The Development and Validation of the Spatial Anxiety Scale for Secondary School Students

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Abstract

This study aims to develop a scale for determining the anxiety levels of secondary school students in situations that require them to use their spatial skills. The scale was developed in three stages. In the first stage, after expert assessments, a pilot study was conducted. In the second stage, the scale was applied to all students (N=348) studying in a secondary school selected by random sampling for exploratory factor analysis, and results supported a structure with two sub-dimensions consisting of 14 items. For confirmatory factor analysis, the scale was applied to a different group of students (N=206), and analysis results confirmed the two-factor structure of the scale. The first factor, including spatial relations and orientation items, was named Anxiety of Spatial Relations and Orientation, and the second was named Anxiety of Spatial Visualization. In the third stage, Cronbach's alpha reliability of the scale was found to be ,82 for the whole scale and ,81 and ,72 for sub-dimensions. The McDonald's omega was also calculated as ,97 for the whole scale and ,96 and ,91 for sub-dimensions of it. The results revealed that the scale measures the spatial anxiety level of students validly and reliably.

Keywords: Secondary School Students, Spatial Anxiety, Spatial Orientation, Spatial Relations, Spatial Skills, Spatial Visualization.

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INTRODUCTION

Spatial skills are defined as the ability to form and control mental images (Lord, 1985), but the nature of spatial skills is still not fully understood (Linn & Petersen, 1985; Tam et al., 2019). There are positive correlations between spatial skills and mathematics achievement (Battista, 1994). Spatial skill is also known as a predictor of STEM achievement (Ramirez et al., 2012; Wai et al., 2009). Regarding spatial skills, spatial anxiety refers to students' anxiety about performing spatial tasks (Ramirez et al., 2012) and affects student performance negatively (Dursun, 2010). Besides, it has been reported that spatial anxiety reduces the ability to focus on the cues required to maintain geographical orientation (Lawton, 1994). Because of the important and multi-dimensional effects of spatial anxiety, there is a need for more research investigating it. This study, aimed to develop a scale for measuring the spatial anxiety levels of secondary school students. Since spatial anxiety scales are limited in the literature (Lawton, 1994; Lyons et al., 2018), this study will contribute to the field.

Theoretical Framework

Spatial skills are defined in different ways by researchers. Tartre (1990) defined it as "mental skills concerned with understanding, manipulating, reorganizing, or interpreting relationships visually" (p. 216). Linn and Petersen (1985) emphasized the symbolic (nonlinguistic) information in spatial skills and expressed it as the "skill in representing, transforming, generating, and recalling symbolic information" (p. 1482). According to Lohman (1993), spatial skills are "to generate, retain, retrieve, and transform well-structured visual images" (p. 3). On the other hand, Casey et al. (2001) emphasized spatial skills as reasoning skills by transforming of mental pictures.

Spatial skill is an important component of intellectual skills (Linn & Petersen, 1985). Besides, it is positively associated with mathematical skills (Tam et al., 2019) and is a significant predictor of students' mathematics success and reasoning skills (Casey et al., 2015; Battista et al., 1982; Hannafin et al., 2008). Moreover, spatial skills play an important role in students' success and participation in the STEM disciplines (Casey et al., 2001; Gunderson et al., 2013; Lauer et al., 2018; Wai et al., 2009). It is also possible to increase the students' success in engineering courses with spatial skills (Sorby, 2009).

Components of Spatial Skills

The only known about spatial skill is that it includes multiple processes (Linn & Petersen, 1985). So there are different classifications related to the components of spatial skills. McGee (1979) and Clements (1998) classified spatial abilities in two components; spatial visualization and spatial orientation. According to Lohman (1979) and Contero et al. (2005), spatial skills involve three types: visualization, relations, and orientation. Linn and Petersen (1985) also explained three components of spatial skills according to the results of a meta-analysis study: spatial visualization, spatial perception, mental rotation. Different researches express two components of spatial skills, but the components are different. Burnett and Lane (1980) defined two types of spatial factors: the first one is spatial relations and orientation as a whole, and the second is spatial visualization. The researchers explaining two factors of spatial skills, including spatial visualization and spatial relations also exist in the literature (e.g., Elliot & Smith, 1983; Pellegrino et al., 1984; Olkun, 2003).

