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Examining Effects of Mathematical Problem-Solving, Mathematical Reasoning and Spatial Abilities on Gifted Students' Mathematics Achievement

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Abstract

This study examines the relationship between gifted students' mathematical abilities, spatial abilities, and their mathematics achievement. 293 7th-grade gifted students (%51 male, %49 female) participated in the study. Mathematical reasoning and problem-solving scale were used to determine mathematics abilities of students, mental rotation and paper folding tests were used to determine spatial abilities of students and lastly, mathematics achievement test was used to determine students' mathematics achievement. Descriptive analysis, as well as Pearson product-moment correlation coefficient and multiple linear regression analysis, were used in the data analysis. The results showed that the mathematics achievement of the students was high, and their mathematical reasoning and problem-solving abilities were above average. There is a high and average significant relationship between gifted students' mathematical abilities and mathematics achievement. The order of importance of the gifted students' mathematical abilities on mathematics achievement is as spatial thinking, mathematical reasoning and problem-solving. Spatial thinking, mathematical reasoning and problem-solving are the significant predictors of mathematics achievement.

Keywords: Gifted, Mathematical abilities, Spatial abilities, Mathematics achievement.

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Contents

1. Introduction

Mathematics is a basic skill used in daily life and the most important component of technologic developments. Mathematics has a wide area of use ranging from the design of the simplest machines to the most complex electronic devices, from a construction of a small toy to a space shuttle. The quality of a society's improvement in science and technology depends on the training and supporting its people. In this respect training and supporting gifted students is especially important. It is known that gifted students have special talents for mathematics and they have a higher potential to become scientists (Assouline and Lupkowski-Shoplik, 2005; Özyaprak, 2012). Gifted students need mathematics to be successful in other fields. Individuals and societies who could use mathematics effectively could find more chances to shape their future (NCTM, 2000). In this respect, it is understood that being successful in mathematics and having knowledge and skills for it are so important for gifted students.

According to Gagne (2005) intelligence is innate, but it can be an ability only if it is improved. For this reason, the variables predicting gifted students' mathematics skills are needed to be defined and systematically developed. The international exams aiming to determine the student achievement in mathematics and science show that Turkish students are not in the desired level (Mullis *et al.*, 2009; Mullis *et al.*, 2012; Ministry of National Education (MEB), 2013). Therefore, cognitive-affective characteristics which effect mathematics achievement become the center of researches (Bilican *et al.*, 2011; Pahlke *et al.*, 2013; Akyuz, 2014). Theoretical explanations suggest that cognitive characteristics are important factors affecting achievement (Bandura, 1997; Bloom, 1998; Schunk and Zimmerman, 1998). Results obtained from studies regarding mathematics achievement support the theoretical explanations (Lopez *et al.*, 1997; Gainor and Lent, 1998; Pajares and Graham, 1999; Chen, 2003; Wang, 2006; Ferla *et al.*, 2009; Usher and Pajares, 2009). Achievement can be defined as the indicator or the measurement of one's taking advantage of a certain academic program or discipline in the school environment (Özgüven, 2005). Mathematics achievement can be defined as the average point one gets from the exams which are done in line with the mathematics curriculum. As in achievement, personal factors are quite important in mathematics achievement (Peker, 2005; Usher, 2009; Akyuz, 2014). Because of the personal factors, each student cannot achieve the same standards (NCTM, 2000; Özgüven, 2005). Accordingly, checking whether the students achieve in accordance with their talents, researching the factors affecting achievement, and giving practical suggestions to teachers and students are quite important. When the literature examined, it can be seen that there are so many factors affecting mathematics and mathematics achievement. The major factor affecting mathematics and mathematics achievement are self-regulation strategies (Uredi and Üredi, 2005) spatial talent (Battista, 1990; Casey *et al.*, 1992) problem-solving skill (Özsoy, 2005; Günhan and Başer, 2008; Arsal, 2009; Alcı *et al.*, 2010) reasoning skill (Kilpatrick *et al.*, 2001; Ball and Bass, 2003; Umay, 2003; Brodie, 2009; Yurt and Sünbül, 2014) learning styles (Peker, 2005; Şentürk and İkikardeş, 2011)_ motivation (Fadlelmula, 2011; Yıldırım, 2011; Yurt, 2015) self-efficacy (Alcı *et al.*, 2010; Yıldırım, 2011; Caliskan, 2014; Yurt, 2014a). Problem-solving, mathematical reasoning and spatial skills have important places as cognitive skills. A mathematical problem is defined as a problem which needs to be solved but cannot be easily solved with the knowledge at hand (Kayan and Cakıroğlu, 2008). Problem-solving skill in mathematics is taught through mathematical problems. Mathematical problems are cases which requires the mathematical knowledge to be applied and which lead to a search for solutions. With the numbers and symbols, one turns a problem he encounters in real life into a mathematical problem. Then, he solves the problem and applies the solution into the real life. Mathematical problem-solving contains the following stages; (i) identifying and formulating a problem (ii) determining the consistency and sufficiency of the data (iii) using models, data and strategies regarding mathematics (iv) producing, enlarging and reproducing mathematical operations (v) using spatial, deductive, inductive, statistical and proportional reasoning approaches in new mathematical situations (vi) evaluating the solutions in terms of accuracy and logical consistency (National Assessment of Educational Progress (NAEP), 2002). Reasoning skill can be seen as the systematic and logical thinking capacity. Reasoning contains deductive and inductive reasoning methods which are performed through models and patterns. Reasoning is a problem-solving approach used by students when encountering nonroutine problems. It is stated that reasoning involves making generalizations and deductions while learning mathematics, justifying the accuracy of mathematical and non-mathematical deductions, and questioning the validity of thoughts and emotions (NCTM, 2000; MEB, 2009). In order to acquire the reasoning skill a student must learn making logical deductions, using mathematical models, rules and relationships while expressing his thoughts, justifying the solutions and answers of a problem, using relationships and patterns while analyzing a mathematical situation, believing in the fact that mathematics is logical field of science, making predictions, and analyzing patterns and relationships in mathematics (Ersoy, 2006). Another variable which is related to the problem-solving and reasoning and has a significant impact on mathematics achievement is spatial ability. Spatial ability is one's ability to move, spin, and bend an object or objects in his mind. Spatial ability also requires to understand new positions or views of objects which are turned around (Guilford and Zimmerman, 1947). Understanding relationships visually, changing, using and expressing by reorganizing them are all about spatial ability (Tartre, 1990). Generally, spatial ability can be stated as the ability which requires to manipulate visual objects in mind, and in two and three-dimensional space (Yurt and Sünbül, 2014). Former studies showed that spatial ability is closely related to the mathematics achievement, problem-solving and reasoning (Smith, 1964; Fennema and Sherman, 1977; Guay and McDaniel, 1977; McGee, 1979; Fennema and Tartre, 1985; Booth and Thomas, 1999; Delialioğlu and Aşkar, 1999; Hegarty and Kozhevnikov, 1999; Van Garderen and Montague, 2003; Kayhan, 2005; Markey, 2009).

