

CURRICULUM & TEACHING STUDIES | RESEARCH ARTICLE

The predictive power of fifth graders' learning styles on their mathematical reasoning and spatial ability

Şahin Danişman and Ergin Erginer

Cogent Education (2017), 4: 1266830



Received: 12 August 2016
Accepted: 27 November 2016

*Corresponding author: Şahin Danişman, Faculty of Education, Elementary Mathematics Education, Düzce University, Düzce 81620, Turkey
E-mail: sahin.danisman@gmail.com

Reviewing editor:
Bronwyn Frances Ewing, Queensland University of Technology, Australia

Additional information is available at the end of the article

CURRICULUM & TEACHING STUDIES | RESEARCH ARTICLE

The predictive power of fifth graders' learning styles on their mathematical reasoning and spatial ability

Şahin Danişman^{1*} and Ergin Erginer²

Abstract: The purpose of this study was to examine fifth graders' mathematical reasoning and spatial ability, to identify a correlation with their learning styles, and to determine the predictive power of their learning styles on their mathematical learning profiles. This causal study was conducted with 97 fifth graders (60 females, 61.9% and 37 males, 38.1%). The data were collected using three instruments: the Test on Learning Styles, the Mathematical Reasoning Test, and the Spatial Ability Test. Considering the combined view of the data on a plane, correlation and regression analyses were performed to identify correlations and prediction. The results showed that the students' spatial ability was better than their mathematical reasoning ability. Their scores for visual, auditory, kinesthetic, reading, and combined learning accounted for 17% of the total variance in mathematical reasoning, whereas their scores accounted for 20% of the total variance in spatial ability. Of the learning styles, only visual learning was a significant predictor of mathematical reasoning and spatial ability.

Subjects: Teaching Practice - Education; Primary Education - Teaching Practice; Education & Training; Study Skills; Primary Education - Teacher Education & Training; Educational Research; Education Studies; Behavioural Management; Teaching & Learning; Child Development

Keywords: learning styles; mathematical reasoning ability; prediction; spatial ability

ABOUT THE AUTHORS

Şahin Danişman is an assistant professor in Elementary Mathematics Education in Düzce University, Turkey. He earned an undergraduate degree from Bogazici University and master's degree from Gaziosmanpaşa University. He holds a PhD in Curriculum and Instruction from Eskisehir Osmangazi University. He now pursues his second PhD in mathematics education in Anadolu University. His professional interests include professional development, educational methodology, and mathematics instruction. He also conducts pedagogical research about effective classroom practices in mathematics education.

Ergin Erginer is an assistant professor in Nevşehir Hacı Bektaş Veli University. He graduated from Department of Elementary Education Pamukkale University in 1993. He earned his MA in curriculum development in Ankara University in 1996, and pursued his PhD in curriculum development in Abant İzzet Baysal University in 2002. His research interests include learning styles, curriculum, and reading and writing skills of children. He has a few books and projects related to his interest areas.

PUBLIC INTEREST STATEMENT

Which one is important in a mathematics classroom: Giving the right answer or focusing on the reasoning process? Or both? It would be more appropriate to consider mathematics instruction to be an instrument for promoting mathematical thinking and reasoning rather than simply teaching formulas and proofs. Mathematical reasoning and spatial ability are indicators of learning mathematics in a meaningful way. What is important, however, is to try to understand how children learn and what interests them and to arrange instructional methods accordingly. This is about learning style, which refers to the way students acquire knowledge to learn and practice. This study aims to examine the relationship among fifth graders' mathematical reasoning, spatial ability, and learning styles. Enlightening those relationships, this research draws attention to the interaction of mathematical profiles and learning styles of the students.

1. Introduction

Although it is feared, disliked, and lamented by most students, mathematics is an indispensable part of our daily lives. Wherever we go and whatever job we do, mathematics, somehow, has been there, influencing our thinking processes (Alkan, 2010; Putnam, 1992). According to students' scores on national and international tests, curricular revisions have been made both in Turkey and around the world, which are mostly reflected in mathematics curricula. Reasoning is a skill that must be taught as part of the mathematics curriculum, in addition to other skills such as questioning, critical thinking, justification, and problem-solving (Ministry of National Education [MoNE], 2013). In other words, the objective is to enable students not only to use procedural skills, but also to learn mental skills with an effective use of mathematics. It would be more appropriate to consider mathematics instruction to be an instrument for promoting mathematical thinking and reasoning rather than simply teaching formulas and proofs (Norfolk, 2006).

1.1. Mathematical reasoning

Despite continuous amendments to the curriculum, it is still questionable whether the target skills can be effectively developed at school. Since school mathematics focuses on routine problems, students get nervous when they encounter a non-routine problem and thus become less successful. Teachers are inclined to be interested in the correct answer to a given problem rather than in the procedures leading to the answer. To promote reasoning, in-class activities should center on the process rather than the product (Umay & Kaf, 2005). In other words, mathematics instruction should not be based on memorization. Instead, it should be done in a way to foster mathematical reasoning. Although they are considered to be an indicator of achievement in mathematics, high test scores do not necessarily show that students are learning meaningfully. Mathematics cannot be memorized and calls for interpretation and construction. Lithner (2008) sees the rote learning as a main factor behind learning difficulties in mathematics. Ball and Bass (2003) claim that every student should have a mathematical reasoning or ability to understand and make sense of mathematics. In line with these, Ross (as cited in Lithner, 2000) explains the objective of mathematics instruction as follows:

[...] It should be noted that mathematics is based on reasoning. [...] Unless students can develop reasoning, mathematics turns into simple use and application of certain procedures and rules and cannot mean anything other than copying and imitating given examples without their meaning being questioned.

One of the most fundamental objectives of mathematics instruction is to come up with logical answers to the question “why,” or to help one develop reasoning. Reasoning is defined as drawing a conclusion from results, judgments, facts, or propositions (Altıparmak & Öziş, 2005) or the line of thought and the way of thinking to reach conclusions (Bergqvist, Lithner, & Sumpter, 2003). Mathematical reasoning is a concept that involves the ability to form mathematical predictions, to develop and evaluate mathematical discussions, and to present mathematical information in a variety of ways: to draw conclusions from evidence in sum (National Council of Teachers of Mathematics [NCTM], 1989, 2009). Mathematical reasoning for elementary school students refers to the ability to recognize reasoning and proof as the basis of mathematics and to make and search for mathematical inferences (National Council of Teachers of Mathematics [NCTM], 2000). NCTM (2009) also puts forward that reasoning should be a part of the mathematics classroom every day.

Mullis, Martin, and Foy (2005, p. 70) identified the dimensions of mathematical reasoning and the target skills for each dimension as in Table 1.

As it can be seen from those dimensions, higher order thinking skills are required to have a good mathematical reasoning. Umay (2003) emphasizes that mathematical reasoning forms the basis of mathematics. Mathematics teaches not only numbers, operations, algebra, geometry, proportion, and area measurement, but also identifying patterns, reasoning, making predictions, using reasoned thinking, and arriving at conclusions. Though it is uncommon in Turkey because of the

Table 1. Mathematical reasoning dimensions and target skills

<i>Analysis</i>
<ul style="list-style-type: none">• Ability to identify, describe, and use relationships between mathematical objects and variables• Ability to use proportional reasoning• Ability to form appropriate geometric figures to make it easier to solve a given problem• Ability to visualize three-dimensional transformations• Ability to compare and match different views of the same data• Ability to draw valid conclusions from given information
<i>Generalization</i>
<ul style="list-style-type: none">• Ability to use more general terms with wider application to restate and expand the scope of conclusions drawn by means of mathematical thinking and problem-solving
<i>Synthesis/association</i>
<ul style="list-style-type: none">• Ability to combine several mathematical processes to reach a conclusion and to combine conclusions to reach other conclusions• Ability to make a connection between different components of information and associated representations and to establish connections between associated mathematical ideas
<i>Justification</i>
<ul style="list-style-type: none">• Ability to provide justification for the accuracy or inaccuracy of a statement by means of mathematical properties or results
<i>Solving non-routine problems</i>
<ul style="list-style-type: none">• Ability to solve problems that exist in a mathematical context or real life and whose similar versions are unlikely to be encountered by students• Ability to apply mathematical operations to more complicated problems that are unfamiliar to students• Ability to use geometric properties to solve non-routine problems

problems with its educational system (Buluç, 2014), making a connection between concepts and coming up with innovative solutions are indispensable components of mathematics. The development of mathematical reasoning depends on the diversity of the questions and activities designed for students. In other words, it depends on the way classes are presented to students and the tasks they are assigned. Student-centered classes, non-routine problems, and group work play a pivotal role in the development of mathematical reasoning (McGraw & Rubinstein-Ávila, 2008). The constructivist approach to education, which has become widespread in recent years, is likely to provide more opportunities for children to develop mathematical reasoning.