Spatial visualization, which is an essential component of spatial skills, described as the ability to imagine the spinning of objects in three-dimensional space and folding or unfolding of flat patterns (Burnet & Lane, 1980; McGee, 1979). Visualization is the revival of the new state of the object due to moving and rotating (Ekstrom et al., 1976). However, it is a complicated ability involving multistep manipulations of spatial information like mental rotation and spatial perception (Linn & Petersen, 1985). The other component of spatial skills is spatial orientation, defined as "understanding and operating on the relationships between the positions of objects in space with respect to one's own position" (Clements & Battista, 1992, p. 69). It includes "the arrangement of elements within a visual

stimulus pattern" (McGee, 1979, p. 892). The next one is spatial perception, and it consists of determining spatial relationships with respect to the orientation of individuals' own bodies (Linn & Petersen, 1985). Another type of spatial skill is mental rotation, and it can be defined as "the ability to rotate a two or three-dimensional figure rapidly and accurately" (Linn & Petersen, 1985, p. 1483). The last one is spatial relations. It was described as "comprehension of the arrangement of elements within a visual stimulus pattern" (McGee, 1979, p. 892) and includes recognizing "the identity of an object when it is seen from different angles" with spatial orientations (Burnet & Lane, 1980, p. 233). As seen in the different definitions, it is very complicated to distinguish the components of spatial skills with strict limits.

Spatial Anxiety and Its Relationships with Spatial Skills

According to Lawton (1994), spatial anxiety is the anxiety about environmental navigation. Schmitz (1997) defined spatial anxiety as concerns about becoming lost. Spatial anxiety, which negatively correlates with spatial skills, negatively affects student academic success (Dursun, 2010). Reducing spatial anxiety and understanding its relationship with spatial skills will contribute to spatial skills development and increase success in STEM disciplines (Ramirez et al., 2012; Wai et al., 2009).

Regarding the studies on spatial anxiety, the results showed that both men (Erkek & Işıksal Bostan, 2015) and women show higher spatial anxiety levels (Ferguson et al., 2015; Lauer et al., 2018; Lawton, 1994; Lyons et al., 2018). It has also been found that adults with high spatial anxiety use lower navigation strategies (Lawton, 1994) and show lower mental rotation performance in their spatial reasoning skills (Ferguson et al., 2015; Lawton, 1994; Lyons et al., 2018). Regarding spatial skills in childhood, Ramirez et al. (2012) examined the relationship between the spatial anxiety and mental rotation performance of first and second-grade students. They found that higher spatial anxiety of children with higher working memory is related to poorer mental rotation performance. The results also revealed that girls showed higher spatial anxiety than boys as in adults (Ferguson et al., 2015; Lawton, 1994). In a different study with third and fourth-grade children, Cardillo et al. (2017) reported similar findings: Spatial anxiety is negatively associated with mental rotation performance, and girls have higher spatial anxiety than boys. More studies investigating spatial anxiety and its relationships with spatial skills from different perspectives will contribute to the field.

The Importance of the Study

The absence of a scale that measures the level of spatial anxiety of secondary school students constitutes the study's point. There are two spatial anxiety scales previously developed. The first is the spatial anxiety scale developed by Lawton (1994) for measuring college undergraduates' navigational skills, consisting of a dimension and eight items. The other is the spatial anxiety scale developed for adults by Lyons et al. (2018). Therefore, this study aimed to develop a "Spatial Anxiety Scale" for secondary school students.

METHOD

This study is a scale development study and aimed to develop the Spatial Anxiety Scale to measure the anxiety levels in situations that require secondary school students to use their spatial skills.

Participants

The data was collected from three groups of participants. The first group consisted of 5th-grade students (N=12) used for the pilot study. In the second stage, the scale was applied to all students (N=348) studying in a public secondary school selected by random sampling. This group includes 177 girls (50.9%) and 171 boys (49.1%); 85 fifth grade (24.4%), 74 sixth grade (21.3%), 97 seventh grade (27.9%), 92 eighth grade (26.4%) students. The scale was reapplied randomly to 206

students studying in a different secondary school for confirmatory factor analysis. There were 93 girls (45.1%) and 113 boys (54.9%) in this group. In terms of grade levels, there were 67 students (32.6%) in the fifth grade, 73 students (35.4%) in the sixth grade, 53 students (25.7%) in the seventh grade, and 13 students (6.3 %) in the eighth grade.

Developing the Scale

The scale was developed in three stages. In the first stage, for the content validity, the items were evaluated by experts, and a pilot study was conducted with 5th-grade students for the clarity of the scale. In the second stage, exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were conducted. After obtaining a meaningful factor structure, in the third stage, the scale's reliability was analyzed.

In the first stage, the studies about spatial skills were investigated, and different classifications about the components of spatial skills were reviewed. The scale was developed based on the classification made by Lohman (1979) and Contero et al. (2005). Lohman (1979) and Contero et al. (2005) classified spatial skills in three components: spatial orientation, relations, and visualization. In this context, the items of the scale were determined. Contero et al. (2005) summarized the features of the literature's most commonly cited paper-and-pencil spatial ability tests, and the items of the scale were constructed considering this summarization. Table 1 presents the types of spatial skills determined by Contero et al. (2005).

