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EXAMINING THE TWO AND THREE DIMENSIONAL SPATIAL VISUALIZATION SKILLS OF SECONDARY SCHOOL STUDENTS

RESEARCH ARTICLE

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Abstract:

In this research, it is aimed to determine the spatial visualization skills of the secondary school students, evaluate them in terms of some variables, and compare with their achievements of the mathematics and science course. Descriptive and correlational screening models were used in the study. The sample of the research is 506 secondary school students. The Spatial Visualization Test and a personal information form were used. Descriptive statistics, independent sample t-test, one-way analysis of variance and the Spearman-Brown correlation coefficient were used to analyse the data. In the research, spatial visualization skills of the students who took pre-school education were significantly higher than those who did not take. Two dimensional spatial visualization skills of the 8th grade students were found to be significantly higher than the 6th and 7th graders, while the three dimensional spatial visualization skills of the 7th and 8th graders were significantly higher than the 6th grade students. In addition, spatial visualization skills of secondary school students who play geometric-mechanical games which one of the six sub-dimensions of intelligence games (MoNE, 2016) and computer games are significantly higher than those who do not play these games. Positive and significant relationship was found between spatial visualization skills of secondary school students and their accomplishment in mathematics and sciences.

Keywords: spatial visualization, geometric-mechanical games, computer games, mathematics, science

ORTAOKUL ÖĞRENCİLERİNİN İKİ VE ÜÇ BOYUTLU UZAMSAL GÖRSELLEŞTİRME BECERİLERİNİN İNCELENMESİ

Öz: Bu araştırmada ortaokul öğrencilerinin uzamsal görselleştirme becerilerini belirlemek; bazı değişkenler açısından değerlendirmek; matematik ve fen dersi başarıları ile karşılaştırmak amaçlanmıştır. Araştırma betimsel ve ilişkisel araştırma niteliğindedir. Araştırmanın örneklemini, 506 ortaokul öğrencisi oluşturmaktadır. Araştırmada kişisel bilgi formu ve Uzamsal Görselleştirme Testi kullanılmıştır. Verilerin analizinde betimsel istatistikler, bağımsız örneklem t-testi, tek yönlü varyans analizi ve Spearman Brown korelâsyon katsayısı kullanılmıştır. Araştırmada okul öncesi eğitimi alan öğrencilerin uzamsal görselleştirme becerileri almayanlara göre anlamlı düzeyde daha yüksek çıkmıştır. 8. sınıf öğrencilerinin iki boyutlu uzamsal görselleştirme becerilerinin 6. ve 7. sınıflara göre; 7. ve 8. sınıf öğrencilerinin üç boyutlu uzamsal görselleştirme becerilerinin ise 6. sınıflara göre anlamlı düzeyde daha yüksek olduğu tespit edilmiştir. Ayrıca zeka oyunlarının altı alt boyutundan biri olan geometrik-mekanik oyunları (MEB, 2016) ve bilgisayar oyunlarını oynayan öğrencilerin uzamsal görselleştirme becerilerinin oynamayanlara göre anlamlı düzeyde daha yüksek olduğu belirlenmiştir. Dahası, ortaokul öğrencilerinin uzamsal görselleştirme becerileri ile matematik ve fen dersi başarıları arasında pozitif ve anlamlı bir ilişki bulunmuştur.

Anahtar Kelimeler: uzamsal görselleştirme, geometrik-mekanik zekâ oyunları, bilgisayar oyunları, matematik, fen bilimleri

Introduction

Spatial ability is the skill to create an images of the visual stimulus that we see around us in the mind and manipulate those images in the mind. According to Linn and Petersen (1985), spatial ability is the ability to represent, transform, create and recall the symbolic and non-linguistic information. According to Sjölinder (1998), it is a cognitive function that enables people to effectively address spatial relationships, visual-spatial tasks, and the orientation of objects in space. Spatial capability is a crucial cognitive skill that is essential for daily jobs and specific activities. Everyday activities, such as driving cars, bringing together furniture pieces, and many areas of expertise such as architectural design, surgical procedures and advanced mathematical problems, require spatial abilities (Rafi, Samsudin & Said, 2008; Terlecki, Newcombe & Little, 2008). Hartman and Bertoline (2005) stated that architecture, astronomy, biochemistry, biology, cartography, chemistry, engineering, geology, mathematics, music, and physics require spatial ability and that only limited success could be achieved at these areas without spatial ability. Jirout and Newcombe (2015) stated that spatial learning is important for children to succeed in science, technology, engineering and mathematics. Mathewson (1999) stated that spatial ability plays a vital role in both scientific creativity and, communication, as it is in many areas. Therefore, individuals who do not have a well-developed spatial ability may face serious problems affecting their academic studies or careers and daily lives, (Rafi et al., 2008). Therefore, while technology is becoming increasingly important these days, individuals are required to have adequate ability to make spatial abstractions, like graphs, diagrams and other visual presentations (Terlecki et al., 2008). In this context, spatial ability has an essential role in the realization of many tasks in daily life, as well as in many disciplines, especially mathematics and geometry. Therefore, without spatial ability, achievements in these areas will be limited and spatial ability needs to be improved.