1.2. Spatial ability

Just as mathematics instruction is expected to develop students' mathematical reasoning, geometry instruction is expected to develop spatial ability, or visual and three-dimensional thinking skills. Spatial ability involves forming, retaining, retrieving, and directing visual images of two and three-dimensional objects (Lohman, 1993). According to Lord and Holland (1997), spatial ability refers to visualizing words or figures in the mind and moving them by focusing on your thoughts. Spatial ability is closely intertwined with mathematics achievement (Hegarty & Waller, 2005) and integral to mathematical thinking (Clements, Battista, Sarama, & Swaminathan, 1997). Spatial ability is significant since it enables one to imagine figures, to think how objects can move and rotate, and to understand how pieces come together to form a whole, and the ability can be improved with spatial thinking activities (Lord, 1987; Sternberg, 1990 as cited in Huk, 2006). Although everyone has the potential, research results show that some people are more skillful in this respect. Since people with spatial ability are likely to be successful in mathematics and science, teachers of these courses must be knowledgeable about spatial ability, identify students who have the ability, and know how it can be improved (Lord & Holland, 1997).

1.3. Learning styles

Mathematical reasoning and spatial ability are indicators of learning mathematics in a meaningful way. What is important, however, is to try to understand how children learn and what interests them and to arrange instructional methods accordingly. This is about learning style, which refers to the way students acquire knowledge to learn and practice (Geer, 1997). Although there are many different definitions in the literature (Coffield, Moseley, Hall, & Ecclestone, 2004), learning styles are defined as students' individual characteristics and preferences that reveal what they think about the learning environment, how they interact with it, and how they react to it (Veznedaroğlu & Özgür, 2005). Learning styles also involve preferred use of sense organs for learning. Learning styles are based on the idea that knowledge is acquired by means of the senses. In this respect, they can be divided into four: visual, auditory, read/write, and kinesthetic (Fleming & Mills, 1992). These learning styles can be summarized as, the visual (V) learner learns best by visualizing the information, e.g. use of charts, diagram, and mind maps, while the auditory (A) learner learns best by hearing the information. The read/write (R) learner learns best when the information is displayed in words; and on the other hand, the kinesthetic (K) learner learns best with practice or simulation.

Considering that human beings are likely to have more than one learning style and learning styles vary from one person to another (Şeker & Yılmaz, 2011), it would be ineffective to teach classes using one single method. Students can learn faster and more easily when they know about and study in accordance with their own learning styles. This idea is supported by Edgar Dale's "cone of experience" (as cited in Lalley & Miller, 2007):

- Learning and permanency increase as more sense organs are involved in the process.
- The best way of learning is to do something: our most vivid memories are often the result of direct experiences.
- The best instruction moves from the concrete to the abstract and from the simple to the complex.

As revealed by theoretical and experimental studies, teachers must be aware that not all elementary students have the same level of mental maturity in mathematics classes. Therefore, teachers must employ a variety of methods for teaching these classes. If teachers attempt to teach mathematical concepts using one single method, many students will have difficulty in comprehending the instruction, or they will not comprehend it at all. Consequently, it will be impossible for such students to be prepared for the mathematical topics to come (Rains, Kelly, & Durham, 2008).

1.4. Importance of the study

Although, there have been various studies related to the mathematical reasoning, spatial ability, and the learning types of the students, a study on the relationship among those has not been encountered in the literature. Kell, Lubinski, Benbow, and Steiger (2013) have found that spatial ability has a unique role in the development of creativity. Ryu, Chong, and Song (2007) revealed that some of the mathematically gifted students were good at spatial ability, while some had difficulties in imagining a three-dimensional object in space from its two-dimensional representation in a plane. Okamoto, Weckbacher, and Hallowell (2014) concluded that there was a strong link between spatial ability and mathematical performance. The findings of the study by Tosto et al. (2014) showed that environmental effects explained most of the variation in spatial ability (~70%) and in mathematical ability (~60%), while genetic factors explained about 60% of the observed relationship between spatial ability and mathematics. Kramarski and Mevarech (2003) found that instructional method with cooperative learning combined with metacognitive training has positively affected the mathematical reasoning and metacognitive knowledge. Aineamani (2011) concluded that the way learners communicated their mathematical reasoning depended on the activities that were given by the textbook being used in the classroom, and the questions which the teacher asked during the lessons. Ali and Kor (2007) revealed that sequential-global and sensing-intuitive learning styles associated significantly with brain hemisphericity. Yazıcı (2014) found that male pre-service teachers had

higher spatial visualization abilities than females in addition to the finding that spatial abilities differentiated depending on their preferences for field-dependent/independent learning styles.

Nordin, Amin, Subari, and Hamid (2013) have found no relationship between visualization skills and learning styles of the students.

1.5. Objective(s) of the study

Research on mathematics education emphasizes that students generally have difficulties in learning mathematics because of its abstract and boring nature (Kislenko, Grevholm, & Lepik, 2005; Nardi & Steward, 2003; Wong, Lam, & Wong, 2001). The main objective is to enable students to be successful in mathematics and develop a positive attitude to it (Colgan, 2014; Mueller, Yankelewitz, & Maher, 2011; National Research Council, 2001). As with previous curricula, the updated mathematics curriculum in Turkey stresses the importance of reasoning as a mathematical process skill and recommends a student-centered approach that takes individual differences into account (MoNE, 2013). This study hopes to identify the relationship learning styles have with mathematical reasoning and spatial ability and to present findings that will enable mathematics instruction to appeal to students' interests and expectations. Based on the results of the study, teachers can see which learning style is particularly associated with mathematical reasoning and spatial ability and shape their instruction accordingly. In this respect, the purpose of this study was to identify the predictive power of fifth graders' learning styles on their mathematical learning profiles (mathematical reasoning and spatial thinking ability). The following questions were posed:

- What is the combined view of the students' scores for learning styles and mathematical learning profiles?
- How are their scores for learning styles correlated with their scores for mathematical learning profiles?
- To what extent do their scores for learning styles predict their scores for mathematical learning profiles?

2. Methodology

2.1. Design

This study was causal since it attempted to identify the predictive power of learning styles on mathematical learning profiles. A causal design examines cause-effect relationships that emerge or exist between certain variables and is used when cause-effect relationships are assumed to exist between research variables (Karadağ, 2009). The independent variable was the students' learning styles, and the dependent variable was their mathematical learning profiles (mathematical reasoning and spatial ability).

2.2. Population and sample

The population for the study was composed of fifth graders from state schools in the center of Tokat, Turkey, during the 2010–2011 academic year. The sample included 97 fifth graders from two different schools selected using convenience sampling. Convenience sampling means involving individuals who are willing to participate in the study or who the researcher can easily contact (Berg, 2001; Patton, 1990). The reasons for using convenience sampling in this study were limitations brought on by the administration of the Test on Learning Styles (TLS). First, after the test was administered to the students, they had the opportunity to share its concepts with their peers, which is why they were not given a copy of the test. Second, it was necessary to choose representative students from large groups since the test was administered individually. Third, the limited facilities of the school where the study took place did not allow the test to be simultaneously administered to students in the same classroom. Fourth, there were a limited number of copies of the instrument. Finally, there was only one person who could administer the test.

The participants of the study included 60 females (61.9%) and 37 males (38.1%).