Table 1. The types of spatial skills (adapted from Contero et al., 2005)

	Spatial Skills	The Types of Abilities
1	Spatial Relations	Performing a mental rotation of 2D objects
		Matching a given image with an image that is identical, but rotated
		Determining whether images of hands rotated in different positions, correspond to the left or right hand (Left or Right Hand Identification)
		Mentally rotating 2D objects (Cards Rotation)
2	Visualization	Viewing two-dimensional parts of a paper and selecting the figure that indicates the appearance of the final unit of paper when the parts are assembled (Paper form)
		Indicating what an unfolded shape would look like when folded (Differential Aptitude)
		Folding a paper mentally a certain number of times, making a hole through the folds, then visualizing the unfolded paper (Paper Folding)
		Visualizing how a piece of paper can be folded to form a given 3D object (Surface Development)
		Identifying rotated versions of 3D objects composed of cubes
3	Spatial Orientation	Identifying in which direction the object has moved when shown pictures of an object in different spatial orientations.
		Imagining an egocentric perspective transformation (Perspective-Taking)

The abilities in Table 1 and transformation questions from 2D to 3D and 3D to 2D, including visualization in mind, were also included in spatial visualization ability following expert opinions. A scale form was developed, including 30 items that measure anxiety of spatial relations, visualization, and orientation.

Content Validity

Two experts in the Mathematics Education Department, one expert from the Turkish Language Education Department, and two mathematics teachers evaluated the scale.. Three items were removed from the scale (items 19, 24, 28), and some adjustments were made on items, resulting in a form with 27 items. Then, for the clarity of the scale, it was applied to fifth-grade students (N = 12), and the statements of the items were revised with the students' feedbacks.

Construct Validity

To determine the scale's construct validity, after excluding the extreme values (N=7), EFA was performed on the data (N=341). As a result of EFA, the anti-image table, which shows the adequacy of items in the scale, was examined. It is stated that this value should be ,50 or more for each item (Özdamar, 2017; Şencan, 2005). Then, Kaiser-Meyer Olkin (KMO) coefficient and Barlett Sphericity Test results were evaluated. The KMO coefficient above ,60 and the Bartlett test being significant (p <0,05) show that the data is suitable for factor analysis and the sample size is sufficient (Büyüköztürk, 2012; Özdamar, 2017). Principal axis factoring with oblique rotation was used for the factor analysis. Principal axis factoring was conducted to determine the hidden structures behind the variables, and Oblique rotation (direct oblimin) was performed considering that the variables are related to each other (Şencan, 2005). All items with a factor loading above ,40 were included in the scale (DeVellis, 2003; Şencan, 2005). As a result of EFA, overlapping items (the difference between factor loadings is lower than ,10) were excluded from the scale (Karagöz, 2019). Since the common variance is affected by the sample size and it is not possible to obtain high common variance values in social sciences, it is suggested that this value should be taken as ,20 (Çokluk et al., 2012; Şencan, 2005). After EFA, the model was also tested with CFA. The fit indexes of χ2/df, RMSEA, SRMR, GFI, CFI, NNFI, AGFI, and IFI were used in the study for the model tested in CFA. The model fits were evaluated based on the following criteria: χ2 / df < 5; GFI > .90, CFI > .90, NNFI > .90, IFI > .90; and RMSEA < .06 and SRMR < .08 (Hu & Bentler, 1999; Jöreskog & Sörbom, 1993; Kline, 2016; Özdamar, 2017; Schumacker & Lomax, 2004; Tabachnick & Fidell, 2007).

Convergent Validity

For the convergent validity of the scale, the Pearson correlation between the students' scores from the Spatial Anxiety Scale (Lawton, 1994) and the scores in this study were analyzed. The Spatial Anxiety Scale (Lawton, 1994) consists of 8 items and one factor. In this study, CFA analysis was also conducted to validate the Spatial Anxiety Scale of Lawton, (1994). The scale was first translated into Turkish and corrected following the expert opinion (a lecturer working in language). It was applied to the participants (N =206), and CFA was conducted. As a result of CFA, the fit indexes were found as χ2 /sd=1,783 GFI=,956 AGFI=,921 CFI=,944 NNFI=,922 IFI=,946 RMSEA=,063 SRMR=,0506. The scale showed a perfect and acceptable fit (Hu & Bentler, 1999; Jöreskog & Sörbom, 1993; Özdamar, 2017; Thompson, 2004), and it was seen that the scale could be used on secondary school students. Cronbach's alpha of the scale in this study was found to be 0.77.

Item Analysis

To determine the reliability of the items in the scale, the item-total test correlations were analyzed. The t-values of the bottom and top 27% groups of the scale related to differences were also examined. Excel, SPSS, and AMOS programs were used for data analysis.

Reliability

The coefficients of Cronbach's alpha and McDonald's omega were calculated for the reliability of the scale. The Cronbach's alpha coefficient assumes that factor loadings and error variances of the items are equal, and McDonald's omega assumes factor loadings and error variances to be different. Therefore, it is suggested that, especially in multi-dimensional scales, the McDonald's omega has higher values than the Cronbach's alpha coefficient (Şencan, 2005, p. 120; Yurdugül, 2006, p. 29).