The factors affecting the development of spatial ability are not entirely apparent. For this reason, the development of spatial ability has been the subject of curiosity for many researchers and many studies have been conducted on which materials and activities can be used. Intelligence games are used in the process of developing high-level life skills such as problem solving, reasoning and multidimensional thinking (Adalar & Yuksel, 2017). Yuksel et. al. (2017) and Yuksel (2019) have stated that playing with geometrical-mechanical games which one of the six sub-dimensions of intelligence games, develop spatial abilities. Jirout and Newcombe (2014) have stated that playing with blocks, puzzles, mazes, develop spatial abilities of children. De Lisi and Wolford (2002) have stated that computer-based teaching activities can be used to improve the spatial abilities of students in schools. Suppiah (2005) stated that three dimensional tangible structures, three dimensional computer models, manipulatives, applications containing free drawings on paper or computer could be used effectively in the development of spatial ability. Boakes (2009) stated that Japanese paper folding art origami could be used as an essential tool in the development of spatial skills. In a study conducted by Cakır, Adsay ve Akgul Ugur (2019), it was found that application with web 2.0 tools had a positive effect on students' spatial thinking skills. Based on these explanations, it is understood that spatial skills could be developed by many materials and activities such as blocks, jigsaws, mazes, computer programs, computer games, and manipulatives.

When the literature on spatial ability is examined, it is seen that there are sub-dimensions of spatial ability and there are various opinions among researchers about the number and meaning of these sub-dimensions. For example; Tartre (1990) emphasized the existence of two components of spatial ability: "spatial visualization", and "spatial orientation". Pellegrino, Alderton and Shute (1984) cited the existence of at least two factors of spatial ability and stated that these factors were "spatial visualization" and "spatial relations". Linn and Petersen (1985) based on their study results, divided the spatial ability into three components as "spatial perception", "mental rotation" and "spatial visualization". Pittalis and Christou (2010) claimed that spatial ability consists of three major spatial ability factors, namely "spatial visualization", "spatial relations" and "spatial orientation". As it can be seen in these studies, it is noteworthy that the spatial ability component that most researchers agree is spatial visualization.

Spatial visualization is considered to be one of the most critical sub-components of spatial ability. Moreover, according to Linn and Petersen (1985), spatial visualization is the task of complex, multi-step manipulations of spatially presented information. Much related research on spatial visualization skills (Battista, 1990; Fennema & Sherman, 1977; Turgut & Yilmaz, 2012) showed that there was a significant and positive relationship between students' spatial visualization skills and mathematics achievements. Yuksel and Bulbul (2014) have expressed the ability of spatial visualization to be an indispensable part of mathematics and geometry courses. Battista, Wheatley and Talsma (1982) have suggested that students should be able to imagine and visualize to achieve a better level at mathematics. Based on these explanations, as in the case with spatial ability, spatial visualization is also prominent and has a positive impact on success at mathematics and geometry.

Despite the importance in many areas, teaching of spatial visualization skills in classrooms is not done adequately. For example, Clements and Sarama (2011) stated that the teaching of spatial visualization skills was primarily overlooked in classroom environments. Piburn et al. (2002) in schools, while verbal and logical-mathematical skills are taught, spatial skills are rarely intervened; however, spatial skills are teachable, and such teaching provides more success in science classes. Rittle-Johnson, Zippert and Boice (2018) have stated that one of the skills that contribute significantly to the development of mathematical skills at early ages is the often neglected spatial visualization ability. Lin and Chen (2016) stated that because of this nature of spatial ability requiring adequate space and time to perform effective training, education programs have difficulty in developing this ability. From all the studies as mentioned earlier, it is understood that activities in curriculum programs are insufficient to develop spatial visualization skills of students. In this context, it is essential to measure the spatial visualization skill levels which can predict the mathematical abilities of the students, and take measures for the development of these skills.