2.3. Data collection instruments

2.3.1. TLS

The TLS, which was used to identify the students' learning styles, was developed by Erginer (2002) based on the studies by Vester (1997, as cited in Erginer, 2002) and Ültanır and Ültanır (2002). The test consists of five common modules that analyze visual, auditory, kinesthetic, reading, and combined learning characteristics and the Module of the Box of Mental Procedures. In the Module of Visual Learning Style, participants are asked to study and recall 10 pictures. In the Module of Auditory Learning Style, the researcher reads out 10 words, and participants are expected to recall them. In the Module of Kinesthetic Learning Style, participants are asked to put their hands into a bag and feel the objects in it. They are expected to recall 10 objects. In the Module of Reading Learning Style, participants are asked to read and recall 10 words. The Module of Combined Learning Style includes pictures, words, and objects revolving around 10 concepts. The Module of the Box of Mental Procedures contains brief questions addressed to participants after each module. The objective is to prevent them from instantly retrieving what they have recalled and thus to get more reliable results. The test is administered to participants individually in five stages, which correspond to the five modules. According to the reliability analysis by Erginer (2002), the test-retest reliability coefficients for the instrument were as follows: $r = .80$ for visual learning style, $r = .85$ for auditory learning style, $r = .84$ for kinesthetic learning style, $r = .87$ for reading learning style, and $r = .90$ for combined learning style. As an example, in the Module of Reading Learning Style, there are 10 words: curtain, typewriter, newspaper, walking stick, clove, ear, sun, eraser, jar, and duck.

2.3.2. The module of the box of mental procedures

In this module, students are asked brief questions for 30 s after each module. The questions are about their name, favorite food, hobbies, or simple mental calculations. The objective is to prevent students from instantly retrieving the pictures, words, or objects they have retained in their sensory memory, to make them remember what they have in their short-term memories, and thus to get more reliable scores on their learning styles. Once students have answered the questions, they are asked to recall the pictures, words, or objects they have remembered and proceed to the next module.

2.3.3. The mathematical reasoning test

The Mathematical Reasoning Test (MRT), which was used to identify the students' mathematical reasoning ability, was developed by Danişman (2011) based on the conceptual framework proposed by Pilten (2008). The draft version of the test contained 30 multiple-choice questions, three questions for each skill in the test. The questions were revised in accordance with expert opinion, and the test was piloted. An item analysis was performed on the test by assigning 1 point to accurate answers and 0 points for inaccurate ones. The item discrimination indexes were calculated, and some items were excluded from the test. The final version of the test contained 10 items. The mean score was 5.1 (out of 10), and the standard deviation was 3.44. The mean difficulty was 51%. Since the items had varying difficulties, the reliability of the final version was assessed using the Kuder-Richardson Formula 20 (KR-20). The test had a KR-20 value of .90, suggesting high reliability. Here is a sample item from the MRT:

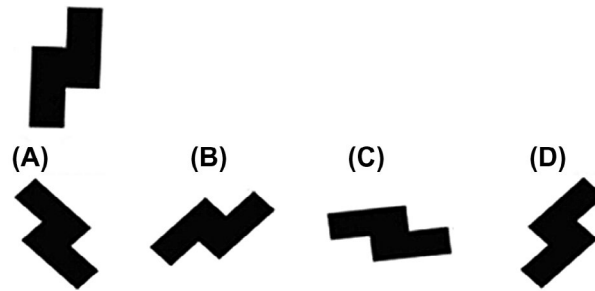
Nine cakes have been made for Berk's birthday. Five girls have shared two cakes equally, and three boys have shared one cake equally. Which of the following is true?

- (a) One girl has eaten more cake than a boy.
- (b) One boy has eaten more care than a girl.
- (c) Everybody has eaten equal amounts of cake.
- (d) The amounts of cake eaten by one girl and one boy cannot be compared.

2.3.4. The Spatial Ability Test

The Spatial Ability Test (SAT), which was used to identify the students' spatial ability, was developed by Danişman (2011) based on the elements specified in a review of literature. Since "visual memory,"

Figure 1. A sample TSA item.



a subcomponent of spatial ability, overlaps with the Module of Visual Learning Style in the TLS, it was excluded from the test. The draft version of the test contained 15 multiple-choice questions, three questions for each skill in the test. The questions were revised in accordance with expert opinion, and the test was piloted. An item analysis was performed on the test by assigning 1 point for each accurate answer and no points for inaccurate answers. The item discrimination indexes were calculated, and some items were excluded from the test. The final version of the test contained five items. The mean score was 2.9 (out of five), and the standard deviation was 1.32. The mean difficulty was 58%. Since the items had varying difficulties, the reliability of the final version was assessed using the Kuder–Richardson Formula 20 (KR-20). The test had a KR-20 value of .59, suggesting moderate reliability. Here is a sample item from the SAT:

Which of the options cannot be obtained by rotating the following Figure 1?

2.4. Administration

First, the MRT and the SAT were administered to a separate sample to test their validity and reliability. Then, the instruments were administered to the participants of this study within one class hour. However, the TLS was administered to the students individually, either in an available classroom or in the library of the school. The administration of the test occurred in five stages, one stage for each learning style, and took 12–15 min for each student altogether. Furthermore, participating in the study was voluntary and announced to the students before conducting the study. The students are told that they might have chosen not to participate in the study. In the first step, the required permissions were acquired from the parents, school managers, and the teachers.

2.5. Data analysis

While the MRT and the SAT were being developed, item analysis was performed using Iteman 3.0, while other statistical analyses were carried out using SPSS 15.0. There were no incomplete data. The mean scores of the students for learning styles and mathematical learning profiles were shown on a hexagonal plane in the form of domains of learning. The broadest and narrowest domains of learning were estimated by adding one standard deviation to the mean scores and subtracting one standard deviation from them, respectively. While the correlation between the mathematical learning profiles and learning styles was identified using the Pearson Product-Moment Correlation Coefficient, the predictive power of the learning styles on the mathematical learning profiles was calculated using multiple linear regression analysis. Before the analysis, the problem of multicollinearity was checked. The variance inflation factors (VIF) were below 10 (ranging between 1.37 and 1.72), and the tolerance statistics were above .20 (ranging between .58 and .73), which suggested no perfect linear relationships between the independent variables or predictive variables.

3. Findings

The results of this study were presented in three sections. The first section provided a combined view of mathematical learning profiles and learning styles on a plane. The second showed the correlation between the two. The final section presented the predictive power of learning styles on mathematical learning profiles.

3.1. The combined view of the scores for learning styles and mathematical learning profiles

Aiming to reply the first research question, this section depicts the combined view of all the scores related to the main variables of the study. For learning styles, the students had the highest and lowest mean scores for visual learning ($\bar{x} = 6.03$) and auditory learning ($\bar{x} = 3.95$), respectively. As for mathematical learning profiles, they had higher mean scores for spatial ability ($\bar{x} = 7.32$) than mathematical reasoning ($\bar{x} = 5.66$) (see Table 2). The mean scores suggested that the students were predominantly kinesthetic and visual learners and that their spatial ability was stronger than their mathematical reasoning ability.

The standard deviations for the students' learning styles and mathematical learning profiles generally moved away from zero. This suggests that the students had varying scores and the group was heterogeneous with differences among its members. When one standard deviation was added to the students' mean scores for learning styles to estimate the maximum possible score, the highest and lowest scores were for visual learning ($\bar{x} = 7.68$) and auditory learning ($\bar{x} = 5.54$). When the same was done for their mathematical learning profiles, spatial ability ($\bar{x} = 9.54$) had a higher value than reasoning ($\bar{x} = 7.78$). When one standard deviation was subtracted from their mean scores for mathematical learning profiles to estimate the minimum possible score, the highest and lowest scores were for visual learning ($\bar{x} = 4.38$) and auditory learning ($\bar{x} = 2.36$). When the same was done for their mathematical learning profiles, spatial ability ($\bar{x} = 5.10$) had a higher value than reasoning ($\bar{x} = 3.54$). These values indicated that no difference was observed when the mean scores were compared. In other words, the standard deviation interacted well with the mean scores. Therefore, the maximum and minimum possible values for learning styles and mathematical learning profiles were as follows: about 55 and 24% for auditory learning, about 61 and 33% for reading learning, about 77 and 44% for visual learning, about 67 and 39% for kinesthetic learning, about 78 and 35% for reasoning, and about 95 and 51% for spatial ability.

The combined view of the students' mathematical learning profiles and learning styles on a plane (see Figure 2) indicated that the highest mean score was for spatial ability. It was followed by visual learning, reasoning, kinesthetic learning, reading learning, and auditory learning. Since combined learning style encompassed all the other learning styles, it was natural that it had a higher mean score than the others. The score for visual learning was quite close to the one for combined learning. The figure strongly suggests that the students were predominantly visual and kinesthetic learners rather than auditory.