1.1. Purpose and Significance of the Study

It is known that gifted students are successful in various fields and they have different abilities. Mathematics is one of the fields they are most successful. When the literature is reviewed it is seen that there have been no studies on the affective skills affecting gifted students' mathematics achievement. In the education of gifted students, great importance has been placed on mathematics. Nevertheless, no suggestions have been given regarding the abilities and skills to be taught to improve gifted students' mathematics achievement. The present study aims to Examine the effects of mathematical problem-solving, mathematical reasoning and spatial abilities on gifted students' mathematics achievement. So, the predictive power and the order of importance of the mathematical problem-solving, mathematical reasoning and spatial abilities affecting gifted students' mathematics achievement can be found. Moreover, the results of this study will contribute to the development of mathematics curriculum for gifted students.

2. Method

2.1. Model of the Study

This study, which examines the relationships among mathematical abilities, spatial abilities and mathematics achievement, is conducted through relational screening model. Relational screening models aim to define the presence and degree of change between two or more variables (Karasar, 2000).

2.2. Study Group

293 7th-grade gifted students (%51 male, %49 female) studying at Science and Art Centers (SAC) in Adana, Bursa, Çorum, Elazığ, İzmir, İzmit, Kayseri, Konya, Manisa and Salihli provinces of Turkey participated in the study. Wechsler Intelligence Scale for Children which is developed by Wechsler in 1949 and revised in 1974 (WISC-R; Wechsler Intelligence Scale for Children-Revised) is used to choose the students, participated in the study, to Science and Art Center. WISC-R is composed of two scales as verbal and performance. WISC-R was adapted to Turkish by Savaşır and Şahin. It was implemented on a sample of 1639 students whose ages differ from 6 to 16. Split-half reliability coefficient is found as 0,97 for verbal intelligence scale and 0,93 for performance intelligence scale and 0,97 for the total intelligence. Correlation between scales is found between 0,51 and 0,86.

WISC-R is composed of 6 verbals (information, similarities, arithmetic, comprehension, vocabulary, digit span) and 6 performance (picture completion, picture arrangement, block design, coding, object assembly, mazes) subscales and one substitution subscale for each. As well as the standard points for these subscales, points for verbal intelligence, performance intelligence and total test intelligence scales are obtained. Average value for these Intelligence Scales is 100 and the standard deviation is 15. The average standard point for each subscale is 10 and the standard deviation is 3 (Tan, 2012). Participants are chosen form the different geographical regions of Turkey to represent students from these regions. Since a limited number of students are studying at the 7th grade of these SACs, convenience sampling method is used.

2.3. Data Collection Tools

Problem-solving Test: to measure students' problem-solving skills, mathematical problem-solving test developed by Yurt (2014b) is used. It has 12 open-ended questions from numbers, measurement, geometry, pattern, algebra, statistics, and probability fields. Students are asked to express the problem in their own words, to plan the solution, to apply the plan, and to check the result they find for each question with help of the instructions. A scoring rubric is used in the evaluation process and a point between 0 and 4 is given to each question. The construct validity of the test is analyzed with factor analysis and it is found that it has a one-factor structure. The reliability of the test is found as 0,75. The time given for the completion of the test is 40 minutes.

