correctly of HSVT were, 5. item with 91.1% correct response rate; 9. item with 89.3% correct response rate; 7.item with 88.6% correct response rate; 3.item with 87.4% correct response rate and 12.item with 86.7% correct response rate.

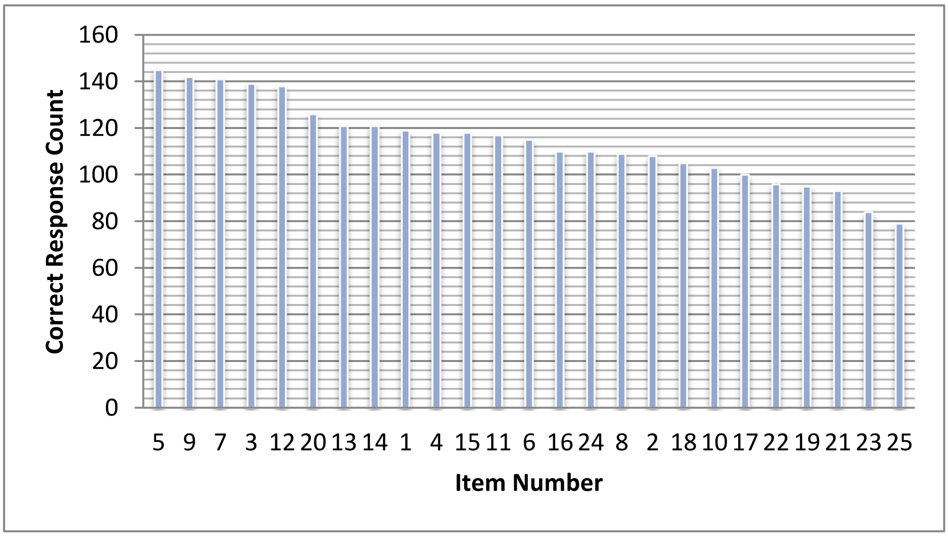

Figure 4. Correct response counts of each item of HSVT

Similar to above results, it is observed that the least items were marked correctly were 25.item with 49.6% correct response rate; 23.item with 52.8% correct response rate; 21.item with 58.4% correct response rate; 19.item with 59.7% correct response rate and 22.item with 60.3% correct response rate. In order to investigate each sample's correct response counts, we analyzed rates for the items 5, 9, 25 and 23. For the item 5 and 9, the results are briefly expressed in the Figure 5.

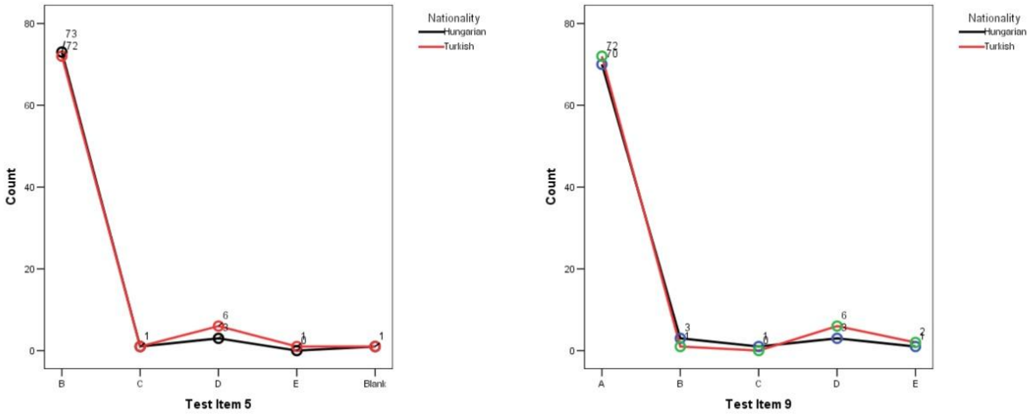

Figure 5. Correct response counts of 5. and 9. items of HSVT

As it seen from the figure above, Hungarian (n of correct response for the item 5 was 73, for the item 9 was 70) and Turkish (n of correct response for the item 5 was 72, for the item 9 was 72) prospective elementary mathematics teachers gave approximately same answers to questions.

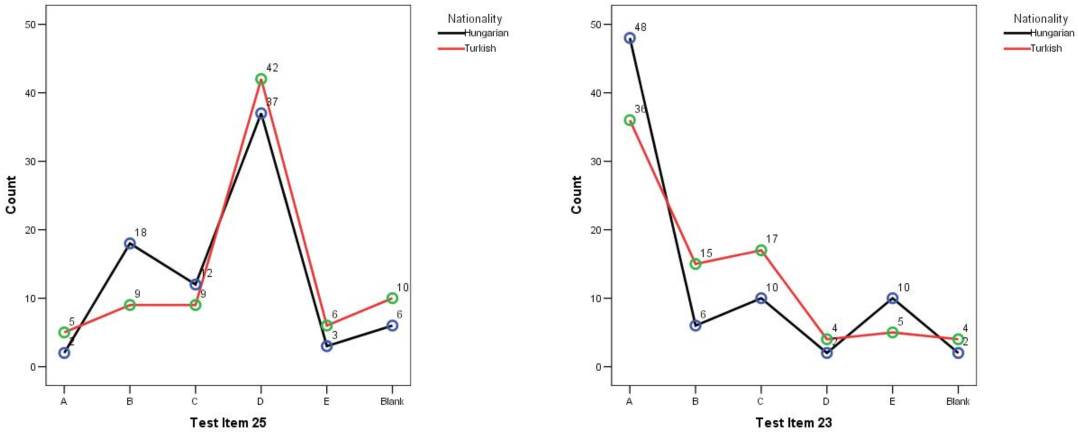

Figure 6. Correct response counts of 25. and 23. items of HSVT

Finally, Figure 6 reports that responses of the least items marked correctly. We also observed that responses show similar characterizations as presented above.