Table 2. The scores for learning styles and mathematical learning profiles with the broadest and narrowest domains of learning

Skills	Learning styles (n = 97)					Mathematical learning profiles (n = 97)	
	Reading	Auditory	Visual	Kinesthetic	Combined	Reasoning	Spatial
\bar{x}	4.69	3.95	6.03	5.27	6.42	5.66	7.32
S	1.43	1.59	1.65	1.39	1.42	2.12	2.22
$\bar{x} + 1S$	6.12	5.54	7.68	6.66	7.84	7.78	9.54
$\bar{x} - 1S$	3.26	2.36	4.38	3.88	5.00	3.54	5.10

Figure 2. The combined view of mathematical learning profiles and learning styles on a plane.

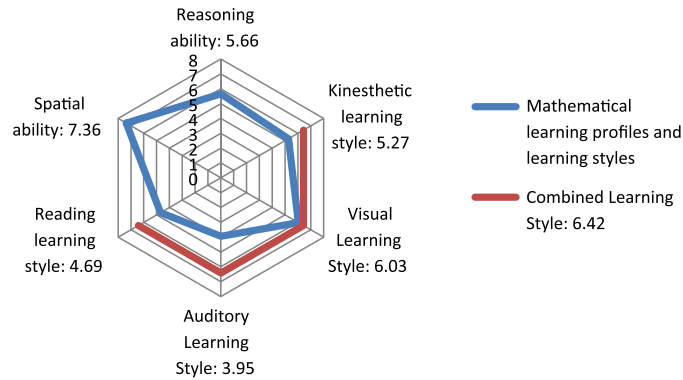
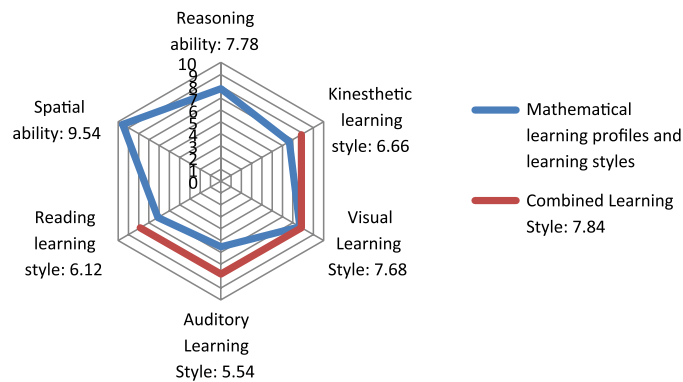


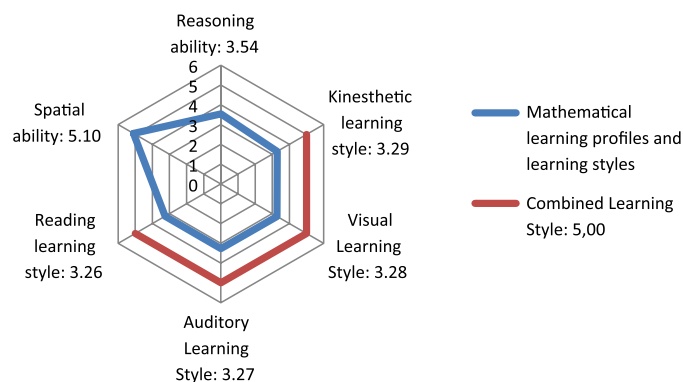
Figure 3. The combined view of mathematical learning profiles and learning styles on a plane for the broadest domain of learning.



The combined view of the students' mathematical learning profiles and learning styles on a plane for the broadest domain of learning (see Figure 3) had the same characteristics as the combined view of the students' mathematical learning profiles and learning styles on a plane. When the scores were taken into consideration as being added one standard deviation, the mean score for spatial ability was higher than the mean scores for the other learning styles. The score for combined learning style encompassed the scores for the other learning styles as well as the score for mathematical reasoning and approached the score for visual learning style.

Similarly, the combined view of the students' mathematical learning profiles and learning styles on the same plane for the narrowest domain of learning (see Figure 4) had the same characteristics as the combined view of the students' mathematical learning profiles and learning styles on a plane. When the scores are taken into consideration as being added one standard deviation, the mean score for spatial ability was higher than the mean scores for the other learning styles. The score for combined learning style approached the one for visual learning style and encompassed the mean scores for all the learning styles.

Figure 4. The combined view of mathematical learning profiles and learning styles on a plane for the narrowest domain of learning.



Considering all three planes, the difference in the mean scores for spatial ability and combined learning style decreased as the domain of learning became narrower. The difference between spatial ability and combined learning style was .90 (6.42–7.32) when all the scores were viewed on a plane. When the domain of learning became broader, the difference rose to 1.70 (9.54–7.84). However, the difference reduced to .10 (5.1–5) when the domain of learning became narrower. This suggests that memory-based learning activities have a significant influence on spatial ability.

3.2. The correlations between the students’ scores for learning styles and mathematical learning profiles

Aiming to reply the second research question, this section reveals the correlation coefficients among the main variables of the study. The Pearson correlation analysis was performed to identify the correlation between the students’ scores for mathematical learning profiles and learning styles. The results showed that there was a moderate, positive, and significant correlation between their scores for mathematical reasoning and spatial ability ($r = .43, p < .05$). The determination coefficient ($r^2 = .18$) suggested that the scores for mathematical reasoning and spatial ability accounted for 18% of the variance in one another. The highest bivariate correlation was between visual learning and reading learning ($r = .57, p < .05$). There was not any significant correlation between reading learning and spatial ability or between auditory learning and reasoning ($p > .05$) (Table 3).

3.3. The predictive power of learning styles for mathematical learning profiles

Aiming to answer the third research question, this part puts forward the regression results. In order to identify the correlation between the students’ scores for learning styles and mathematical learning profiles, the latter was considered as the dependent variable. A multiple regression analysis was performed to determine the extent to which learning styles accounted for variance in mathematical learning profiles.

The results of the multiple regression analysis showed bivariate and partial correlations between the predictive variables and the dependent variable of mathematical reasoning (see Table 4). Although the highest correlation was between the scores for visual learning and mathematical reasoning ($r = .36, p < .05$), the correlation between the two variables decreased to $r = .21$ when the other variables were taken into account. According to the standardized regression coefficient (β), the

Table 3. The correlation between the students’ scores for mathematical learning profiles and learning styles (n = 97)

	Spatial	Reading	Visual	Auditory	Kinesthetic	Combined
Reasoning	.43*	.28*	.36*	.20	.30*	.25*
Spatial		.20	.37*	.23*	.35*	.28*
Reading			.57*	.44*	.35*	.42*
Visual				.47*	.38*	.31*
Auditory					.27*	.37*
Kinesthetic						.45*

*Level of significance at $p < .05$.

Table 4. The values for the predictive power of learning styles on mathematical reasoning

Variable	B	Standard error	β	t	Bivariate r	Partial r
Constant	1.39	1.09	–	1.28	–	–
Reading	.08	.18	.05	.43	.28	.05
Auditory	–.03	.15	–.02	–.20	.20	–.02
Visual	.34	.16	.26	2.10	.36*	.21*
Kinesthetic	.22	.17	.15	1.31	.30	.14
Combined	.13	.17	.09	.74	.25	.08

Notes: $R = .41$; $R^2 = .17$; $F(5, 91) = 3.74$; $p < .05$.

Table 5. The values for the predictive power of learning styles on spatial ability

Variable	B	Standard error	β	t	Bivariate r	Partial r
Constant	2.48	1.12	-	2.22	-	-
Reading	-.17	.19	-.11	-.90	.20	-.09
Auditory	.05	.16	.04	.33	.23	.04
Visual	.39	.17	.29	2.36	.37*	.24*
Kinesthetic	.33	.18	.21	1.91	.35	.20
Combined	.21	.18	.13	1.18	.28	.12

Notes: $R = .45$; $R^2 = .20$; $F(5, 91) = 4.65$; $p < .05$.

predictive variables that influenced mathematical reasoning were as follows, in order of importance: visual learning, kinesthetic learning, combined learning, reading learning, and auditory learning. According to the results of the t-test on the significance of the regression coefficients, only visual learning was a significant predictor of mathematical reasoning at the level of .05. Reading, auditory, kinesthetic, and combined learning did not have a statistically significant effect on mathematical reasoning. When reading, auditory, visual, kinesthetic, and combined learning were considered together, they had a moderate and significant correlation with mathematical reasoning ($R = .41$; $R^2 = .17$, $p < .05$). These five variables accounted for about 17% of the total variance in mathematical reasoning.