Spatial Ability Tests: Paper folding and mental rotation tests are used to measure students' spatial abilities. With the paper folding test, the spatial visualization ability is measured, and with the mental rotation test, the spatial relations ability is measured. While calculating the general spatial ability points of students the points they obtain from both of the tests are totalized. There are 20 questions in the paper folding test. The quality of each question is equal. In every question first of all the paper is folded, then students make holes on it and lastly, they unfold the paper. Students must predict where the holes will be when the papers unfolded. Every correct answer gets 1 point and every wrong answer or unanswered question gets 0 points (Ekstrom *et al.*, 1976) Mental rotation test has 24 questions. The quality of each question is equal. Mental rotation test requires to manipulate the views of the three-dimensional shapes in the mind. For each question, students are given a three-dimensional shape and four answer choices which are the same as the given shape but in a different view. Students are asked to find the two correct ones out of four. Students get 1 point for every two correct answers and 0 points for one correct or wrong answer (Vandenberg and Kuse, 1978). Paper folding and mental rotation tests are also speed tests. The paper folding test lasts 6 minutes and mental rotation test lasts 16 minutes. Cronbach's Alpha reliability coefficients for paper folding and mental rotation tests are found as 0,75 and 0,72 respectively.

Mathematical Reasoning Test: In order to measure students' mathematical reasoning ability, Mathematical Reasoning subtest developed by Yeşildere (2006) is used. It is based on the mathematical power concept defined by NAEP (2002). Test consists of 10 open-ended questions. Answers are graded between 0 and 4 points according to the scoring rubric. High points obtained from the test show that the mathematical reasoning ability is high. Confirmatory factor analysis of one-factor structure of mathematical reasoning test is done by Yurt (2014b) and as a result, an item is extracted from the test. The Cronbach's Alpha Reliability coefficient of the final test, consisting of 9 questions, is found as 0,76. *Mathematics Achievement:* In order to determine the students' mathematics achievement a placement test developed by Ministry of Education in 2011 is used. It involves 7th-grade mathematics subjects. There are 18 questions in it. To ensure the reliability of the test, views of four mathematics teachers are received. The Kappa value is calculated as 0.89. Kappa values over 0.81 are accepted as perfect adaptation (Landis and Koch, 1977). Therefore, it can be said that there is a perfect adaptation among the opinions received to evaluate achievement test. After the item analysis, average difficulty coefficient is found as 0.46 and average item discrimination is calculated as 0.48. The reliability of the test is examined through KR-20 coefficient and found as 0.86.

2.4. Data Collection Process

Data was collected in the 2015-2016 education year. Suitable SACs for data collection are selected and necessary permissions are received from Ministry of Education Directorate General for Special Education and Guidance Services Department of Gifted Students Education. Data were collected by the mathematics teachers working in the aforementioned SACs in four separate sessions. Tests were implemented on 474 students but not all of them participated in every session. 293 students participating in all the sessions were included in the study. Mathematical problem-solving test, mathematical reasoning test, mental rotation and paper folding tests, and mathematics achievement test were implemented in the first, second, third and fourth sessions respectively.

2.5. Data Analysis

Pearson Product-Moment Correlation method is used to calculate the relationship among mathematical problem-solving skill, mathematical reasoning skill and spatial ability points. With the Pearson Correlation analysis, the strength and direction of the linear relationship between two variables can be determined. The values between 0 and ±0.29, ±0.30 and ±0.59, ±0.60 and ±1 show low, medium and high relationship respectively (Cokluk *et al.*, 2012). In order to determine the effect of mathematical problem-solving skill, mathematical reasoning skill and spatial ability on mathematics achievement, multiple linear regression analysis was used. Before implementing multiple linear regression analysis, the following hypothesis were tested; (i) multivariate normal distribution, (ii) whether there is a linear relationship between the independent variable and predictive variables, (iii)whether there is a multicollinearity problem between the independent variable and predictive variables. In order to examine the multivariate normal distribution, Mardia's multivariate standardized kurtosis coefficient is calculated and examined. That Mardia's multivariate standardized kurtosis coefficient is below 8 means that the data has the multivariate normal distribution values (Yılmaz and Varol, 2015). In this study, the standardized kurtosis coefficient is calculated as 0,307 and it was understood that the data meets the multivariate normal distribution. In the next step, whether the linearity hypothesis was met or not was examined by creating scatter plot matrix of dependent and independent variables. When the matrix examined it was seen that the scattering diagram created to present the relationship between standardized surplus value and standardized predictive values defined a linear relationship. Finally, whether there is a multicollinearity problem between the variables was examined. That the Variance Inflation Factor (VIF) coefficient is below 10 and Durbin-Watson (D-W) coefficient is between 1,5 and 2,5 shows that there isn't a multicollinearity problem between variables. In the present study D-W coefficient was found as 1,90 and the highest VIF value was found as 1,97. These results show that there isn't any multicollinearity problem between the variables. As a result of analysis, it was understood that the data set meets necessary hypothesis for multiple linear regression analysis.