RESULTS

Findings Related to the Construct Validity of the Scale

Exploratory Factor Analysis

As a result of EFA, KMO was found to be ,909. Barlett's test of sphericity was significant ($\chi 2$ (2704, 192) = 351, p<,05) The diagonal of the anti-image correlation matrix was examined, and it was decided to exclude four items (items 3, 6, 10, 17) with an anti-image value less than ,50. As a result of EFA, a five-factor structure that explains 38,793% of the total variance was obtained. The factors, eigenvalues, and total variances explained were presented in Table 2.

Table 2. Factors as a result of EFA

Factors	Eigenvalues	Total variances explained
1	7,203	24,447
2	2,827	8,256
3	1,310	2,595
4	1,134	1,935
5	1,002	1,561
Total variance		38,793

In Table 2, it is seen that five factors with eigenvalues greater than one emerged as a result of EFA. However, when the variance rate explained by the eigenvalues falls below 10% (in some features, this ratio can be taken as 5%), it can be judged that the factor determined for that eigenvalue cannot adequately explain the latent structure of the phenomenon and that factor can be neglected (Özdamar, 2017). Therefore, the percentage of variance explained by factors 3, 4, and 5 has fallen below 5%. The scree plot of EFA was presented in Figure 1.
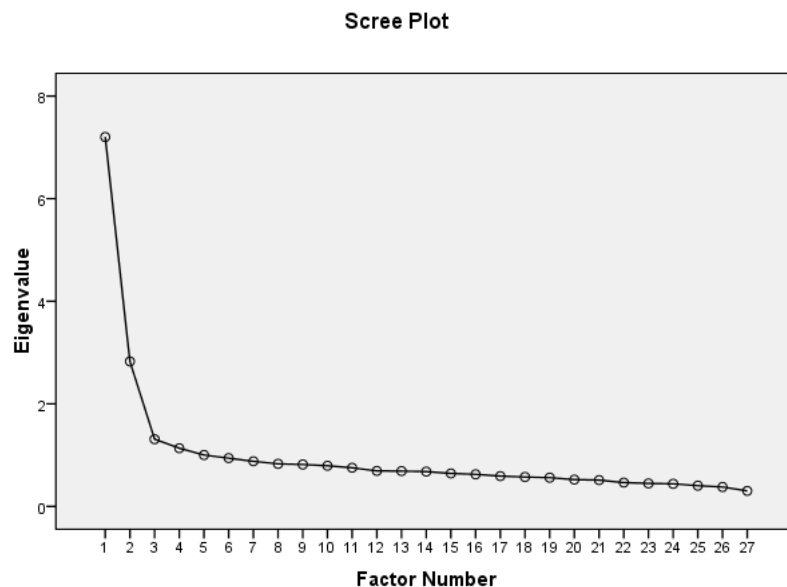

Figure 1. Scree plot as a result of EFA

According to Figure 1, the slope flattens after the third point. However, considering the theoretical background of the scale, three components of spatial skills according to Lohman (1979) and Contero et al. (2005), the rotated EFA solution was limited to 3 factors. EFA was conducted again, and as a result of the second EFA, it was observed that all of the items loaded on two factors,

and there was no item in the third factor. Therefore, it was decided to neglect the third factor. So EFA was conducted by limiting the oblimin rotation to 2 factors. As a result, five items (items 1, 2, 11, 12, 27) whose factor loadings were below ,40 and 4 overlapping items (items 5, 8, 9, 25) were excluded from the scale. Analysis results showed that nine items of spatial relations and spatial orientation abilities loaded on the first factor, so the first factor was named "Anxiety of Spatial Relations and Orientation (ASRO)". The second factor consists of 5 items that measure spatial visualization ability, and it was named "Anxiety of Spatial Visualization (ASV)". Factor loadings of items were presented in Table 3.

Table 3. Factor Loadings of Items

Items		Factor loadings	
		ASRO	ASV
14	It makes me uneasy to think about how the shapes on the surfaces of a cube look from different angles.	,678	
15	I am afraid to confuse right and left when I need to transform a two-dimensional shape in my mind.	,600	
18	I hesitate to imagine the look of an object on the different parts of a table.	,592	
7	I am anxious when I am asked to draw a top view of a figure viewed from the side.	,578	
21	When I need to change my location, it confuses me to imagine how the objects look according to the new location I am in.	,562	
23	When asked about a new shape that will be created by rotating a geometric shape around an axis, I panic.	,551	
26	It makes me anxious to visualize a two-dimensional shape drawn on paper by rotating it in the desired direction.	,518	
4	I panic when I need to determine what the appearance of objects will be relative to any point.	,481	
30	I feel bad when I am asked to draw the image from the desired direction by rotating a shape made of cubes in my mind.	,472	
20	A question that asks the closed state of an opened cube and shapes on its surfaces does not bother me.		,699
22	Drawing symmetry of an object relative to a line does not worry me.		,675
29	I am not concerned about determining which edges will overlap if I am asked to combine an open prism in my mind.		,583
13	It does not bother me to draw a three-dimensional image of an object photographed from different angles.		,523
16	It does not scare me to determine the appearance of the water when a glass with water is tilted at different angles.		,519
Eigenvalues:		4,111	1,936
Variance explained:		24,710	9,338
Total variances explained:		34,048	

