

# A Scale Development Study Intended for Mathematics Teacher Candidates: Mathematical Visualization Perception Scale

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## ABSTRACT

The aim of this study is to develop a valid and reliable measurement tool that measures mathematical visualization perceptions for mathematics teacher candidates. Therefore, the type of study is a survey research. Research was carried out with 462 (336 Female, 125 Male) mathematics teacher candidates from a university located in the Eastern Anatolia region Turkey in 2018-2019 spring season. Exploratory and confirmatory factor analyzes were performed for the analysis of research data. In the process of development of Mathematical Visualization Perception Scale (MVPS); the preparation of the pool of material, testing of the validity of the scope and appearance, conducting the trial application, ensuring the construction validity, calculating the reliability and establishing the final scale were followed. As a result of the exploratory factor analysis, a valid and reliable 5-point Likert-type scale consisting of 42 items, with 6 factors [Additional Drawing (AD), Spatial Thinking (ST), Direction Concept (DC), Relation with Daily Life (RDL), Transition from Algebra to Geometry (TAG) and Transition from Geometry to Algebra (TGA)] was created. Cronbach Alpha internal stability coefficient of these factors was calculated as 0.938. The factor structure of the scale was also confirmed by confirmatory factor analysis. As a result of the findings obtained, it was suggested to the researchers who will study in the related field to evaluate mathematical visualization perceptions of mathematics teacher candidates by using related scale with different sample groups or different variables.

**Keywords:** visualization perception, mathematical visualization, scale development, mathematics teacher candidates, mathematics education

## INTRODUCTION

Although the concept of visualization is cared in other disciplines, it is also considered important in the field of mathematics education. For this reason, the concept of visualization has taken part in science literature and some scientists have defined the concept of visualization. Arcavi (2003) described visualization as a process of revealing something new with visuals and mentioned about its significance in mathematics education. In addition, Arcavi (2003) described visualization as a creation skill, process and product. Olkun and Altun (2003) described the visualization as the ability to visualize the new situations that would occur as a result of moving two-dimensional and three-dimensional objects and the parts of these objects into space. Presmeg (1986) describes mathematical visualization as the degree to which a person selects a visual method while solving a problem that can be solved with by both visual and non-visual methods. Uysal Kog and Baser (2012) define mathematical visualization as the ability of students to present a concept or problem, to use schemas to support problem solving in order to acquire understanding, to draw the appropriate scheme with pencil paper or in/ some cases by using computer.

Visualization in mathematics teaching is an important subject and it needs to be investigated. The mental image that characterizes visualization is the ability of external representations, process and visualization (Gutiérrez, 1996). The main importance of visualization in mathematics education is its contribution to the affective development of the individual as important as his / her cognitive development (Uysal Kog & Baser, 2012). Visualization enables concretization as well as in the construction of concepts in mathematics. Moyer (2001) stated that it is important to visualize and present abstract mathematical expressions. Duval (1999) argues that symbolic expressions and visualization are the essence of understanding mathematics. If the visualization is used at the beginning learning process of a subject in mathematics, during the learning of concepts and during the measurement of whether desired behaviors are gained or not, ease of understanding and permanence of information is provided (Uysal Kog & Baser, 2011). Doyuran (2014) stated that students cannot establish the relationship between geometrical concepts, have problems in understanding and using mathematical symbols, have problems in understanding the problems relating geometric concepts with daily life and that this problem can be solved by visualization.