3. Findings

Gifted students' mathematics achievement test, mathematical reasoning test, mathematical problem-solving test and spatial abilities are presented descriptively. The descriptive values the students participated in the study get from the tests are examined and the points of Mathematics achievement, mathematical reasoning, mathematical problem-solving and spatial abilities tests are shown in Table 1.

Table-1. Gifted student's points of Mathematics achievement, mathematical reasoning, mathematical problem-solving and spatial abilities

Variables	Minimum	Maximum	$\bar{X}$	Sd
Mathematics Achievement	0	20	14,60	2,89
Mathematical Reasoning	0	40	23,57	7,50
Problem-Solving	0	56	29,57	11,17
Spatial Ability	0	44	28,22	7,78

Source: These data obtained from Data Collection Tools that mathematics achievement test, mathematical reasoning test, mathematical problem-solving test and spatial ability test.

As is seen in Table 1 gifted students' mathematics achievement ranges from 0 to 20 points. Gifted students' mathematics achievement test average is calculated as 14,60±2,89. According to these results, gifted students' mathematics achievement is high. Gifted students' mathematical reasoning test points range from 0 to 40. Gifted students' mathematical reasoning test average is calculated as 23,57±7,50. These results show that gifted students mathematical reasoning skills are above average. Gifted students' problem-solving test points range from 0 to 56. Gifted students' problem-solving test average is calculated as 29,57±11,17. These results show that gifted students problem-solving skills are above average. Gifted students' spatial ability test average is calculated as 28,22±7,78. These results show that gifted students spatial abilities are above average.

Multiple regression analysis results regarding predictive power of mathematical skills on mathematics achievement

The relationships among gifted students' mathematics achievement, mathematical problem-solving skills, mathematical reasoning skills, and spatial abilities are shown in Table 2.

As is seen in Table 2, a strong positive relationship is found among gifted students' mathematics achievement, mathematical reasoning ($r=0.60$, $p<0.01$) and spatial abilities ($r=0.64$, $p<0.01$). A moderate positive relationship is found between gifted students' mathematics achievement and mathematical problem-solving skills ($r=0.46$, $p<0.01$). A strong positive relationship between gifted students' mathematical reasoning skills and problem-solving skills ($r=0.66$, $p<0.01$), and between their mathematical reasoning skills and spatial abilities ($r=0.60$, $p<0.01$). A moderate positive relationship is found between gifted students' mathematical problem-solving skills and spatial abilities ($r=0.47$, $p<0.01$).

Table-2. Relationships among gifted students' mathematics achievement, mathematical skills and spatial abilities

	Variables	Minimum	Maximum	$\bar{X}$	Sd	V1	V2	V3	V4
V1	Mathematics Achievement	0	20	14,60	2,89	1			
V2	Mathematical Reasoning	0	40	23,57	7,50	,60**	1		
V3	Problem-Solving	0	56	29,57	11,17	,46**	,66**	1	
V4	Spatial Ability	0	44	28,22	7,78	,64**	,60**	,47**	1

**p<0,01 N=293

Multiple regression analysis results regarding predictive power of mathematical skills and spatial abilities on mathematics achievement are shown in Table 3.

Table-3. Multiple Regression Analysis Results Regarding the Effects of Mathematical Reasoning, Mathematical Problem-Solving and Spatial Ability on Mathematics Achievement

Predictor Variables	R	R²	Standardized β	t	F
(Fixed)	,695	,483		14,16**	89,96**
Mathematical Reasoning			,301	5,809**	
Problem-Solving			,066	1,172	
Spatial Ability			,426	8,025**	

**p<0,01,

When the results are examined, it is seen that the mathematical reasoning, mathematical problem-solving and spatial ability significantly affects mathematics achievement (R= 0,695; R2= 0,483; F=89,96; p<0,01). These variables together explain 48% of the total variance in mathematics achievement. However, when the significance test results belonging to calculated coefficients are examined, it is understood that of the predictor variables only mathematical reasoning and spatial abilities are the significant predictors of mathematics achievement. According to the calculated standardized β coefficients, the most effective variables on mathematics achievement are successively spatial ability (β=0.426; p<0.01), mathematical reasoning skills (β=0.301; p<0.01), and mathematical problem-solving skills (β=0.066; p>0.05).

4. Results, Discussion and Suggestions

In line with the purpose of the study first of all the relationship among mathematics achievement and spatial abilities, mathematical reasoning skills and mathematical problem-solving skills is examined. It is determined that the mathematics achievement has a strong relationship with spatial abilities and mathematical reasoning skills, and it has a moderate relationship with mathematical problem-solving skills. These results show that gifted students' mathematics achievement is mostly related to spatial abilities and mathematical reasoning skills.