There are researches conducted on different samples (especially high schools and universities) in various disciplines. However, it is noteworthy that although the samples studied are in different age groups, the main spatial visualization tests are used repeatedly, and there is no distinction between two and three dimensional spatial visualization skills in these studies. Therefore, in this research, it is aimed to determine the spatial visualization skills of secondary school students by using a valid and reliable test, which measures both the two and three dimensional spatial skills with different question types, to evaluate them in terms of some variables, and to compare these scores with their achievements in mathematics and science. In response to this general purpose, the answer to the following questions was investigated.

- What is the level of spatial visualization skills of secondary school students?
- Do spatial visualization skills of the secondary school students change in a statistically significant way according to the variables like, "gender", "class", "pre-school education status", "elective intelligence games taking courses", "frequency of playing geometric-mechanical games", "frequency of playing a computer games"?
- Is there a significant relationship between secondary school students' spatial visualization skills and their achievements in mathematics and science courses?

Method

Research Design

Descriptive scanning model was used in order to determine the spatial visualization skills of the secondary school students and to evaluate regarding some variables; meanwhile, the correlational scanning model was used to compare the achievements of mathematics and science courses.

Research Sample

The population of the study consisted of the students studying in secondary schools in the central districts of Diyarbakir. The sample of the study comprises of 506 students in six secondary schools who were chosen by simple random sampling method from the secondary schools in the central districts of Diyarbakir Province in the 2017-2018 academic year. Secondary school students, who were in the process of abstract thinking, were selected as the study group, in order to develop their spatial skills, which required abstract thinking skills. The characteristics of the sample group are given in Table 1.

Table 1. The Characteristics of the Sample Group

	Variables	Frequency	Percentage
Gender	Girls	234	46%
	Boys	272	54%
Class	6th grade	167	33%
	7 th grade	175	35%
	8th grade	164	32%
Pre-school education status	Received	291	58%
	Not received	215	42%
Elective intelligence games taking courses	Received	153	30%
	Not received	355	70%
Frequency of playing geometric-mechanical games	Never	61	12%
	Occasionally	370	73%
	Often	75	15%
Frequency of playing a computer game	Never	89	18%
	Occasionally	293	58%
	Often	124	24%

Data Collection Tools and Implementation

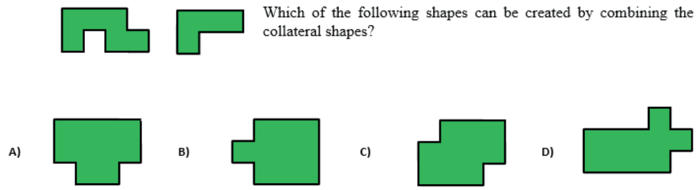
In this research, the Spatial Visualization Test (SVT) developed by Dokumaci-Sutcu (2017) and a personal information form, were used as data collection tools. Data collection tools were applied to the students during their classes. In the personal information form, students were asked about their classes, gender, pre-school education, elective intelligence games courses taken/or not, the frequency of playing geometric-mechanical games, the frequency of playing computer games, and the marks of mathematics and science courses.

SVT consists of a total of 29 items with four options to measure the spatial visualization skills of secondary school students and has a two-factor structure. The test consists of questions such as mental integration, mental seperation, paper folding, surface development, cube counting, cube contact count, which measure spatial visualization skill. The first factor which consists of 14 items, measures students' two dimensional spatial visualization skills, and the second factor, which consists of 15 items, measures students' three dimensional spatial visualization skills. After the expert opinion was taken at the development stage of the test, firstly the exploratory factor analysis was performed via the Tetrachoric Correlation Matrix. Afterwards, confirmatory factor analysis was performed by using the Asymptotic Covariance Matrix and the Weighted

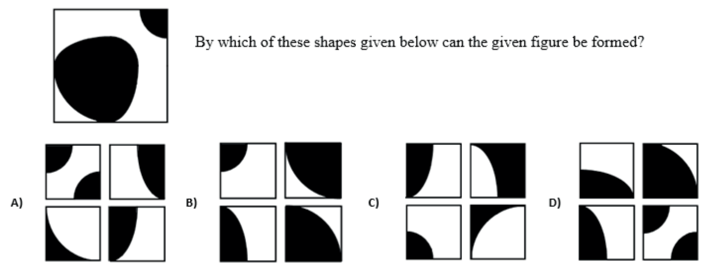
Least Squares Method. It was found that the two-factor structure had adequate fit indices (χ^2/sd:1.26, RMSEA:0.029, GFI:0.96, AGFI:0.95, SRMR: 0.074, NNFI:0.92, CFI:0.93). Item analysis was performed for 29 items; the test, which consisted of items with different difficulty levels, was found to be moderately difficult and highly distinguishing. The KR-20 internal consistency coefficient was calculated to be .77 for the first factor consisting of 14 items, and .78 for the second factor consisting of 15 items. The KR-20 internal consistency coefficient belonging to the entire test was calculated as .78. Table 2 gives an example for each questions in SVT.