In the field of mathematics education, it is possible to come across studies that emphasize the importance of visualization and that visualization should be used not only in the field of geometry but also in the field of algebra. In Gunaydin's (2011) study, algebra and geometry problems of secondary school students were examined in terms of visualization of solution processes. The researcher found a positive and significant relationship between thinking structures and visualization in this study. Orhun (2007) found that there is a cognitive deficiency between formal arithmetic and visualization in the study of the fourth grade students. Although the researcher found no significant difference between female and male students in this study, it was found that the visualization success was low in general. Delice and Sevimli (2010) examined the drawings on the shapes given in a mathematical problem. The researchers stated that the dimension and representation types in which geometry problems are expressed in their studies affect the students' additional drawing behaviors. There are also studies showing that the concept of visualization is also related to spatial intelligence and spatial visualization concepts. Burnett and Lane (1980) described Spatial visualization as the ability to visualize the new situations that would occur as a result of moving two-dimensional and three-dimensional objects consisting of one or more parts and the parts of these objects into space. In his (2014) study, Unlu stated that all bilateral relations among geometry success, spatial visualization ability, geometry self-efficacy, attitude and anxiety were significant. Ergin and Turnuklu (2015) examined the relationship between the images of eighth grade students on geometric objects and their geometric and spatial thinking, and said that spatial thinking had an effect on geometrical objects. Yolcu and Kurtulus (2010) examined the effect of dynamic computer software on the spatial abilities of sixth grade students. Boakes (2009) investigated the spatial visualization skills of seventh grade students by showing the origami as a teaching tool in the secondary school mathematics course and concluded that it had a positive effect.

## THEORETICAL FRAMEWORK

Geretschlager (1995) mentioned the connection between origami and geometry and gave examples of how to use origami for teaching geometric shapes. Arıcı and Aslan Tutak (2015) examined the effects of their origami activities on spatial visualization, geometric reasoning and geometry success. Although there are studies linking the concept of visualization with different concepts, there are also studies which express that this concept has an importance on its own and researches its essence in cognitive or affective sense. Kog and Baser (2014) examined the effect of visualization approach on students' level of learned helplessness and abstract thinking skills in mathematics and found that visualization approach positively affects students' abstract thinking skills and learned helplessness in mathematics. Delice and Sevimli (2014) examined the visualization process of university students on quadratic surfaces. They talked about the differences in performance of students in terms of faculty and stated that their learning experiences caused these differences.

Rapid developments in the field of science have also led to changes in the aims of mathematics education. It is not enough for students to being able to memorize formulas and to make mathematical operations fast. They are expected to have the ability to think mathematically, express mathematically, value mathematics and have a good problem solving skills (Baki, 2006). The geometry learning area, which has an important place in the solution of mathematical problems, takes place in all levels of primary, secondary and high school education. This process starts with spatial relations in the first year and continues until the subject of solid objects in the twelfth grade. In this process, it is aimed that the students will be able to use mathematical terminology correctly and express the mathematical concepts with different forms of representation. Although perception is realized by the interaction of all senses, visual perception has an important place in perception. In visual perception, the individual recognizes, differentiates and interprets visual stimuli by combining them with previous experiences (Koc, 2002). In the light of this information, visualization perception and ability are thought to be closely related to mathematics. Especially, in the period starting from the first grade to the twelfth grade, finding the acquisition of this learning area emphasizes the necessity to investigate the concept of mathematical visualization which is thought to be directly related to this field. The fact that this kind of scale was not developed for the mathematics teacher candidates when the literature was reviewed, strengthens the original aspect of the study and it is foreseen that the mathematical visualization perception scale developed in the study will contribute to the literature by using new scientific studies.

## METHOD

### Research Model

In this study, a scale development study was conducted to determine mathematical visualization perceptions of mathematics teacher candidates. In this direction, in the study 5-point Likert-type scale (whose validity and reliability tests were carried out by making exploratory and confirmatory factor analyzes) consisting of 42 items with 6 factors was created. The study is of the type of survey research because there is a process aiming to determine the specific characteristics of a group (Buyukozturk, 2016).

### Research Sample

The study population consisted of all mathematics teachers who were studying in 2018-2019 academic year spring semester in elementary mathematics education department of a university education faculties in Turkey's Eastern Anatolia. The sample of the study consists of 462 mathematics teacher candidates, each half of which is 231 (168 Female, 63 Male) mathematics teacher candidates, selected from this population by simple random sampling method, divided into two halves for EFA and CFA. A simple random sampling method is a type of sampling where all units in the population have the chance to be elected equally and independently (Karasar, 2002). In scale development studies, if the scale number is more than 30, the sample size is sufficient to

be 2 or 3 times the number of items (Secer, 2015, p. 59). In the present study, implementation of application with 236 mathematics teacher candidates for the draft scale of 72 items indicates that the sample size is sufficient for the scale of development. During the development phase of the scale, data on 5 mathematics teacher candidates were excluded from the analysis due to inaccurate and incomplete information filling, so the remaining 462 (336 Female, 126 Male) data were evaluated.