CONCLUSION AND DISCUSSION

In this study, we compared Heinrich spatial visualization test performances of prospective Hungarian and Turkish elementary mathematics teachers. We drew the following conclusions. It is first observed that each group had an adequate spatial visualization level. Besides, we found that there was a significant difference between prospective Hungarian and Turkish elementary mathematics teachers' scores of HSVT in favor of Hungarian sample. We think that one of the reason of this finding may be related to teacher training programs. In order to interpret this fact, we analyze mathematics content courses of the each group. Table 2 summarizes the elementary mathematics teacher training courses in Hungary and Turkey.

Table 2. *Comparisons of Mathematics Teacher Training Programs of Hungary and Turkey*

Hungarian				***Turkish (Only Quantitative Courses)***			
Semester	Course Name	Credits T*	Credits A**	Semester	Course Name	Credits T*	Credits A**
1	Trigonometry and Coordinate Geometry	2	2	1	Computer I	2	2
	Sets and Functions	2	2		General Mathematics	4	2
	Algebra	2	2				
	Informatics	0	3				
	Combinatorics	3	2				
2	Linear Algebra I	2	2	2	Computer II	2	2
	Introduction to Analysis	4	2		Abstract Mathematics	3	0
	Introduction to Algebra and Number Theory	3	2		Geometry	3	0
	Geometry I	2	2				
3	Number Theory I	3	2	3	Analysis I	4	2
	Calculus	4	3		Linear Algebra I	3	0
	Geometry II	2	2		Physics I	4	0
	Algebra	2	2		Graph Theory (Elective)	2	0
	Set Theory and Mathematical Logic	3	2				
4	Number Theory II	3	2	4	Analysis II	4	2
	Multivariable Functions, Differential Equations	5	3		Linear Algebra II	3	0
	Geometry Models	3	2		Physics II	4	0
	Introduction to Probability Theory	2	2				
5				5	Analysis III	3	0
	Differential Geometry	3	2		Analtyic Geometry I	3	0
	Elementary	0	2		Statistics and	2	2

	Mathematics				Probability I		
					Introduction to Algebra	3	0
					Computer Based Mathematics Teaching	2	0
					Differential Equations	4	0
6	History of Mathematics	2	0	6	Analtyic Geometry II	3	0
					Statistics and Probability II	2	2

*Theoretical
**Application

Optional professional subjects in Hungary: Complex Functions (Credits: 3, 2), Computer Geometry (Credits: 0-2), Convex Geometry (Credits: 3-2), Descriptive Geometry (Credits: 3-2), Introduction to Lie Theory (Credits: 3-2), Numerical Mathematics (Credits: 4-2), Projective Geometry (Credits: 3-2), Statistics (Credits: 4-2), Topology (Credits: 3-2). Hungarian prospective teachers get more mathematics area cources from than those Turkish do. Because, Turkish prospective mathematics teachers take educational sciences courses (like Introduction to Educational Sciences, Educational Physcology, Classroom Management, Special Teaching Methods etc.) with the lectures of mathematics content subjects.

It can be seen from the Table 2, Hungarian prospective teachers get more mathematics content courses from than those Turkish do. Because, Turkish prospective mathematics teachers take educational sciences courses (like Introduction to educational sciences, Learning physcology, Classroom management, Special teaching methods etc) together with the lectures of mathematics content subjects. Moreover, it can be concluded from the Table 2 Hungarian sample takes more lectures related to computer and geometry fields which may develop their geometrical and spatial reasoning. To develop spatial ability, the related literature suggests activities including isometric & technical drawings, computer applications and use of geometric manipulative in the teaching process (Baki, Kosa & Guven, 2011; Kurtuluş & Uygan 2010; Kurtuluş, 2011; Olkun, 2003; Nagy-Kondor, 2010; Turgut, 2010). In the mentioned courses there are a lot of applications need the use of spatial thinking. Therefore, suffice it to say that the related literature supports results of the present study.

The second result of the study was about gender difference. We did not observe any gender difference for each or overall groups. While males perform in each group, there was not a significant difference in scores of HSVT. This result also supported the findings of Turgut (2010) and Turgut and Yenilmez (2012) implemented by other spatial ability tests (Card Rotation Test, Cube Comparison Test, Surface Development Test). This report was a part of ongoing international project dealt by two authors. As a further work, we will investigate mental cutting performances and mental rotation performances of the Hungarian and Turkish junior level prospective teachers with respect to variables gender and nationality. As a limitation of this study, we could not interpret significant difference in favor of Hungarian sample deeply. The discussion on this topic was only factor of *gender* and *training curriculums*. However, in the related literature there are various factors effecting spatial ability. In order to make further interpretations about the obtained results, we will analyze each group's data qualitatively in terms of prepared spatial visualization, mental rotation and spatial orientation tasks. On the other hand, similar studies were conducted and concluded that students' education of preschool, primary, middle and secondary school are also important in the development of spatial ability (Bosnyak & Nagy-Kondor, 2008; Kalogirou & Gagatsis, 2011; Turgut, 2007; Turgut, 2010). Therefore, the next step in the project will be comparing of curriculums from preschool to university level and deal with another variables such as *preschool education* and *spatial experience*.

ACKNOWLEDGEMENT

The first author would like to thank Tübitak-BİDEB for their financial supports during his PhD studies. The authors would like to thank the referees for careful reading of the manuscript and for the constructive comments that have substantially improved the presentation of the paper.

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Submitted: September 2012

Accepted: May 2013