In addition, the results of the multiple regression analysis showed bivariate and partial correlations between the predictive variables and the dependent variable of spatial ability (see Table 5). Although the highest correlation was between the scores for visual learning and spatial ability ($r = .37$, $p < .05$), the correlation between the two variables decreased to $r = .24$ when the other variables were taken into account. According to the standardized regression coefficient (β), the predictive variables that influenced spatial ability were as follows, in order of importance: visual, kinesthetic, combined, reading, and auditory learning. According to the results of the t-test on the significance of the regression coefficients, only visual learning was a significant predictor of mathematical reasoning at the level of .05. When reading, auditory, visual, kinesthetic, and combined learning were considered together, they had a moderate and significant correlation with spatial ability ($R = .45$; $R^2 = .20$, $p < .05$). These five variables accounted for about 20% of the total variance in mathematical reasoning.

4. Discussion and conclusion

This study identified the learning styles of fifth graders as well as their mathematical reasoning and spatial ability. The results showed that their spatial ability was more advanced than their mathematical reasoning. Bivariate correlations were identified between all the variables, except between reasoning and auditory learning, namely: reading learning, visual learning, auditory learning, kinesthetic learning, combined learning, spatial ability, and reasoning. Only visual learning was a significant predictor of mathematical reasoning and spatial ability.

According to the results, the students were predominantly visual and kinesthetic learners. This finding is also supported by several other studies in both Turkish and foreign literature (Bedir, 2007; Demir, 2010; Eskici, 2008; Felder & Silverman, 1988; Gürgen, 2010; Park, 2002; Tepehan, 2004; Ültanır & Ültanır, 2002; Wallace, 1995).

The students had moderate scores for mathematical reasoning, while their scores for spatial ability were significantly higher than the others. The finding suggests that the students' spatial ability was highly advanced, whereas their mathematical reasoning was moderate. The finding is also supported by Demirtaş and Duran (2007), who studied how developed elementary school students were in terms of multiple intelligences. The authors observed that the students' visual/spatial intelligence was *highly developed*, but their logical/mathematical intelligence was *moderately developed*. Several

other studies support the finding that elementary school students have moderate mathematical reasoning ability (Altun & Arslan, 2006; Yazgan & Bintaş, 2005). Ildırı (2009) examined textbooks and workbooks for fifth graders. The author found that almost three-quarters of the problems in the books were accompanied by visuals (figures, pictures, tables, and graphs) and thus mostly appealed to visual learners. This might be the reason why the students in this study had such high scores for visual learning. Ildırı's study (2009) also concluded that a quarter of the problems in the books were non-routine problems, which can explain why the students in this study had moderate mathematical reasoning ability.

However, some other studies have reported findings that do not confirm the idea that elementary school students have advanced spatial ability and moderate mathematical reasoning ability. For example, Olkun and Altun (2003) compared elementary school students' spatial thinking skills and achievement in geometry. They observed that the students had low scores for spatial thinking. Similarly, Turğut and Yılmaz (2012) found secondary school students' spatial ability to be rather low. Işık and Kar (2011) examined elementary school students' logical thinking and reasoning. They concluded that the students had difficulty in reasoning during problem-solving activities. Likewise, Umay and Kaf (2005) reported that students moving to secondary school had weakened reasoning ability.

In this study, the standard deviation of the scores for mathematical reasoning was higher than that of the scores for learning styles, which might have been caused by differences among the students in terms of their mathematical skills, learning background, attitudes toward and achievement in mathematics, and mathematical anxiety (Dursun & Dede, 2004; Keçeci, 2011; Taşdemir, 2009; Tatar & Dikici, 2008). Alternatively, it might have been influenced by whether the students had attended a preschool, how educated their parents were, and whether their mothers worked. Güven (2007) attempted to identify preschoolers' instinctive mathematical ability. The author concluded that students attending a preschool had better instinctive mathematical ability. Similarly, children whose parents enjoyed a high educational status and whose mothers worked had higher instinctive mathematical ability. These differences influence elementary school students' mathematical achievement, mathematical reasoning, and spatial ability at varying degrees. In addition, attitudes toward mathematics might be the reason for differences among students in terms of mathematical achievement and ability. In Tobias' study, some students considered themselves to lack mathematical ability or mathematical intelligence and reported that it would be wrong to expect them to be successful in mathematics (as cited in Kloosterman & Stage, 1992). Other students reported that anyone could learn mathematics and develop mathematical ability as long as they made sufficient effort. This suggests that students who do not believe that they can develop mathematical ability are not willing to study, nor do they make effort to improve their problem-solving skills. In this respect, it is not surprising that students with different views on their mathematical ability will have varying degrees of mathematical reasoning ability. Adams (2007) asserted that mathematical reasoning can greatly differ from one person to another and childhood difficulties can survive into adulthood. The author identified three basic reasons for differences in mathematical ability, namely: genetic, cognitive, and behavioral, and adds that the environment and gender differences can have their own effects. On the other hand, York and Clark (2007) maintain that differences in mathematical ability have nothing to do with gender. According to them, if there are differences between genders, this is probably caused by inequality of opportunities, level of socialization, and other environmental factors.

The standard deviations for the students' spatial ability were high. The reason for this might be associated with whether they had access to computers at home or school, whether they took computer classes, whether their classes were computer assisted, and whether they had access to the Internet. Yıldız (2009) tested the effectiveness of a computer-assisted method and found that the use of the method generated better results in terms of spatial visualization and mental rotation. Similarly, Rafi, Samsudin, and Said (2008) used computer-assisted instruction and reported that it led to higher scores for spatial visualization. They added that males had higher scores than females. Likewise, Samsudin, Rafi, and Hanif (2011) demonstrated that computer-assisted instruction and gender were pertinent factors in mental rotation and spatial visualization, two components of spatial

ability. The groups that used computers had higher scores than those that did not. In addition, males had better results than females. McClurg, Lee, Shavali, and Jacobsen (1997) found that the use of computers developed spatial ability. In a study by Olkun and Altun (2003), those children who had access to computers at home and early childhood computer experience were more successful in the geometry test. The differences among the participants of this study in terms of spatial ability might also depend on whether they played video games and which video games they played most (Gagnon, 1985; Okagaki & Frensch, 1994; Subrahmanyam & Greenfield, 2002). However, some other studies reported that computer games do not have an effect on spatial ability (Hirvasoja, 2004).

The standard deviations for the students' learning styles suggest that there were not many differences among the students. Wallace (1995) reported that students and teachers have similar learning styles. Considering that teachers are inclined to teach their classes in accordance with their own learning styles, it is not surprising that the students did not greatly differ from one another in terms of learning styles. Even so, Montgomery and Groat (1998) and Geer (1997) maintain that students come with their own learning styles and thus there should be some differences among them.

There was a moderate, positive, and significant correlation between the students' scores for mathematical reasoning and spatial ability. Delialioğlu and Aşkar (1999) demonstrated that visual ability, which involves logical thinking skills, mathematical ability, problem-solving skills, spatial orientation, and spatial vision, has a positive influence on student achievement. This suggests an interplay between spatial ability and mathematical ability. Similarly, Turğut and Yılmaz (2012) demonstrated a correlation between spatial ability and mathematical achievement. Likewise, Tai, Yu, Lai, and Lin (2003) report a connection between logical thinking and spatial ability. Olkun and Altun (2003) hold that an improvement in skills in spatial development will lead to a corresponding improvement in mathematical thinking. In addition, there was a positive and significant correlation between the scores for visual learning and those for mathematical reasoning and spatial ability. Most research in the literature has demonstrated a positive correlation between visual instruction or visual learning style and achievement in mathematics and geometry (Bayrak, 2008; Demir, 2010; Garderen, 2006; Guzel & Sener, 2009).

The students' learning styles accounted for 17% of the variance in mathematical reasoning. Similarly, Anzelmo-Skelton (2006) investigated students with learning difficulties. She found that the students' learning styles had an effect on their selection of appropriate procedures for problem-solving and on their responses. However, some other studies do not confirm this finding. For instance, Hegarty and Kozhevnikov (1999) did not observe a clear correlation between the use of spatial and visual demonstrations and achievement in mathematical problem-solving.