### Process Steps

Mathematical Visualization Perception during the development of the scale; item pooling, testing the scope and appearance validity, performing the trial application, ensuring the building validity, calculating the reliability and establishing the final scale were followed (Buyukozturk, 2016). In order to establish the item pool, interviews were conducted with 28 mathematics teacher candidates outside the research sample, including their feelings and thoughts about mathematical visualization and visualization perception. Some of the items that can be included in the scale have been determined with the help of the opinions of the mathematics teacher candidates about mathematical visualization and perception. In addition, mathematical visualization and perception studies in the literature were utilized. Thus, an item pool consisting of 80 items of 5-point Likert type (1: Strongly Disagree, 2: Disagree, 3: Undecided, 4: Agree, 5: Strongly Agree) that was thought to be included in the scale was created. The pool of items was examined by four field experts in terms of content validity, two assessment and evaluation experts for appearance validity, and one Turkish language expert for the simplicity of the language and spelling rules. In order to assure content validity, experts were asked to complete assessment forms (rated (i) "appropriate", (ii) item should be reviewed a little, (iii) "item should be seriously reviewed (and (iv) "item not appropriate". The answers in these forms were collected in a single form and examined by Davis (1992) technique. According to this technique, the number of experts marking options (i) and (ii) is divided by the total number of experts giving opinion; The content validity index (CGI) is determined for each item and items whose index value is less than 0.80 are excluded from the scale. At this point, 8 items with a CGI value of less than 0.80 were excluded from the scale and 4 items were made simpler in terms of language and intelligibility according to experts' views. The draft scale was conducted to 462 mathematics teacher candidates in Eastern Anatolia in the fall season of 2018-2019 academic year. Accordingly, the lowest score that can be obtained from the scale is 72 and the highest score is 360. Item analysis based on item-scale correlation value was performed in order to examine whether the items of the scale were related and to eliminate items that could not be included in the scale (Baykul, 2010, p. 371). Exploratory Factor Analysis (EFA) was used to find out how many structures the scale measures. EFA is a statistical technique that determines the number of sub-dimensions by examining the relationship between the items in the measurement tool (Secer, 2015, p. 78). Confirmatory factor analysis (CFA) was used to determine whether the structure obtained by EFA was verified. Based on the data of the scale developed in line with a theoretical structure, CFA tests whether the predefined and limited structure is validated as a model (Cokluk, Sekercioglu, & Buyukozturk, 2012, p. 275). The Cronbach's alpha reliability coefficient was also calculated for additional evidence of the reliability of the final scale.

### Data Analysis

In the research, the data obtained from the draft scale were transferred to the computer and converted to digital form. Item analysis was performed to determine the internal consistency of the items with the scale. The construct validity of the scale was performed with EFA and SPSS 23.0, and the level of consistency of the structure was realized with CFA and Lisrel 8.80 package program. The reliability of the final scale and its sub-dimensions were examined with Cronbach's alpha reliability coefficient.

## FINDINGS

### Item Analysis

In order to determine whether the items in the scale were related to the perception of mathematical visualization, item-scale correlation value (ISCV) analysis was performed. The data obtained are shown in **Table 1**.