As seen in Table 3, a scale consisting of two sub-dimensions explaining 34,048% total variance was obtained. The first factor explains 24,710% of the total variance, and the second factor explains 9,338% of it. The factor loadings of the items in the first factor ranged from ,678 to ,472 and in the second factor ranged from ,699 to ,519. The inter-factor correlation values of the scale were presented in Table 4.

Table 4. Inter-factor correlation values of the scale

Factors	ASRO	ASV	SAS
ASRO	1		
ASV	,323**	1	
SAS	,879**	,735**	1

** p <,01

ASRO: Anxiety of Spatial Relations and Orientation, ASV: Anxiety of Spatial Visualization, SAS: Spatial Anxiety Scale

The inter-factor correlation values in Table 4 showed a low positive correlation between ASRO and ASV [r =,323, p<,01], and high levels of positive correlations between ASRO, ASV factors, and total scores of SAS. Şencan (2005) states that if the scale obtained from factor analysis consists of two or more sub-factors and the relationship between these factors is ,60 and above, the sub-dimensions are dependent, and they all measure one conceptual structure together. In this case, factors are not evaluated as a sub-scale, and it is assumed that the expressions of sub-dimensions measure a single conceptual structure. The correlation values between ASRO and ASV factors are less than ,60 so it can be said that they are independent of each other and measure two different conceptual structures. Therefore, the correlation results also confirm the two-factor structure of the scale.

Confirmatory Factor Analysis

The construct validity of the scale consisting of 14 items and two factors was tested with CFA. Table 5 presents the fit indexes of the scale as a result of CFA.

Table 5. The fit indexes of the scale

Fit indexes	χ2	sd	χ2 /sd	RMSEA	SRMR	GFI	CFI	NNFI	AGFI	IFI
SAS	81,385	76	1,071	0,019	0,0446	0,925	0.990	0.989	0.925	0.991

The fit indexes in Table 5 suggested that the model fit the data well, $\chi2$ (81,385) = 1,071, p = ,315, RMSEA=0,019, SRMR=0,0446, GFI=0,925, CFI=0.990, NNFI=0.989, IFI=0.991 (Hu & Bentler, 1999; Jöreskog & Sörbom, 1993; Özdamar, 2017; Thompson, 2004). Figure 2 shows the factor loadings of the two-dimensional scale model. The factor loadings in ASRO are between ,49 and ,66; the factor loadings in ASV vary between ,46 and ,64.
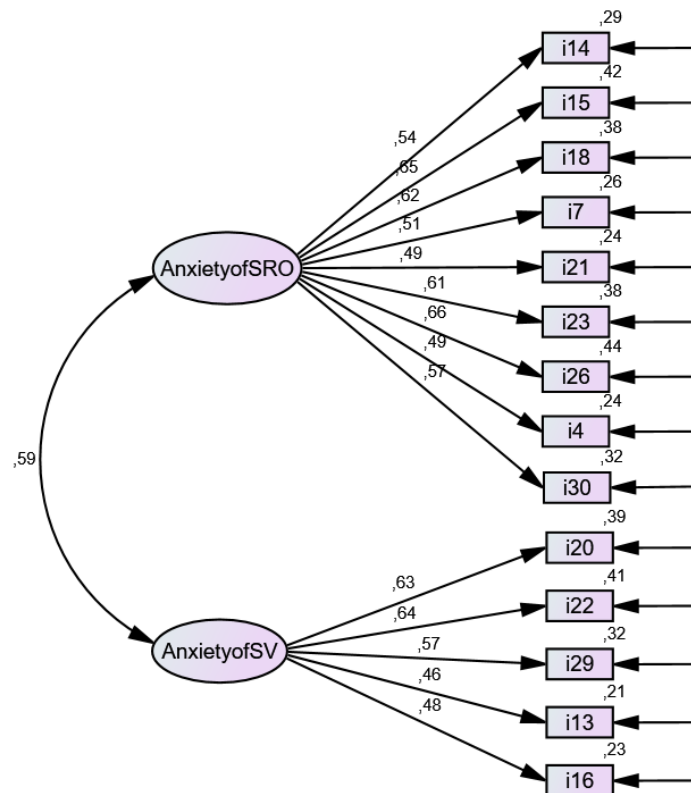

Figure 2. Measurement Model for Spatial Anxiety Scale

Findings Related to Convergent Validity of the Scale

For the convergent validity of the scale, the correlation between the "Spatial Anxiety Scale", which measures anxiety for navigational skills developed by Lawton (1994), and the anxiety scale developed in this study, was analyzed. Correlation analysis results revealed that; spatial anxiety involving navigational skills has a moderately positive correlation with the anxiety of spatial relations and orientation [r =,446, p<,01]. The results also showed that spatial anxiety (Lawton, 1994) was in a low positive [r =,175, p<,05] with spatial visualization anxiety and in a low positive [r =,397, p<,01] relationship with total spatial anxiety scores (Şencan, 2005). Significant positive correlations between all these spatial anxiety types reveal that the developed scale provides convergent validity.