In the studies conducted on non-gifted students, significant relationships found between mathematics achievement and spatial ability (Delialioğlu and Aşkar, 1999; Kayhan, 2005; Prugh, 2012; Yurt, 2014b) mathematical reasoning skills (Umay and Kaf, 2005; Yurt, 2014b) and mathematical problem-solving skills (Pape and Wang, 2003; Özsoy, 2005; Alcı *et al.*, 2010; Yurt, 2014b). In this respect, results obtained from the gifted students are consistent with the literature. Another finding of the study is that the most important variable predicting the mathematics achievement is spatial ability. Spatial ability requires to manipulate visual objects in mind, and in two and three-dimensional space (Olkun, 2003). Previous studies emphasized that spatial ability is of vital importance in teaching mathematics (Delialioğlu and Aşkar, 1999; Van Garderen and Montague, 2003; Kayhan, 2005; Mix and Cheng, 2012). Since the majority of the topics in mathematics are related to spatial abilities, individuals with spatial abilities tend to be successful in mathematics (Casey *et al.*, 1995; Yurt and Sünbül, 2014; Bruce and Hawes, 2015). Especially mathematics topics such as geometry, measurements and algebra base on the spatial relations and visualization. When encountered with a mathematical situation, individuals must mentally associate the components related to spatial abilities and use them. For instance, when asked to compare the areas of two polygons, individuals must use spatial visualization, mental renovation and mental degradation together. Studies conducted on the fields of neurology and cognitive sciences suggest that human brain tends to perceive numbers spatially (De Hevia *et al.*, 2008). It is observed that in human brain the areas in which numeric and spatial activities occur are very close to each other (Tommasi *et al.*, 2009). Therefore, several studies are carried out to enhance students' mathematics achievement and performances by improving their spatial abilities (Yurt and Sunbul, 2012; Cheng and Mix, 2014; Hawes *et al.*, 2015). When the studies stating the importance of spatial abilities for mathematics and the results of this study are examined together, it can be suggested that gifted students overachieve in mathematics due to their spatial abilities.Another finding of the study is that mathematical reasoning is the second most effective variable after spatial ability on gifted students' mathematics achievement. Studies in the field suggest that spatial ability is an important ability affecting mathematics achievement (Markey, 2009; Cetin and Ertekin, 2011; Yurt and Sünbül, 2014). In this respect results obtained from this study support the studies in the literature. Mathematics achievement cannot be improved without reasoning skill and it is stated that reasoning ability is of great importance for teaching mathematics (Ball and Bass, 2003). Reasoning skill is an important skill which holds together the mathematical competencies, and which enables to use these competencies effectively. Reasoning skill is of great significance in that it holds together mathematical skills and makes it possible to use them effectively. In this respect reasoning skill plays and important role in improving mathematical competence (Kilpatrick *et al.*, 2001). Reasoning skill has a mediating role in solving mathematical equations. This skill is used latently in the problem-solving process and it coordinates ideas and hypothesis necessary for solving the mathematical problem (Leighton and Sternberg, 2004). In this study, the data obtained from the gifted students support the theoretical explanations. It is understood that gifted students overachieve in mathematics depending on their using of reasoning skills effectively. An important finding of the study is that although mathematical problem-solving skill is associated with mathematics achievement when it is included in the regression analysis a long with the spatial ability and mathematical problem-solving skill, it has no significant effect on mathematics achievement. This result is not consistent with the results of other studies suggesting that mathematical problem-solving has a significant effect on mathematics achievement (Özsoy, 2005; Taşdemir, 2008; Aydoğdu and Yenilmez, 2012; Yurt and Sünbül, 2014). One of the probable causes for this result may be that the spatial abilities and reasoning skills, gifted students have, are more associated with the mathematics achievement and they come into prominence. Therefore, it is possible that mathematical problem-solving skill has no significant effect on mathematics achievement. Another probable cause for this finding may be related to the structure of the test used for measuring gifted students' mathematical problem-solving skills. In order to get high scores from this test, students have to follow the problem-solving steps instead of finding the correct result. It is observed that gifted students tend to find the correct results instead of following the problem-solving steps. In this respect, in the future researches, different tests can be used to study the effect of gifted students' mathematical problem-solving skills on their mathematics achievement.

References

Akyuz, G., 2014. The impact of student and school factors on mathematics success at timss 2011. Education and Science, 39(172): 150-162. View at Google Scholar

Alcı, B., M. Erden and A. Baykal, 2010. Explanatory and predictive relationships between problem solving skills, self-efficacy perceptions, cognitive self-regulating strategies, and numerical scores of oss perceived by university students in mathematics achievement. Boğaziçi University Education Journal, 25(2): 55-68.

Arsal, Z., 2009. The effect of self-regulation teaching on the mathematical achievements and attitudes of elementary school students. Education and Science, 34(152): 3-14.

Assouline, S.G. and A. Lupkowski-Shoplik, 2005. Developing math talent: A guide for educating gifted and advanced learners in math. Teksas, USA: Prufrock Press Inc.