The students' learning styles accounted for 20% of the variance in spatial ability. Grigoriadou, Papanikolaou, and Gouli (2006) report that it is an advantage to have a variety of learning styles and the most productive and successful students in any groups are usually those who are more visual. Çakmak (2009) and Eisenberg (1999) demonstrated that visual instruction develops spatial ability. Similarly, Gülten and Gülten (2004) report a high correlation between achievement in geometry classes and visual learning style.

To conclude, learning styles, mathematical reasoning, and spatial abilities of fifth-grade students have dichotomously mutual relationships and students' learning styles are an important predictor of their mathematical reasoning and spatial abilities. As mathematical reasoning and spatial ability generate the core of mathematics instruction and may be thought as the indicators of student achievement, it is important for teachers and educators to focus on the variables—one of which is learning styles handled within the current study—affecting these two core elements of mathematics education. It may be recommended to deal with other factors related to these abilities of students in the future studies. What is more, we determined the mathematical reasoning and spatial abilities of the students using quantitative tools conducted simultaneously for all the students. Future studies may investigate these abilities for individual students to get data that are more detailed.

Funding

The authors received no direct funding for this research.

Author details

Şahin Danişman¹

E-mail: sahin.danisman@gmail.com

Ergin Erginer²

E-mail: erginerginer@gmail.com

¹ Faculty of Education, Elementary Mathematics Education, Duzce University, Duzce 81620, Turkey.

² Faculty of Education, Erginer's department is Educational Sciences, Nevşehir Hacı Bektaş Veli University, Nevşehir, Turkey.

Note:

This article has been prepared as a part of the master's thesis of the first author.

Citation information

Cite this article as: The predictive power of fifth graders' learning styles on their mathematical reasoning and spatial ability, Şahin Danişman & Ergin Erginer, *Cogent Education* (2017), 4: 1266830.

Correction

This article was originally published with the 'Note' section omitted. This version has been corrected to include this section after the Author Details section at the end of the article.

Cover image

Source: Authors.

References

- Adams, J. W. (2007). Individual differences in mathematical ability: Genetic, cognitive and behavioural factors. *Journal of Research in Special Educational Needs*, 7, 97–103. doi:10.1111/j.1471-3802.2007.00085.x
- Aineamani, B. (2011). *Communicating mathematics reasoning in multilingual classrooms in South Africa* (Master's thesis). University of the Witwatersrand, Johannesburg. Retrieved from <http://wiredspace.wits.ac.za/>
- Ali, R. M., & Kor, L. K. (2007). Association between brain hemisphericity, learning styles and confidence in using graphics calculator for mathematics. *Eurasia Journal of Mathematics, Science & Technology Education*, 3, 127–131. Retrieved from <http://www.ejmste.org>
- Alkan, V. (2010). Matematikten nefret ediyorum [I hate mathematics]. *Pamukkale University Journal of Education*, 28, 189–199. Retrieved from <http://pauegitimdergi.pau.edu.tr/>
- Altıparmak, K., & Öziş, T. (2005). An investigation upon mathematical proof and development of mathematical reasoning. *Ege Journal of Education*, 6, 25–37. Retrieved from <http://egitim.ege.edu.tr/efdergi/>
- Altun, M., & Arslan, Ç. (2006). A study on learning of the problem solving strategies by secondary school students. *Journal of Uludağ University Faculty of Education*, 19(1), 1–21. Retrieved from <http://dergipark.ulakbim.gov.tr>
- Anzelmo-Skelton, N. (2006). Learning style, strategy use, personalization of mathematical word problems and responses of students with learning disabilities. *International Journal of Special Education*, 21(1), 1–10. Retrieved from <http://www.internationaljournalofspecialed.com>
- Ball, D., & Bass, H. (2003). Making mathematics reasonable in school. In J. Kilpatrick, G. Martin, & D. Schifter (Eds.), *A Research companion to principles and standards for school mathematics* (pp. 27–44). Reston, VA: National Council of Teachers of Mathematics.
- Bayrak, M. E. (2008). *Investigation of effect of visual treatment on elementary school students' spatial ability and attitude toward spatial ability problems* (Unpublished master's thesis). Middle East Technical University, Ankara.
- Bedir, G. (2007). *Evaluating learning style profiles of 4th and 5th grade primary school students, teacher and their parents* (Unpublished dissertation). İnönü University, Malatya.
- Berg, B. L. (2001). *Qualitative research methods for the social sciences*. Boston, MA: Allyn & Bacon.
- Bergqvist, T., Lithner, J., & Sumpter, L. (2003). Reasoning characteristics in upper secondary school students' task solving. *Research reports in Mathematics education* 3. Umea: Department of Mathematics, Umea University.
- Buluç, B. (2014). An analysis of students' mathematics achievements according to school climate in the frame of TIMSS 2011 results. *The Journal of the Industrial Arts Education Faculty of Gazi University*, 33, 105–121. Retrieved from <http://dergipark.ulakbim.gov.tr>
- Çakmak, S. (2009). *An investigation of the effect of origami-based instruction on elementary students' spatial ability in mathematics* (Unpublished master's thesis). Middle East Technical University, Ankara.
- Clements, D. H., Battista, M. T., Sarama, J., & Swaminathan, S. (1997). Development of students' spatial thinking in a unit on geometric motions and area. *The Elementary School Journal*, 98, 171–186. doi:10.1086/461890
- Coffield, F., Moseley, D., Hall, E., & Ecclestone, K. (2004). *Learning styles and pedagogy in post-16 learning: A systematic and critical review*. London: LSRC Reference, Learning & Skills Research Centre. Retrieved from <http://skills.nl/lenenlerenu/bronnen/Learning%20styles%20by%20Coffield%20e.a..pdf>
- Colgan, L. (2014). *Making math children will love: Building positive mathitudes to improve student achievement in mathematics*. Retrieved from http://www.edu.gov.on.ca/eng/literacynumeracy/inspire/research/WW_MakingMath.pdf
- National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: Author.
- National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: Author.
- National Council of Teachers of Mathematics. (2009). *Focus in high school mathematics: Reasoning and sense making*. Reston, VA: Author.
- Danişman, Ş. (2011). *Determining the mathematical learning profiles of primary school fifth grade students and their relationship with the learning styles* (Unpublished master's thesis). Gaziosmanpaşa University, Tokat.
- Delialioğlu, Ö., & Aşkar, P. (1999). Contribution of students' mathematical skills and spatial ability to achievement in secondary school physics. *Hacettepe University Journal of Education*, 16–17, 34–39. Retrieved from <http://dergipark.ulakbim.gov.tr>
- Demir, R. (2010). *An examination of learning styles and multiple intelligences fields of ninth grade students* (Unpublished Master's Thesis). Çukurova University, Adana.
- Demirtaş, Z., & Duran, A. (2007). Primary school 6, 7, and 8. Grades students' level of improvement of multiple intelligence domains. *Electronic Journal of Social Sciences*, 6, 208–220. Retrieved from <http://dergipark.ulakbim.gov.tr>
- Dursun, Ş., & Dede, Y. (2004). The factors affecting students' success in mathematics: Mathematics teachers' perspectives. *Gazi University Journal of Gazi Educational Faculty*, 24, 217–230. Retrieved from <http://dergipark.ulakbim.gov.tr>
- Eisenberg, A. N. (1999). *An educational program for paper sculpture: A case study in the design of software to enhance children's spatial cognition* (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses database, UMI No: 9925379
- Erginer, E. (2002). *A study developing a model for learning style inventory* (Unpublished Dissertation). Abant İzzet Baysal University, Bolu.