Findings Related to Item Analysis

For the item analysis of the scale, item-total score correlations were analyzed with the Pearson Correlation coefficient. Table 6 shows the comparisons of t-values of the bottom and top 27% groups of the scale, "corrected item-total correlations" and "Cronbach's alpha if item deleted" values.

Table 6. Item Analysis Results

	Items		M	SD	t	Corrected item-total correlation	Cronbach's alpha if item deleted
ASRO	i14	Top	2,92	1,60	13,037**	,495	,800
		Bottom	1,20	0,52			
	i15	Top	3,35	1,20	15,761**	,558	,794
		Bottom	1,20	0,54			
	i18	Top	2,75	1,38	10,969**	,491	,800
		Bottom	1,12	0,36			
	i7	Top	3,19	1,22	11,213**	,418	,805
		Bottom	1,48	0,82			
	i21	Top	2,90	1,17	9,252**	,416	,805
		Bottom	1,43	0,96			
	i23	Top	3,17	1,22	10,063**	,463	,801
		Bottom	1,49	1,03			
	i26	Top	2,95	1,24	10,298**	,482	,800
		Bottom	1,35	0,82			
	i4	Top	2,84	1,24	10,324**	,394	,806
		Bottom	1,29	0,72			
	i30	Top	3,12	1,41	10,729**	,464	,801
		Bottom	1,32	0,77			
ASV	i20	Top	3,42	1,50	12,179**	,449	,802
		Bottom	1,54	0,94			
	i22	Top	3,17	1,19	11,536**	,413	,805
		Bottom	1,44	0,82			
	i29	Top	3,35	1,21	9,612**	,380	,808
		Bottom	1,67	1,16			
	i13	Top	3,38	1,29	9,439**	,362	,810
		Bottom	1,70	1,12			
	i16	Top	3,26	1,28	12,135**	,389	,807
		Bottom	1,32	0,84			

**p<0,001

In Table 6, it is seen that there is a significant difference between the bottom and top 27% groups of the scale (p <,001) and the corrected item-total correlations are above ,30 (Büyüköztürk, 2012; Şencan, 2005). Considering the Cronbach's alpha value of the whole scale (α=,83), the values of "Cronbach alpha if item deleted" show that all items contribute to the reliability of the scale.

Findings Related to the Reliability of the Scale

The coefficients of Cronbach's alpha and McDonald's omega of the scale are presented in Table 7.

Table 7. Cronbach's alpha and McDonald's omega coefficients

Factors	Cronbach's alfa	McDonald's omega
ASRO	,81	,96
ASV	,72	,91
SAS	,83	,97

In Table 7, it is seen that all reliability coefficients of the scale were ,70 and above. These results are accepted to be reliable (Büyüköztürk, 2012; Şencan, 2005; Özdamar, 2017). Therefore, Cronbach's alpha and McDonald's omega coefficients showed that the scale and sub-dimensions are quite and highly reliable.

Evaluation of Spatial Anxiety Scale

The spatial anxiety scale consists of 14 items and two sub-dimensions. The first sub-dimension is ASRO including 9 items (items 14, 15, 18, 7, 21, 23, 26, 4, 30) and the second is ASV including 5 items (items 20, 22, 29, 13, 16). It has 5 negative items (items 13, 16, 20, 22, 29). The scale was developed in the five-Likert type scored as "strongly disagree" (1), "disagree" (2), "neither agree nor disagree" (3), "agree" (4), and "strongly agree" (5). The minimum-maximum score range of the scale is between 14-70 points. The high score obtained from the scale indicates a high anxiety level, a low score indicates a low anxiety level.

DISCUSSION AND CONCLUSION

In this study, the validity and reliability of the spatial anxiety scale developed to measure secondary school students' spatial anxiety levels were examined. It was aimed to develop the spatial anxiety scale based on the components of spatial skills by Lohman (1979) and Contero et al. (2005), including spatial visualization, spatial relations, and spatial orientation skills. However, the analysis results showed that the scale has a two-factor structure. The first factor consists of spatial relations and spatial orientation items, and the second factor consists of spatial visualization items. Therefore, it was observed that this scale structure was not parallel for the classification of Lohman (1979) and Contero et al. (2005). Loading the items of spatial relations and spatial orientation skills in the same sub-dimension revealed a similar result to the study by Burnett and Lane (1980). Burnett and Lane (1980) defined two types of spatial factors: spatial relations, and orientation as one factor, and the second is spatial visualization. So the first factor, consisting of spatial relations and spatial orientation items, was named Anxiety of Spatial Relationships and Spatial Orientation, and the second factor consisting of spatial visualization items was Anxiety of Spatial Visualization. Based on the results, it can be asserted that, rather than three sub-dimensions, spatial skills consist of two sub-dimensions, spatial relations and spatial orientation as one factor and the other is spatial visualization.