Aydoğdu, N. and K. Yenilmez, 2012. An investigation of the problems of problem solving in mathematics. Presented at the X. National Congress of Science and Mathematics Education, June 27-30, Nigde.

Ball, D.L. and H. Bass, 2003. Making mathematics reasonable in school. In j. Kilpatrick, w. G. Martin, & d. Schifter. (eds.), a research companion to principles and standards for school mathematics. Reston, VA: National Council of Teachers of Mathematics.

Bandura, A., 1997. Self-efficacy: The exercise of control. New York: Freeman.

Battista, M.T., 1990. Spatial visualization and gender differences in high school geometry. Journal for Research in Mathematics Education, 21(1): 47-60. View at Google Scholar | View at Publisher

Bilican, S., R.N. Demirtasli and S. Kilmen, 2011. The attitudes and opinions of the students towards mathematics course: The comparison of timss 1999 and timss 2007. Educational Sciences in Theory and Practice, 11(3): 1277-1283. View at Google Scholar

Bloom, B.S., 1998. Human qualities and learning in school (translation d. A. Özçelik). 3rd Edn., Istanbul: MEB Publications.

Booth, R.D. and M.O. Thomas, 1999. Visualization in mathematics learning: Arithmetic problem-solving and student difficulties. Journal of Mathematical Behavior, 18(2): 169-190. View at Google Scholar | View at Publisher

Brodie, K., 2009. Working with learner contributions: A key dimension of professional practice. In Elaborating Professionalism. Dordrecht: Springer. pp: 123-138.

Bruce, C.D. and Z. Hawes, 2015. The role of 2d and 3d mental rotation in mathematics for young children: What is it? Why does it matter? And what can we do about it? Zentralblatt for Didactics of Mathematics, 47(3): 331-343. View at Google Scholar | View at Publisher

Caliskan, M., 2014. Cognitive input behaviors, mathematical reasoning, relations between time and mathematical success. Turkey Social Research Journal, 18(1): 345-357.

Casey, M.B., R. Nuttall, E. Pezaris and C.P. Benbow, 1995. The influence of spatial ability on gender differences in mathematics college entrance test scores across diverse samples. Developmental Psychology, 31(4): 697-705. View at Google Scholar | View at Publisher

Casey, M.B., E. Pezaris and R.L. Nuttall, 1992. Spatial ability as a predictor of math achievement: The importance of sex and handedness patterns. Neuropsychologia, 30(1): 35-45. View at Google Scholar | View at Publisher

Cetin, H. and E. Ertekin, 2011. The relationship between eighth grade primary school students' proportional reasoning skills and success in solving equations. International Journal of Instruction, 4(1): 47-62. View at Google Scholar

Chen, P.P., 2003. Exploring the accuracy and predictability of the self-efficacy beliefs of seventh-grade mathematics students. Learning and Individual Differences, 14(1): 77-90. View at Google Scholar | View at Publisher

Cheng, Y.L. and K.S. Mix, 2014. Spatial training improves children's mathematics ability. Journal of Cognition and Development, 15(1): 2-11. View at Google Scholar | View at Publisher

Cokluk, O., G. Sekercioglu and Ş. Buyukozturk, 2012. The most abundant SPSS and LISREL applications for social sciences. Ankara: Pegem Publishing.

De Hevia, M.D., G. Vallar and L. Girelli, 2008. Visualizing numbers in the mind's eye: The role of visuo-spatial processes in numerical abilities. Neuroscience & Biobehavioral Reviews, 32(8): 1361-1372. View at Google Scholar | View at Publisher

Delialioğlu, Ö. and P. Aşkar, 1999. Contribution of students' mathematical skills and spatial ability of achievement in secondary school physics. Hacettepe University Education Faculty Magazine, 16(16): 34-39. View at Google Scholar

Ekstrom, R.B., D. Dermen and H.H. Harman, 1976. Manual for kit of factor-referenced cognitive tests. Princeton, NJ: Educational Testing Service, 102.

Ersoy, Y., 2006. Innovations in mathematics curricula of elementary schools-I: Objective, content and acquisition. Elementary Education Online, 5(1): 30-44. View at Google Scholar

Fadlelmula, F.K., 2011. Assessing power of structural equation modeling studies: A meta-analysis. Education Research Journal, 1(3): 37-42. View at Google Scholar

Fennema, E. and J. Sherman, 1977. Sex-related differences in mathematics achievement, spatial visualization and affective factors. American Educational Research Journal, 14(1): 51-71. View at Google Scholar | View at Publisher

Fennema, E. and L.A. Tartre, 1985. The use of spatial visualization in mathematics by girls and boys. Journal for Research in Mathematics Education, 16(3): 184-206. View at Google Scholar | View at Publisher

Ferla, J., M. Valcke and Y. Cai, 2009. Academic self-efficacy and academic self-concept: Reconsidering structural relationships. Learning and Individual Differences, 19(4): 499-505. View at Google Scholar | View at Publisher

Gagne, F., 2005. From noncompetence to exceptional talent: Exploring the range of academic achievement within and between grade levels. Gifted Child Quarterly, 49(2): 139-153. View at Google Scholar | View at Publisher

Gainor, K.A. and R.W. Lent, 1998. Social cognitive expectations and racial identity attitudes in predicting the math choice intentions of black college students. Journal of Counseling Psychology, 45(4): 403-413. View at Google Scholar | View at Publisher

Guay, R.B. and E.D. McDaniel, 1977. The relationship between mathematics achievement and spatial abilities among elementary school children. Journal for Research in Mathematics Education, 8(3): 211-215. View at Google Scholar | View at Publisher

Guilford, J.P. and W.S. Zimmerman, 1947. The guilford-zimmerman aptitude survey, form a. Sheridan Supply Company.