- Eskici, M. (2008). *The relationships between junior high school student's learning styles and academic performance and their sex* (Unpublished Master's Thesis). Trakya University, Edirne.
- Felder, R. M., & Silverman, L. K. (1988). Learning and teaching styles in engineering education. *Engineering Education*, 78, 674–681. Retrieved from <http://www4.ncsu.edu/unity/lockers/users/f/felder/public/Papers/LS-1988.pdf>
- Fleming, N. D., & Mills, C. (1992). Not another inventory, rather a catalyst for reflection. *To Improve the Academy*, 11, 137–155. Retrieved from <http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1245&context=podimproveacad>
- Gagnon, D. (1985). Videogames and spatial skills: An exploratory study. *Educational Technology Research and Development*, 33, 263–275. Retrieved from <http://www.jstor.org/stable/30218172>
- Garderen, D. V. (2006). Spatial visualization, visual imagery, and mathematical problem solving of students with varying abilities. *Journal of Learning Disabilities*, 39, 496–506. doi:10.1177/00222194060390060201
- Geer, A. (1997). *Teaching for inclusion: Diversity in the college classroom*. Chapell Hill, NC: Center for Teaching and Learning.
- Grigoriadou, M., Papanikolaou, K., & Gouli, E. (2006, July). Investigating how to group students based on their learning styles. *6th IEEE International Conference on Advanced Learning Technologies* (pp. 1139–1140). Kerkrate: IEEE Computer Society.
- Gülten, D. Ç., & Gülten, İ. (2004). An investigation on the relationship between the learning styles and geometry lesson notes of the 10th Grade students. *Eurasian Journal of Educational Research*, 16, 74–87. Retrieved from <http://www.ejer.com.tr/tr/>
- Gürgen, L. (2010). *Comparing fifth grade students' individual learning styles and learning style of the class* (Unpublished Master's Thesis). Gaziosmanpaşa University, Tokat.
- Güven, Y. (2007). Intuition mathematics ability of preschool children. *Journal of Marmara University Institute of Social Sciences*, 7, 389–395. Retrieved from <http://uvt.ulakbim.gov.tr>
- Guzel, N., & Sener, E. (2009). High school students' spatial ability and creativity in geometry. *Procedia Social and Behavioral Sciences*, 1, 1763–1766. Retrieved from www.sciencedirect.com <http://dx.doi.org/10.1016/j.sbspro.2009.01.312>
- Hegarty, M., & Kozhevnikov, M. (1999). Types of visual-spatial representations and mathematical problem solving. *Journal of Educational Psychology*, 91, 684–689. doi:10.1037//0022-0663.91.4.684
- Hegarty, M., & Waller, D. A. (2005). Individual differences in spatial abilities. In P. Shah & A. Miyake (Eds.), *The Cambridge handbook of visuospatial thinking* (pp. 121–169). New York, NY: Cambridge University Press. <http://dx.doi.org/10.1017/CBO9780511610448>
- Hirvasoja, M. (2004). *Improving spatial skills through computer games* (Bachelor's thesis). University of Jyväskylä, Jyväskylä. Retrieved from http://users.jyu.fi/~jorma/kandi/2004/Kandi_Hirvasoja.pdf
- Huk, T. (2006). Who benefits from learning with 3D models? The case of spatial ability. *Journal of Computer Assisted Learning*, 22, 392–404. doi:10.1111/j.1365-2729.2006.00180.x
- Ildırın, A. (2009). *The investigation of problems in the fifth grade mathematics textbook and study book of student of the primary education and the definition opinions of the teachers about this problems* (Unpublished Master's Thesis). Çukurova University, Adana.
- İşık, C., & Kar, T. (2011). Investigating of the number perception and nonroutine problem solving skills of 6th, 7th and 8th grade students. *Journal of Kırşehir Education Faculty*, 12, 57–72. Retrieved from <http://dergipark.ulakbim.gov.tr>
- Karadağ, E. (2009). Spiritual leadership and organizational culture: A study of structural equation model. *Educational Sciences: Theory & Practice*, 9, 1357–1405. Retrieved from <http://eric.ed.gov/>
- Keçeci, T. (2011, April). *Matematik kaygısı ve korkusu ile mücadele yolları* [Ways of struggle with mathematics anxiety and fear]. Paper presented at the 2nd International Conference on New Trends in Education and Their Implications, Antalya. Retrieved from <http://www.iconte.org/FileUpload/ks59689/File/012.pdf>
- Kell, H. J., Lubinski, D., Benbow, C. P., & Steiger, J. H. (2013). Creativity and technical innovation: spatial ability's unique role. *Psychological Science*, 24, 1831–1836. doi:10.1177/0956797613478615
- Kislenko, K., Grevholm, B., & Lepik, M. (2005). "Mathematics is important but boring": Students' beliefs and attitudes towards mathematics. In C. Bergsten, B. Grevholm, H. S. Masoval, & F. Ronning (Eds.), *Relating practice and research in mathematics education* (pp. 349–360). Trondheim: Tapir Academic Press.
- Kloosterman, P., & Stage, F. K. (1992). Measuring the beliefs about mathematical problem solving. *School Science And Mathematics*, 92, 109–115. Retrieved from [http://onlinelibrary.wiley.com/journal/10.1111/\(ISSN\)1949-8594](http://onlinelibrary.wiley.com/journal/10.1111/(ISSN)1949-8594) <http://dx.doi.org/10.1111/ssm.1992.92.issue-3>
- Kramarski, B., & Mevarech, Z. R. (2003). Enhancing mathematical reasoning in the classroom: The effects of cooperative learning and metacognitive training. *American Educational Research Journal*, 40, 281–310. doi:10.3102/00028312040001281
- Lalley, J. P., & Miller, R. H. (2007). The learning pyramid: Does it point teachers in the right direction? *Education*, 128, 64–79. Retrieved from www.ebscohost.com
- Lithner, J. (2000). Mathematical reasoning in task solving. *Educational Studies in Mathematics*, 41, 165–190. Retrieved from <http://www.jstor.org/stable/3483188> <http://dx.doi.org/10.1023/A:1003956417456>
- Lithner, J. (2008). A research framework for creative and imitative reasoning. *Educational Studies in Mathematics*, 67, 255–276. doi:10.1007/s10649-00-9104-2
- Lohman, D. F. (1993, July). *Spatial ability and g*. Paper presented at the First Spearman Seminar, University of Plymouth, UK. Retrieved from https://www.e-education.psu.edu/drupal6/files/sgam/Spatial_Ability_and_G.pdf
- Lord, T., & Holland, M. (1997). Preservice secondary education majors and visual spatial perception: An important cognitive aptitude in the teaching of science and mathematics. *Journal of Science Teacher Education*, 8, 43–53. Retrieved from <http://www.jstor.org/stable/43156082> <http://dx.doi.org/10.1023/A:1009401419061>
- McClurg, P., Lee, J., Shavaliar, M., & Jacobsen, K. (1997). Exploring children's spatial visual thinking in an hypergami environment. *Educational Resources Information Center- ED408976*, 257–266. Retrieved from <http://eric.ed.gov/>
- McGraw, R., & Rubinstein-Ávila, E. (2008). Middle school immigrant students developing mathematical reasoning in Spanish and English. *Bilingual Research Journal*, 31, 147–173. doi:10.1080/15235880802640656
- Ministry of National Education. (2013). *Ortaokul matematik dersi* (5, 6, 7 ve 8.sınıflar) öğretim programı [The secondary school (5, 6, 7, and 8 grades) mathematics curriculum]. Ankara: Author.
- Montgomery, S. M., & Groat, L. N. (1998). Student learning styles and their implications for teaching. *The Center For Research on Learning and Teaching Occasional Papers, The University of Michigan*, 10, 1–8. Retrieved from http://www.crlt.umich.edu/sites/default/files/resource_files/CRLT_no10.pdf
- Mueller, M., Yankelevitz, D., & Maher, C. (2011). Sense making as motivation in doing mathematics: Results from two studies. *The Mathematics Educator*, 20, 33–43. Retrieved from <http://eric.ed.gov/>