Table 2. An Example for Each Question in the SVT

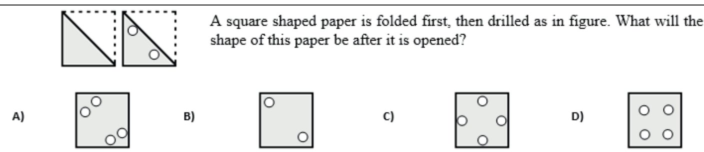
2D Mental İntegration



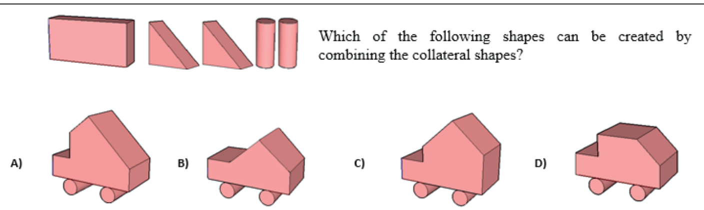
2D Mental Seperation



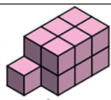
2D Paper Folding



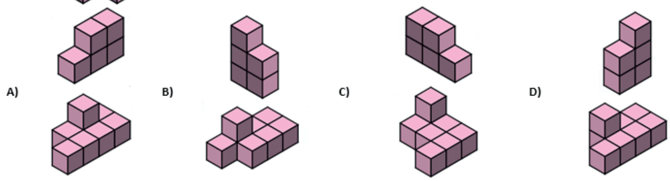
3D Mental İntegration



3D Mental Seperation

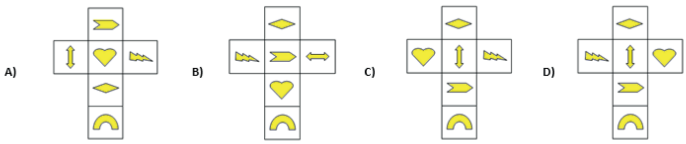


The collateral figure consisting of unit cubes can be formed by combining which of the two shapes given below?

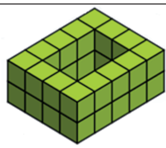


3D Surface Development

Which of the following could be the opened status of cube, given in the closed status with different shapes on each side?



3D Cube Counting



The inside of the figure made up of unit cubes is completely empty. How many cubes will you need to fill this space?

A) 8 B) 10 C) 12 D) 14

3D Cube Contact Count

How many cubes does the cube, which is represented by the collateral white color, face in the shape consisting of unit cubes?

A) 2 B) 3 C) 4 D) 5

Data Analyses

Descriptive statistics were used to determine the spatial visualization skills of secondary school students. Besides, to determine the type of analysis appropriate to the data obtained, it was tested whether the data showed normal distribution characteristics for the sub-groups of each independent variables. For this purpose, histogram, normal Q-Q, detrended normal Q-Q, box-line graphs, kurtosis and skewness values were examined (Buyukozturk, 2011). The kurtosis and skewness values of the subgroups of the independent variables, except for the mathematics and science course grades, were found to be in the range of +1, -1, and their graphs showed a normal distribution characteristic. Therefore, independent sample t-test was used to assess the spatial visualization skills of secondary school students concerning "gender", "pre-school education status", "elective intelligence games course taking" variables. In order to use one-way variance analysis (ANOVA), it is also examined whether the variance of the groups is equal or not. For this, Levene test was used and since the data obtained from the groups were $p>.05$, it was determined that the variances of the groups were equal. Therefore, ANOVA was used to assess the spatial visualization skills of secondary school students in terms of “classroom”, “frequency of playing geometric-mechanical games”, “frequency of playing computer games”. In cases where the difference is determined, the LSD test was used to determine between which groups the diversity was occurring. Since the kurtosis and skewness values of students’ mathematics and science course grades were not within the range of +1, -1 and the graphs did not show normal distribution characteristics, Spearman-Brown correlation coefficient was used to compare the spatial visualization skills of the secondary school students with their achievements of mathematics and science courses.