Günhan, B.C. and N. Başer, 2008. Impact of probabilistic learning on students' attitudes towards mathematics and their success. Abant İzzet Baysal University Journal of Education Faculty, 23(3): 227-242.

Hawes, Z., J. Moss, B. Caswell and D. Poliszczuk, 2015. Effects of mental rotation training on children's spatial and mathematics performance: A randomized controlled study. Trends in Neuroscience and Education, 4(3): 60-68. View at Google Scholar | View at Publisher

Hegarty, M. and M. Kozhevnikov, 1999. Types of visual–spatial representations and mathematical problem solving. Journal of Educational Psychology, 91(4): 684-689. View at Google Scholar | View at Publisher

Karasar, N., 2000. Scientific research methods. Ankara: Nobel Publication Distribution.

Kayan, F. and E. Cakıroğlu, 2008. Beliefs of elementary mathematics teacher candidates towards mathematical problem solving. Hacettepe University Journal of Education, 35(35): 218-226.

Kayhan, E.B., 2005. An examination of the spatial skills of high school students. Unpublished Master's Thesis, Middle East Technical University, Ankara.

Kilpatrick, J., J. Swafford and B. Findell, 2001. Adding it up: Helping children learn mathematics. Washington, DC: National Academy Press.

Landis, J.R. and G.G. Koch, 1977. The measurement of observer agreement for categorical data. Biometrics, 33(1): 159–174. View at Google Scholar | View at Publisher

Leighton, J.P. and R.J. Sternberg, 2004. The nature of reasoning. Cambridge: Cambridge University Press.

Lopez, F.G., R.W. Lent, S.D. Brown and P.A. Gore, 1997. Role of social–cognitive expectations in high school students' mathematics-related interest and performance. Journal of Counseling Psychology, 44(1): 44-52. View at Google Scholar | View at Publisher