- Mullis, I. V. S., Martin, M. O., & Foy, P. (2005). *IEA's TIMMs 2003 international report on achievement in the mathematics cognitive domains: Findings from a developmental project*. Boston, MA: TIMMS & PIRLS International Study Center. Retrieved from <http://timssandpirls.bc.edu>
- Nardi, E., & Steward, S. (2003). Is mathematics T.I.R.E.D? A profile of quiet disaffection in the secondary mathematics classroom. *British Educational Research Journal*, 29, 345–366. doi:10.1080/0141192031000155999
- National Research Council. (2001). *Adding it up: Helping children learn mathematics*. Washington, DC: National Academy Press.
- Nordin, M. S., Amin, N., Subari, K., & Hamid, M. Z. (2013). Visualization skills and learning style patterns among engineering students at Universiti Teknologi Malaysia. *Procedia- Social and Behavioral Sciences*, 93, 1769–1775. doi:10.1016/j.sbspro.2013.10.114
- Norfolk, T. S. (2006). *Why should anyone study mathematics?* Retrieved from www.math.uakron.edu/~norfolk/why223f06.doc
- Okagaki, L., & Frensch, P. A. (1994). Effects of video game playing on measures of spatial performance: Gender effects in late adolescence. *Journal of Applied Developmental Psychology*, 15, 33–58. doi:10.1016/0193-3973(94)90005-1
- Okamoto, Y., Weckbacher, L. M., & Hollowell, D. (2014, July). How is spatial reasoning related to mathematical thinking and how important is early exposure to spatial activities? In P. Liljedahl, C. Nicol, S. Oesterle, & D. Allan (Eds.), *Proceedings of the 38th conference of the international group for the psychology of mathematics education and the 36th conference of the north American chapter of the psychology of mathematics education* (Vol. 1, pp. 177–179). Vancouver: PME.
- Olkun, S., & Altun, A. (2003). İlköğretim öğrencilerinin bilgisayar deneyimleri ile uzamsal düşünme ve geometri başarıları arasındaki ilişki [The relationship among elementary school students' computer experience, computer ownership and their achievement in geometry]. *The Turkish Online Journal of Educational Technology*, 2, 86–91. Retrieved from <http://www.tojet.net>
- Park, C. C. (2002). Crosscultural differences in learning styles of secondary English learners. *Bilingual Research Journal*, 26, 213–229. doi:10.1080/15235882.2002.10668720
- Patton, M. Q. (1990). *Qualitative evaluation and research methods*. Newbury Park, CA: Sage.
- Pilten, P. (2008). *The effect of metacognitive instruction on mathematical reasoning of fifth grade primary school students* (Unpublished doctoral dissertation). Gazi University, Ankara.
- Putnam, R. T. (1992). Teaching the “hows” of mathematics for everyday life: A case study of a fifth grade teacher. *The Elementary School Journal*, 93, 163–177. Retrieved from <http://www.jstor.org/stable/1001699>
<http://dx.doi.org/10.1086/461720>
- Rafi, A., Samsudin, K. A., & Said, C. S. (2008). Training in spatial visualization: The effects of training method and gender. *Educational Technology & Society*, 11, 127–140. Retrieved from <http://www.ifets.info/>
- Rains, J. R., Kelly, C. A., & Durham, R. L. (2008). The evolution of the importance of multi-sensory teaching techniques in elementary mathematics: Theory and practice. *Journal of Theory and Practice in Education*, 4, 239–252. Retrieved from <http://eku.comu.edu.tr>
- Ryu, H., Chong, Y., & Song, S. (2007). Mathematically gifted students' spatial visualization ability of solid figures. In J. H. Woo, H. C. Lew, K. S. Park, & D. Y. Seo (Eds.), *Proceedings of the 31st Conference of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp. 137–144). Seoul: PME.
- Samsudin, K., Rafi, A., & Hanif, A. S. (2011). Training in mental rotation and spatial visualization and its impact on orthographic drawing performance. *Educational Technology & Society*, 14, 179–186. Retrieved from <http://www.ifets.info/>
- Şeker, M., & Yılmaz, K. (2011). Investigation into the effects of the use of learning styles on students' learning levels in social studies teaching. *Kastamonu University Kastamonu Education Journal*, 19, 251–266. Retrieved from <http://www.kefdergi.com>
- Subrahmanyam, K., & Greenfield, P. M. (2002). Effect of video game practice on spatial skills in girls and boys. *Journal of Applied Developmental Psychology*, 15, 13–32. doi:10.1016/0193-3973(94)90004-3
- Tai, D. W. S., Yu, C. H., Lai, L. C., & Lin, S. J. (2003). A study on the effects of spatial ability in promoting the logical thinking abilities of students with regard to programming language. *World Transactions on Engineering and Technology Education UICEE*, 2, 251–254. Retrieved from <http://www.wiete.com.au/journals/WTE&TE/Pages/index.html>
- Taşdemir, C. (2009). Elementary education second level students' attitude to the mathematic lesson: An example for Bitlis city. *Dicle University Journal of Ziya Gökalp Faculty of Education*, 12, 89–96. Retrieved from <http://www.zgefdergi.com>
- Tatar, E., & Dikici, R. (2008). Matematik eğitiminde öğrenme güçlükleri [Learning difficulties in mathematics education]. *Mustafa Kemal Journal of University Social Sciences Institute*, 5, 183–193. Retrieved from <http://sbed.mku.edu.tr/>
- Tepehan, T. (2004). *Determining the relationship between type of high school graduated and undergraduate course groups regarding the learning styles and academic achievement of Turkish Naval Academy first year midshipmen* (Unpublished master's thesis). Yıldız Technical University, İstanbul.
- Tosto, M. G., Hanscombe, K. B., Haworth, C. M. A., Davis, O. S. P., Petrill, S. A., Dale, P. S., ... Kovas, Y. (2014). Why do spatial abilities predict mathematical performance? *Developmental Science*, 17, 462–470. doi:10.1111/desc.12138
- Turğüt, M., & Yılmaz, S. (2012). Investigation of 7th and 8th grade students' spatial ability. *Dicle University Journal of Ziya Gökalp Faculty of Education*, 19, 69–79. Retrieved from <http://www.zgefdergi.com>
- Ültanır, Y. G., & Ültanır, E. (2002). İlköğretim beşinci sınıf çocuklarında öğrenme tipleri [Learning styles of elementary school fifth grade students]. *Abant İzzet Baysal University Journal of Faculty of Education*, 1, 38–56. Retrieved from <http://www.efdergi.ibu.edu.tr>
- Umay, A. (2003). Mathematical reasoning ability. *Hacettepe University Journal of Education*, 24, 234–243. Retrieved from <http://www.efdergi.hacettepe.edu.tr>
- Umay, A., & Kaf, Y. (2005). A study on flawed reasoning in mathematics. *Hacettepe University Journal of Education*, 28, 188–195. Retrieved from <http://www.efdergi.hacettepe.edu.tr>
- Veznedaroğlu, R. L., & Özgür, A. O. (2005). Learning styles: Definitions, models and functions. *Elementary Education Online*, 4(2), 1–16. Retrieved from <http://ilkogretim-online.org.tr>
- Wallace, J. (1995). Learning styles in the Philippines. *Education*, 115, 552. Retrieved from <https://www.questia.com>
- Wong, N., Lam, C., & Wong, K. P. (2001). Students' view of mathematics learning: A cross-sectional survey in Hong Kong. *Educational Journal*, 29, 37–59. Retrieved from <http://hkier.fed.cuhk.edu.hk/journal/>
- Yazgan, Y., & Bintaş, J. (2005). Fourth and fifth grade students' levels of using problem solving strategies: A teaching experiment. *Hacettepe University Journal of Education*, 28, 210–218. Retrieved from <http://www.efdergi.hacettepe.edu.tr>

Yazıcı, E. (2014). Spatial visualization abilities of field dependent/independent preservice teachers. *Electronic Journal of Research in Educational Psychology*, 12, 371–390. doi:10.14204/ejrep.33.13141

Yıldız, B. (2009). *The effects of using three-dimensional virtual environments and concrete manipulatives on spatial*

visualisation and mental rotation abilities (Unpublished master's thesis). Hacettepe University, Ankara.

York, R., & Clark, B. (2007). Gender and mathematical ability: The toll of biological determinism. *Monthly Review*, 59, 7–15. doi:10.14452/MR-059-06-2007-10_2



© 2017 The Author(s). This open access article is distributed under a Creative Commons Attribution (CC-BY) 4.0 license.

You are free to:

Share — copy and redistribute the material in any medium or format

Adapt — remix, transform, and build upon the material for any purpose, even commercially.

The licensor cannot revoke these freedoms as long as you follow the license terms.

Under the following terms:

Attribution — You must give appropriate credit, provide a link to the license, and indicate if changes were made.

You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

No additional restrictions

You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits.



Cogent Education (ISSN: 2331-186X) is published by Cogent OA, part of Taylor & Francis Group.

Publishing with Cogent OA ensures:

- Immediate, universal access to your article on publication
- High visibility and discoverability via the Cogent OA website as well as Taylor & Francis Online
- Download and citation statistics for your article
- Rapid online publication
- Input from, and dialog with, expert editors and editorial boards
- Retention of full copyright of your article
- Guaranteed legacy preservation of your article
- Discounts and waivers for authors in developing regions

Submit your manuscript to a Cogent OA journal at www.CogentOA.com