Findings

In this section, the findings obtained as a result of the analysis of the identified sub-problems of the research are included.

Descriptive statistical results of the average SVT scores of the secondary school students are presented in Table 3.

Table 3. Descriptive Statistical Results of the Average SVT Scores of the Secondary School Students

SVT	N	Minumum	Maximum	Mean	Std. Deviation
2D	506	.00	14.00	7.04	3.04
3D	506	.00	15.00	7.77	3.14

According to Table 3, the average of the secondary school students’ two dimensional spatial visualization scores is 7.04, whereas the average of three dimensional spatial visualization scores is 7.77. According to these findings, it could be said that two and three dimensional spatial visualization skills of secondary school students’ are moderate.

The t-test results of the average SVT scores of the secondary school students, concerning the “gender” variable are included in Table 4.

Table 4. The t-Test Results of the Average SVT Scores of the Secondary School Students, Concerning the "Gender" Variable

SVT	Gender	N	Mean	Std. Deviation	df	t	Sig.
2D	Girls	234	6.96	2.89	504	.564	.573
	Boys	272	7.11	3.17			
3D	Girls	234	7.64	2.91	504	.897	.370
	Boys	272	7.89	3.32			

In Table 4, there was no statistically significant difference between boys and girls regarding the average scores obtained from the two dimensional spatial visualization part of the SVT [$t_{(504)}$=.564, p>.05]. Again as seen in Table 4, there was no statistically significant difference between boys and girls regarding the average scores obtained from the three dimensional spatial visualization part of the SVT [$t_{(504)}$=.897, p>.05]. In that case, it could be said that there is no significant relationship between two and three dimensional spatial visualization skills and gender.

The ANOVA results of the average SVT scores of the secondary school students, concerning the "class" variable are included in Table 5.

Table 5. The ANOVA Results of the Average SVT Scores of the Secondary School Students, Concerning the "Class" Variable

SVT	Class	N	Mean	Std. Deviation		Sum of Squares	df	Mean Square	F	Sig.
2D	6th	167	6.53	2.91	Between Groups	125.214	2	62.607	6.921	.001
	7th	175	6.89	2.97	Within Groups	4549.995	503	9.046		
	8th	164	7.73	3.14	Total	4675.209	505			
Significant Differences: 6 th - 8th, 7 th - 8 th										
3D	6th	167	7.14	2.81	Between Groups	101.233	2	50.617	5.218	.006
	7th	175	8.01	3.42	Within Groups	4879.083	503	9.700		
	8th	164	8.16	3.07	Total	4980.316	505			
Significant Differences: 6 th - 7 th, 6 th - 8 th										

According to Table 5, a statistically significant difference was found in the two dimensional spatial visualization average scores of 6, 7, and 8th grade students [$F_{(2,503)}$=6.921, p<.05]. Again in Table 5, a statistically significant difference was found between the three dimensional spatial visualization average scores of 6, 7, and 8th grade students [$F_{(2,503)}$=5.218, p<.05]. According to the results of the LSD test, which has performed to find the reason of the difference, the two dimensional spatial visualization skills of the 8th grade students in comparison to the 6th and 7th grade students, also the three dimensional spatial visualization skills of the 7th and 8th grade students in contrast to the 6th grade students appeared to be significantly higher.

The t-test results of the average SVT scores of the secondary school students, concerning the "pre-school education status" variable are included in Table 6.

Table 6. The t-Test Results of the Average SVT Scores of the Secondary School Students, Concerning the "Pre-school Education Status" Variable

SVT	Pre-school Education Status	N	Mean	Std. Deviation	df	t	Sig.
2D	Received	291	7.46	3.04	504	3.665	.000
	Not received	215	6.47	2.96			
3D	Received	291	8.19	3.12	504	3.491	.001
	Not received	215	7.21	3.09			

In Table 6, there was a statistically significant difference in the average scores of students who have and have not received pre-school education, from the two dimensional spatial visualization part of SVT [$t_{(504)}$=3.665, p<.05]. Again as seen in Table 6, there was a statistically significant difference in the average scores of students who have and have not received pre-school education, from the three dimensional spatial visualization part of SVT [$t_{(504)}$=3.491, p<.05]. Accordingly, the two and three dimensional spatial visualization skills of the students who received pre-school education could be stated to be significantly higher than the students who did not receive preschool education.

The t-test results of the average SVT of the secondary school students, concerning the "elective intelligence games taking courses" variable are included in Table 7.