Cronbach's alpha and McDonald's omega coefficients of the scale showed that the scale was quite reliable to be used in researches. These results revealed that the scale is a valid and reliable measurement tool that can measure the spatial anxiety levels of secondary school students. Investigating students' spatial anxiety level and its relationships with other variables is important for

the future mathematics and STEM success of students (Ramirez et al., 2012). However, different findings of the researches require further investigation on spatial anxiety. For instance, spatial anxiety does not predict geometry success (Erkek & Işıksal Bostan, 2015), or teachers' spatial anxiety significantly predicts students' spatial skills (Gunderson et al., 2013) are quite important results in terms of mathematics education.

Spatial sense must receive greater attention in instruction and researches (Clements, 1998). Investigating the variables that affect spatial anxiety or designing experimental studies to decrease the students' spatial anxiety levels will both contribute to the field and guide the researchers. Adaptation of this scale to different education levels or developing new ones can be suggested for future studies.

REFERENCES

Battista, M. T. (1994) On Greeno's Environmental/model view of conceptual domains: A spatial/geometric perspective. *Journal for Research in Mathematics Education, 25*(1), 86-99.

Battista, M. T., Wheatley, G. H., & Talsma, G. (1982). The importance of spatial visualization and cognitive development for geometry learning in pre service elementary teachers. *Journal for Research in Mathematics Education, 13*(5), 332-340.

Burnet, S. A., & Lane, D. M. (1980). Effects of academic instruction on spatial visualization. *Intelligence, 4*(3) 233-242.

Büyüköztürk, Ş. (2012). *Sosyal bilimler için veri analizi el kitabi: İstatistik, araştirma deseni, SPSS uygulamaları ve yorum (16. Baskı) [Handbook of data analysis for social sciences: Statistics, research design, SPSS practice and interpretation (16. Edition)].* Pegem Akademi.

Cardillo, R., Vincenzi, I., & Gallani, A. (2017). Spatial tasks and emotional factors: A study conducted with the Italian adaptation of the Child Spatial Anxiety Questionnaire (CSAQ). *Psicologia Clinica Dello Sviluppo, 21*(3), 483-502.

Casey, M. B., Nutall, R. L., & Pezaris, E. (2001). Spatial–mechanical reasoning skills versus mathematics self-confidence as mediators of gender differences on mathematics subtests using cross national gender based items. *Journal for Research in Mathematics Education, 32*(10), 28–57.

Casey, B. M., Pezaris, E., Fineman, B., Pollock, A., Demers, L., & Dearing, E. (2015). A longitudinal analysis of early spatial skills compared to arithmetic and verbal skills as predictors of fifth-grade girls' math reasoning. *Learning and Individual Differences, 40*, 90–100. doi:10.1016/j.lindif.2015.03.028

Clements, D. H. (1998). *Geometric and spatial thinking in young children.* National Science Foundation.

Clements D. H., & Battista, M. T. (1992). Geometry and spatial reasoning. In D. A. Gruws (Ed.). *Handbook of research on mathematics teaching and learning* (pp. 420-464). MacMilan.

Contero, M., Naya, F., Compnay, P., Saorin, J. K., & Conesa, J. (2005). Improving visualization skills in engineering education. *Computer Graphics in Education, 25*(5), 24-31.

Çokluk, Ö., Şekercioğlu, G., & Büyüköztürk, Ş. (2010). *Sosyal bilimler için çok değişkenli istatistik SPSS ve LISREL uygulamaları [Multivariate statistics SPSS and LISREL applications for social sciences].* PegemAkademi.

DeVellis, R. (2003). *Scale development: theory and applications (2nd ed.).* Sage.

Dursun, Ö. (2010). *The relationships among preservice teachers'spatial visualization ability, geometry self-efficacy, and spatial anxiety* (Master Thesis). Middle East Technical University, Ankara.

Ekstrom, R.B., French, J.W., Harman, H.H. (1976). Manual for Kit of Factor Referenced Cognitive Tests. Educational Testing Service.

Elliot, J., & Smith, I. M. (1983). *An international dictionary of spatial tests.* The NFER-Nelson Publishing Company, Ltd.

Erkek, Ö., & Işıksal Bostan, M. (2015). The role of spatial anxiety, geometry self-efficacy and gender in predicting geometry achievement. *Elementary Education Online, 14*(1), 164-180.