Markey, S.M., 2009. The relationship between visual-spatial reasoning ability and math and geometry problem-solving. PhD Thesis. Available from ProOuest Dissertations and Theses database. (UMI No. 3385692).
McGee, M.G., 1979. Human spatial abilities: Sources of sex differences. New York: Praeger.
MEB, 2009. Primary education (grades 6-8) mathematics course curriculum and guide (national education ministry board of education and training board). Ankara: State Books Administration Printing House.
Ministry of National Education (MEB), 2013. Pisa 2012 national preliminary report. Ankara: MEB.
Mix, K.S. and Y.L. Cheng, 2012. The relation between space and math: Developmental and educational implications. Advances in Child Development and Behavior, 42: 197-243. *View at Google Scholar*
Mullis, I.V.S., M.O. Martin, R.G. J., C.Y. O'Sullivan and P. Corinna, 2012. Timss 2011 assessment frameworks. Amsterdam, Netherlands: The International Association for the Evaluation of Educational Achievement (IEA).
Mullis, I.V.S., M.O. Martin, D.F. Robitaille and P. Foy, 2009. Timss advanced 2008 international report: Findings from iea's study of achievement in advanced mathematics and physics in the final year of secondary school. TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College.
National Assessment of Educational Progress (NAEP), 2002. Mathematics framework for the 2003 national assessment of educational progress. Washington, DC: Author.
NCTM, 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, 3(1): 1-10. *View at Google Scholar*
Özgüven, İ.E., 2005. Individual recognition techniques. Ankara: Nobel Publication Distribution.
Özsoy, G., 2005. The relationship between problem solving skills and mathematics success. Gazi Education Faculty Magazine, 25(3): 179-190.
Özyaprak, M., 2012. Comparison of levels of visual-spatial capability of students with and without gifted students. Turkish Journal of Giftedness and Education, 2(2): 137-153. *View at Google Scholar*
Pahlke, E., J.S. Hyde and J.E. Mertz, 2013. The effects of single-sex compared with coeducational schooling on mathematics and science achievement: Data from Korea. Journal of Educational Psychology, 105(2): 444-452. *View at Google Scholar | View at Publisher*
Pajares, F. and L. Graham, 1999. Self-efficacy, motivation constructs, and mathematics performance of entering middle school students. Contemporary Educational Psychology, 24(2): 124-139. *View at Google Scholar | View at Publisher*
Pape, S.J. and C. Wang, 2003. Middle school children's strategic behavior: Classification and relation to academic achievement and mathematical problem solving. Instructional Science, 31(6): 419-449. *View at Google Scholar*
Peker, M., 2005. The relationship between learning styles and mathematics success of students who have won primary school mathematics teaching. Eurasian Journal of Educational Research, 21: 200-210.
Prugh, L.A., 2012. Spatial reasoning in undergraduate mathematics: A case study. Unpublished PhD Thesis, University of Oklahoma, Norman, Oklahoma.
Schunk, D.H. and B.J. Zimmerman, 1998. Self-regulated learning: From teaching to self-reflective practice. Guilford Press, New York, USA.
Şentürk, F. and N.Y. İkikardeş, 2011. The effect of learning and teaching styles on the 7th grade students' mathematical success. Necatibey Education Faculty Electronic Science and Mathematics Education Journal, 5(1): 250-276. *View at Google Scholar*
Smith, I.M., 1964. Spatial ability. London: University of London Press.
Tan, S., 2012. Examination of wisc-r profiles of a group of students at a level of intelligence. New Medical Journal, 29(3): 170-173.
Tartre, L.A., 1990. Spatial orientation skill and mathematical problem solving. Journal for Research in Mathematics Education, 21(3): 216-229. *View at Google Scholar | View at Publisher*
Taşdemir, A., 2008. The effect of mathematical thinking skills on academic success, problem solving skills and attitudes of primary school sudents in science and technology course. Doctoral Thesis. Gazi University. Institute of Educational Sciences. Ankara.
Tommasi, L., M.A. Peterson and L. Nadel, 2009. Cognitive biology: Evolutionary and developmental perspectives on mind, brain, and behavior. Cambridge, USA: MIT Press.
Umay, A., 2003. Mathematical reasoning ability. Hacettepe University Journal of Education, 24: 234-243. *View at Google Scholar*
Umay, A. and Y. Kaf, 2005. A study of imperfect reasoning in mathematics. Hacettepe University Journal of Education, 28(28): 188-195.
Uredi, I. and L. Üredi, 2005. The power of self-regulatory strategies and motivational beliefs of primary school 8th graders to predict mathematical success. Mersin University Education Faculty Journal, 1(2): 250-260.
Usher, E.L., 2009. Sources of middle school student's self-efficacy in mathematics a qualitative investigation. American Educational Research Journal, 46(1): 275–314. *View at Google Scholar | View at Publisher*
Usher, E.L. and F. Pajares, 2009. Sources of self-efficacy in mathematics: A validation study. Contemporary Educational Psychology, 34(1): 89-101. *View at Google Scholar | View at Publisher*
Van Garderen, D. and M. Montague, 2003. Visual-spatial representation, mathematical problem solving, and students of varying abilities. Learning Disabilities Research & Practice, 18(4): 246-254. *View at Google Scholar | View at Publisher*
Vandenberg, S.G. and A.R. Kuse, 1978. Mental rotations, a group test of three-dimensional spatial visualization. Perceptual and Motor Skills, 47(2): 599-604. *View at Google Scholar | View at Publisher*
Wang, J., 2006. An empirical study of gender difference in a relationship between self- concept and mathematics achievement in a crosscultural context. Educational Psychology, 26(5): 689-706. *View at Google Scholar | View at Publisher*
Yeşildere, S., 2006. An examination of mathematical thinking and knowledge formation processes of 6th, 7th and 8th grade students with different mathematical power (Doctoral Dissertation, DEU Institute of Educational Sciences).
Yıldırım, S., 2011. Self-efficacy, intrinsic motivation, anxiety and mathematics achievement: Findings from Turkey, Japan and Finland. Necatibey Education Faculty Electronic Science and Mathematics Education Journal, 5(1): 277-291. *View at Google Scholar*
Yılmaz, V. and S. Varol, 2015. Structural equation modeling with ready software: Amos, eqs, lisrel. Dumlupınar University Journal of Social Sciences, 44(44): 28-44.
Yurt, E., 2014a. The predictive power of self-efficacy sources for mathematics achievement. Education and Science, 39(176): 159-169. *View at Google Scholar | View at Publisher*
Yurt, E., 2014b. A structural equation model that describes the mathematical achievements of eighth grade students. Unpublished Doctorate Thesis, Necmettin Erbakan University, Konya.
Yurt, E., 2015. Understanding middle school students' motivation in math class: The expectancy-value model perspective. International Journal of Education in Mathematics, Science and Technology, 3(4): 288-297. *View at Google Scholar | View at Publisher*
Yurt, E. and A.M. Sunbul, 2012. Effect of modeling-based activities developed using virtual environments and concrete objects on spatial thinking and mental rotation skills. Educational Sciences: Theory and Practice, 12(3): 1987-1992. *View at Google Scholar*
Yurt, E. and A.M. Sünbül, 2014. Adapting the scale of mathematics self-efficacy resources to Turkish. Education and Science, 39(175): 145-157.
Yurt, E. and A.M. Sünbül, 2014. A structural equation model explaining 8th grade students' mathematics achievements. Educational Sciences: Theory and Practice, 14(4): 1642-1652. *View at Google Scholar*