Table 7. The t-Test Results of the Average SVT Scores of the Secondary School Students, Concerning the "Elective Intelligence Games Taking Courses" Variable

SVT	Elective Intelligence Games Taking Courses	N	Mean	Std. Deviation	df	t	Sig.
2D	Received	153	7.05	3.28	504	.030	.976
	Not received	353	7.04	2.94			
3D	Received	153	7.82	3.26	504	.199	.842
	Not received	353	7.76	3.10			

As seen in Table 7, from the average scores of two dimensional spatial visualization part of the SVT, there was no statistically significant difference between the students who did or did not receive the elective intelligence games course [$t_{(504)}$=.030, p>.05]. Again in Table 7, from the average scores of three dimensional spatial visualization part of the SVT, there was no statistically significant difference between the students who did or did not receive the elective intelligence games course [$t_{(504)}$=.199, p>.05]. According to this results, it could be said; there is no significant relationship between the two and three dimensional spatial visualization skills and taking elective intelligence games courses.

The ANOVA results of the average SVT scores of the secondary school students, concerning the "frequency of playing geometric-mechanical games" variable are included in Table 8.

Table 8. The ANOVA Results of the Average SVT Scores of the Secondary School Students, Concerning the "Frequency of Playing Geometric-Mechanical Games" Variable

SVT	Frequency	N	Mean	Std. Dev.		Sum of Squares	df	Mean Square	F	Sig.
2D	Never	61	5.44	2.67	Between Groups	180.791	2	90.395	10.117	.000
	Occasio-nally	370	7.22	3.07	Within Groups	4494.419	503	8.935		
	Often	75	7.47	2.84	Total	4675.209	505			
Significant Differences: Never-Occasionally, Never-Often										
3D	Never	167	6.34	2.55	Between Groups	152.926	2	76.463	7.967	.000
	Occasio-nally	175	7.90	3.17	Within Groups	4827.390	503	9.597		
	Often	164	8.32	3.12	Total	4980.316	505			
Significant Differences: Never-Occasionally, Never-Often										

According to Table 8, there was a statistically significant difference between the average SVT scores of whom never play geometric-mechanical games, and of whom played those occasionally or often, from the two dimensional spatial visualization part [$F_{(2,503)}$=10.117, p<.05]. Again as seen in Table 8, there was a statistically significant difference between the average SVT scores of whom never play geometric-mechanical games, and of whom played those occasionally or often, from the three dimensional spatial visualization part [$F_{(2,503)}$=7.967, p<.05]. According to the results of the LSD test which performed to find the basis of the difference, the two and three dimensional spatial visualization skills of the students who occasionally and frequently play geometric-mechanical games are significantly higher than those who do not play.

The ANOVA results of the average SVT scores of the secondary school students, concerning the "frequency of playing computer games" variable are included in Table 9.

Table 9. The ANOVA Results of the Average SVT Scores of the Secondary School Students, Concerning the "Frequency of Playing Computer Games" Variable

SVT	Frequency	N	Mean	Std Dev.		Sum of Squares	df	Mean Square	F	Sig.
2D	Never	85	6.08	2.73	Between Groups	94.584	2	47.292	5.193	.006
	Occasionally	295	7.26	3.06	Within Groups	4580.625	503	9.107		
	Often	126	7.16	3.09	Total	4675.209	505			
Significant Differences: Never-Occasionally, Never-Often										
3D	Never	85	6.98	2.87	Between Groups	65.191	2	32.596	3.336	.036
	Occasionally	295	7.95	3.05	Within Groups	4915.125	503	9.772		
	Often	126	7.91	3.46	Total	4980.316	505			
Significant Differences: Never-Occasionally, Never-Often										

In Table 9, there was a statistically significant difference between the average SVT scores of whom never play computer games, and of whom played those occasionally or often, from the two dimensional spatial visualization part [$F_{(2,503)}=5.193$, $p<.05$]. Again according to Table 9, there was a statistically significant difference between the average SVT scores of whom never play computer games, and of whom played those occasionally or often, from the three dimensional spatial visualization part [$F_{(2,503)}=3.336$, $p<.05$]. According to the results of the LSD test which performed to find the basis of the difference, the two and three dimensional spatial visualization skills of the students who occasionally and frequently play computer games are significantly higher than those who do not play.

The Spearman-Brown Correlation Coefficient for the relationship between secondary school students' average scores and their mathematics achievement is presented in Table 10.