Ferguson, A. M., Maloney, E. A., Fugelsang, J., & Risko, E. F. (2015). On the relation between math and spatial ability: The case of math anxiety. *Learning and Individual Differences, 39*, 1–12. doi:10.1016/j.lindif.2015.02.007

Gunderson, E. A., Ramirez, G., Beilock, S. L., & Levine, S. C. (2013). Teachers' spatial anxiety relates to 1st-and 2nd-graders' spatial learning. *Mind, Brain, and Education, 7*(3), 196-199.

Hannafin, R. D., Truxaw, M. P., Vermillion, J. R., & Liu, Y. (2008). Effects of spatial ability and instructional program on geometry achievement. *The Journal of Educational Research, 101*(3), 148-156.

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural equation modeling: a multidisciplinary journal, 6*(1), 1-55.

Jöreskog, K. G., & Sörbom, D. (1993). *LISREL 8: Structural equation modeling with the SIMPLIS command language.* SSI Scientific Software International Inc.

Karagöz, Y. (2019). *SPSS AMOS META uygulamalı istatistiksel analizler.* Nobel Yayıncılık.

Kline, R. B. (2016). *Principles and practice of structural equation modeling (Fourth Edition).* The Guilford Press.

Lauer, J. E., Esposito, A. G., & Bauer, P. J. (2018). Domain-specific anxiety relates to children's math and spatial performance. *Developmental psychology, 54*(11), 2126.

Lawton, C. A. (1994). Gender differences in way-finding strategies: Relationship to spatial ability and spatial anxiety. *Sex Roles, 30*(11/12), 765-779.

Linn, M. C., & Petersen, A. C. (1985). Emergence and characterization of gender differences in spatial abilities: A meta-analysis. *Child Development, 56*, 1479-1498.

Lohman, D. F. (1979). Spatial ability: Individual differences in speed and level (technical report No:9). Aptitude Research Project, School of Education, Stanford University.

Lohman, D. F. (1993). Spatial ability and G. In First Spearman Seminar, University of Plymouth, Plymouth, United Kingdom.

Lord, T. R. (1985). Enhancing the visuo-spatial aptitude of students. *Journal of Research in Science Teaching, 22*, 395–495.

Lyons, I. M., Ramirez, G., Maloney, E. A., Rendina, D. N., Levine, S. C., & Beilock, S. L. (2018). Spatial Anxiety: A novel questionnaire with subscales for measuring three aspects of spatial anxiety. *Journal of Numerical Cognition, 4*(3), 526-553.

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

Olkun, S. (2003). Making connections: Improving spatial abilities with engineering drawing activities. *International journal of mathematics teaching and learning, 3*(1), 1-10.

Özdamar, K. (2017). *Ölçek ve test geliştirme yapısal eşitlik modellemesi IBM SPSS, IBM SPSS AMOS ve MINTAB uygulamalı.[Scale and test development Structural equation modeling IBM SPSS, IBM SPSS AMOS and MINTAB applied].* Nisan Kitabevi.

Pellegrino, J. W, Alderton, D. L., & Shute, V. J. (1984). Understanding spatial ability. *Educational Psychologist, 19*(3), 239-253.

Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2012). Spatial anxiety relates to spatial abilities as a function of working memory in children. *The Quarterly Journal of Experimental Psychology, 65*(3), 474-487.

Schmitz, S. (1997). Gender-related strategies in environmental development: Effects of anxiety on wayfinding in and representation of a three-dimensional maze. *Journal of Environmental Psychology, 17*, 215-228.

Schumacker, R. E. & Lomax, R. G. (2004). *Beginner's guide to structural equaiton modeling.* Lawrence Erlbaum Associates.

Sorby, S. (2009). Educational research in developing 3-D spatial skills for engineering students. *International Journal of Science Education, 31*(3), 459–480.

Şencan, H. (2005). *Sosyal ve davranışsal ölçümlerde geçerlilik ve güvenirlik [Validity and reliability in social and behavioral measurements].* Seçkin Matbaası.

Tabachnick, B.G., & Fidell, L.S. (2007). *Using multivariate statistics (5th ed.).* Pearson Education.

Tam, Y. P., Wong, T. T. Y., & Chan, W. W. L. (2019). The relation between spatial skills and mathematical abilities: The mediating role of mental number line representation. *Contemporary Educational Psychology, 56,* 14-24.

Tartre, L. A. (1990). Spatial orientation skill and mathematical problem solving. *Journal for Research in Mathematics Education, 21*, 216–229.

Thompson, B. (2004). *Exploratory and confirmatory factor analysis: Understanding concepts and applications.* American Psychological Association.

Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology, 101*(4), 817–835.

Yurdugül, H. (2006). The comparison of reliability coefficients in parallel, tau-equivalent, and congeneric measurements. *Ankara University, Journal of Faculty of Educational Sciences, 39*(1), 15-37.