Table 10. The Spearman-Brown Correlation Coefficient for the Relationship Between Secondary School Students' Average Scores and Their Mathematics Achievement

SVT		Mathematics Achievements
2D	Correlation Coefficient	.336
	Sig.	.000
	N	506
3D	Correlation Coefficient	.332
	Sig.	.000
	N	506

In Table 10, there seems a moderate, positive and significant, relationship between two dimensional spatial visualization score averages of the SVT and mathematics achievements of secondary school students [r=.336; p<.05]. Again according to Table 10, there seems a moderate, positive and significant, relationship between three dimensional spatial visualization score averages of the SVT and mathematics achievements of secondary school students [r=.332; p<.05]. Accordingly, students with high mathematics achievements would also have significantly higher scores both from two and three dimensional spatial visualization skills. Considering the coefficient of determination was "r^2 =.11", it could be seen that 11% of the total variance of both two and three dimensional spatial visualization skills stems from the mathematics success.

The Spearman-Brown Correlation Coefficient for the relationship between secondary school students' average scores and their science achievement is presented in Table 11.

Table 11. The Spearman-Brown Correlation Coefficient for the Relationship Between Secondary School Students' Average Scores and Their Science Achievement

SVT		Science Achievements
2D	Correlation Coefficient	.292
	Sig.	.000
	N	506
3D	Correlation Coefficient	.295
	Sig.	.000
	N	506

According to Table 11, there seems a low, positive and significant relationship between two dimensional spatial visualization score averages of the SVT and science achievements of secondary school students [r=.292; p<.05]. Again as seen in Table 11, there seems a low, positive and significant, relationship between three dimensional spatial visualization score averages of the SVT and science achievements of secondary school students [r=.295; p<.05]. Accordingly, students with high science achievements would also have significantly higher scores both from two and three dimensional spatial visualization skills. Considering the coefficient of determination was "r^2 =.09", it could be seen that 9% of the total variance of both two and three dimensional spatial visualization skills stems from the science success.

Conclussion and Discussion

In the research, it was found that both the two and three dimensional spatial visualization skills of secondary school students were intermediate. In a study conducted by Turgut and Yilmaz (2012) and Topraklıoğlu and Öztürk (2019), the spatial visualization skills of the 7th and 8th grade students were found to be low. Rittle-Johnson et al. (2018) have stated that one of the skills that contribute significantly to the development of mathematical skills at early ages is the often neglected spatial visualization ability. Lin and Chen (2016) stated that because of this nature of spatial ability requiring adequate space and time to perform effective training, education programs have difficulty in developing this ability. Based on these explanations, it can be said that the reason for the lack of spatial visualization skills of secondary school students is due to the lack of adequate teaching of these skills in the classroom environments.

When the relationship between the two and three dimensional spatial visualization skills and gender of the secondary school students were examined, although the two and three dimensional spatial visualization skill scores of the boys were higher than the girls, there was no statistically significant difference between the scores. Achieving similar results in the literature is possible. For example, a study conducted by Uzun (2019), it was found that the spatial abilities of secondary school students did not show a significant difference according to gender. In the study by Morris (2018) found that there was no significant difference between the spatial visualization skills of elementary and secondary school school girls and boys. In the study of the Cilingir-Altinel (2018) with the 4th grade students, it has emerged that there is no significant difference between the students genders and two dimensional spatial visualization skills. Rafi et al. (2008) showed that while the spatial visualization skill scores of male students were higher than that of female students, the difference between scores was not statistically significant. Besides, in another study by Jirout and Newcombe (2015), the relationship between spatial games and spatial skills was examined in terms of gender, and it was stated that the spatial skills were better for boys as they played more spatial games than girls. Although the results of all these researches do not make a definitive judgment, the fact that male students have relatively higher spatial visualization skill scores compared to female students may because they tend to play games that require the use of spatial visualization skills such as building with blocks.

In the research, there was no significant correlation between the two and three dimensional spatial visualization skills of secondary school students and whether or not they took the elective intelligence games course. According to Devecioglu and Karadag (2014), the reason for this finding may be due to insufficient training of teachers who teach the elective intelligence games, who generally are not directly educated in this field, but mainly mathematics teachers or basically who else more or less interested in the area. However, it is thought that the course of intelligence games (especially in the geometric-mechanical games unit) involves the game activities, that allows the student to develop many features as spatial skills.

In the research, two and three dimensional spatial visualization skills of the students who took pre-school education were significantly higher than those who did not take. Similarly, the spatial visualization skills of the 7th and 8th grade students who had pre-school education were significantly higher than those who had not received, in the study of Turgut and Yilmaz (2012). In the study conducted by Uzun (2019), it was found that the spatial abilities of secondary school students showed a significant difference according to their pre-school education status. In another study by Cilingir-Altinel (2018), two dimensional spatial visualization skills of fourth-grade students who received pre-school education, compared to those who did not have pre-school education were significantly higher. Bosnyak and Nagy-Kondor (2008) also argued that the development of spatial skills should be initiated in the early stages of childhood. Therefore, the reason for these findings could be that the students who took pre-school education in early childhood have been able to use spatial visualization skills such as use paper folding, paper cutting, ornamentation, choosing geometric shapes, combining and de-matching appropriately in an early age. Differently, in a study conducted by Dundar, Yilmaz and Terzi (2019), prospective teachers' spatial abilities do not differ according to their pre-school education status.

Two dimensional spatial visualization skills of the 8th grade students were found to be significantly higher than the 6th and 7th graders, while the three dimensional spatial visualization skills of the 7th and 8th graders were significantly higher than the 6th grade students. Similarly, in the study conducted by Turgut (2007), the spatial visualization levels of the 6th grade students were lower than the 7th and 8th grade students. These findings may be because 6th grade students have not fully achieved their spatial visualization skills because they are just at the beginning of their transition from abstract thinking to concrete thinking.

In the research, the two and three dimensional spatial visualization skills of secondary school students who play geometric-mechanical games and computer games are significantly higher than those who do not play these games. There are researches in the literature that support these findings. For example, Yuksel et. al. (2017) and Yuksel (2019) have stated that playing with geometric-mechanical games develop spatial abilities. Cilingir-Altinel (2018) has determined that fourth grade elementary school students have a positive and significant relationship between their two dimensional spatial visualization skills and their skills in puzzle games. In the research conducted by Dokumaci-Sutcu (2017), it was found that geometric-mechanical activities of both the concrete materials and the computer environment, improved the two and three dimensional spatial visualization skills of the 7th grade students. Demirkaya and Masal (2017) have shown that geometric-mechanical game-based activities are effective of the secondary students' development of spatial skills. Martin-Dorta et al. (2014) stated that activities such as playing with construction building toys and three dimensional computer games at small ages have a strong relationship with spatial visualization capability. However, it is still possible to reach different results even though the literature is limited. For example; Caldera et al. (1999) showed that there is no relationship between the activities of play with blocks of the kindergarten students and the spatial skill performances. With all of these research results, it could be said that the spatial visualization skills of students can be developed with computer games and geometric-mechanical games such as puzzles, Lego, blocks, however, not being a definite judgment.

In the research, a moderate, positive and significant relationship was found between the two and three dimensional spatial visualization skills of secondary school students and their accomplishment in mathematics. Similar results can be reached in the literature. In their study, Gurbuz, Erdem and Gulburnu (2018) pointed that out there was a positive correlation between the spatial abilities and mathematical reasoning of the 8th grade students. Turgut and Turgut (2018) found that the effect of spatial visualization skills on mathematics achievement was moderate. Tam, Wong and Chan (2018) found a positive relationship between the spatial skills and mathematical skills of the 2nd grade students in primary school. According to Bishop (1980), the reason for these findings is that the spatial ability could help the students to organize the problem with mental pictures in solving math problems, to organize the information between the components of the problem, and to show the relationships in the tree diagrams, Venn schemes, graphs, and other forms. Again, in the research, a low, positive and significant relationship was found between the two and three dimensional spatial visualization skills of secondary school students and the successes of science courses. In this research, Tracy (1990) found that the 5th grade students with high spatial ability had significantly higher science achievement scores than the students with low spatial ability. Based on the results of all these studies, it can be said that there is a positive and significant relationship between the spatial visualization skills of the secondary school students and their achievement of mathematics and science course.

Recommendations

To conclude, some of the suggestions developed in light of the findings of the research can be listed as follows: The importance of spatial ability in pre-school education support campaigns can be encouraged. In-depth analysis can be done to see why secondary school students are not capable of spatial visualization skills. It can be explored that why the students take the intelligence games courses which may allow the development of many features, can't make any difference within the spatial visualization skills. Experimental research for the improvement of spatial visualization abilities can be done by utilising both computer games and geometric-mechanical games such as Lego, tangram, jigsaw. Longitudinal surveys could be performed to define the factors that influence the development of spatial abilities of students from elementary school to secondary schools. Similar research can be done for other sub-skills of spatial ability and for various class levels.

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