**Table 1.** ISCV of the Draft Scale Items

Item	ISCV	Item	ISCV	Item	ISCV
m <sub>1</sub>	0.397	m <sub>25</sub> *	0.099	m <sub>49</sub>	0.206
m <sub>2</sub>	0.427	m <sub>26</sub>	0.207	m <sub>50</sub>	0.256
m <sub>3</sub> *	-0.026	m <sub>27</sub> *	0.099	m <sub>51</sub> *	0.171
m <sub>4</sub>	0.333	m <sub>28</sub> *	0.096	m <sub>52</sub> *	0.128
m <sub>5</sub>	0.408	m <sub>29</sub> *	0.156	m <sub>53</sub> *	0.107
m <sub>6</sub>	0.216	m <sub>30</sub>	0.273	m <sub>54</sub> *	0.132
m <sub>7</sub>	0.302	m <sub>31</sub>	0.234	m <sub>55</sub>	0.209
m <sub>8</sub>	0.288	m <sub>32</sub> *	0.164	m <sub>56</sub> *	0.129
m <sub>9</sub>	0.201	m <sub>33</sub> *	0.110	m <sub>57</sub>	0.276
m <sub>10</sub>	0.302	m <sub>34</sub> *	0.173	m <sub>58</sub>	0.389
m <sub>11</sub> *	-0.023	m <sub>35</sub> *	0.052	m <sub>59</sub>	0.253
m <sub>12</sub>	0.202	m <sub>36</sub>	0.228	m <sub>60</sub>	0.289
m <sub>13</sub>	0.265	m <sub>37</sub>	0.229	m <sub>61</sub>	0.293
m <sub>14</sub> *	0.160	m <sub>38</sub>	0.350	m <sub>62</sub>	0.251
m <sub>15</sub>	0.222	m <sub>39</sub>	0.333	m <sub>63</sub>	0.224
m <sub>16</sub>	0.334	m <sub>40</sub> *	0.130	m <sub>64</sub>	0.263
m <sub>17</sub>	0.211	m <sub>41</sub>	0.209	m <sub>65</sub> *	0.058
m <sub>18</sub> *	0.065	m <sub>42</sub> *	0.085	m <sub>66</sub>	0.234
m <sub>19</sub> *	0.160	m <sub>43</sub>	0.251	m <sub>67</sub>	0.238
m <sub>20</sub> *	0.163	m <sub>44</sub> *	0.140	m <sub>68</sub>	0.205
m <sub>21</sub>	0.207	m <sub>45</sub>	0.208	m <sub>69</sub>	0.349
m <sub>22</sub>	0.201	m <sub>46</sub>	0.201	m <sub>70</sub>	0.337
m <sub>23</sub>	0.204	m <sub>47</sub>	0.221	m <sub>71</sub> *	0.159
m <sub>24</sub>	0.201	m <sub>48</sub> *	0.153	m <sub>72</sub>	0.349

\*Items whose ISCV value is less than 0.20 and excluded from the scale

When the data of **Table 1** is examined, 25 items whose ISCV value is less than 0.20 (item m<sub>3</sub>, m<sub>11</sub>, m<sub>14</sub>, m<sub>18</sub>, m<sub>19</sub>, m<sub>20</sub>, m<sub>25</sub>, m<sub>27</sub>, m<sub>28</sub>, m<sub>29</sub>, m<sub>32</sub>, m<sub>33</sub>, m<sub>34</sub>, m<sub>35</sub>, m<sub>40</sub>, m<sub>42</sub>, m<sub>44</sub>, m<sub>48</sub>, m<sub>51</sub>, m<sub>52</sub>, m<sub>53</sub>, m<sub>54</sub>, m<sub>56</sub>, m<sub>65</sub>, m<sub>71</sub>) were excluded from the scale (Tavsancil, 2010, p. 146). For the remaining 47 items, after the item was deleted, the internal consistency coefficient of the scale was examined and it was determined that there were no items that reduced the reliability of the scale. After the completion of this process, exploratory factor analysis step was started.

### Exploratory Factor Analysis (EFA)

In the study, the scores were converted to z scores to obtain univariate normality, and z values outside the  $\pm 3.29$  ( $p < 0.001$ ) range were accepted as extreme values (Field, 2009; Tabachnick & Fidell, 2013). In this analysis, it was determined that there was no univariate extreme value in the data set and the Explanatory Factor Analysis process was started. In order to determine the factor structure of the scale, firstly Exploratory Factor Analysis was performed. Before Exploratory Factor Analysis, the suitability of the data for factor analysis was examined by KMO coefficient and Bartlett sphericity test, and KMO = 0.846 Bartlett sphericity test was calculated as 13773,782 ( $p < 0.001$ ). KMO value is between 0.80-0.89, so it is at "very good" level for the sample adequacy criterion (Akgul, 2003). In addition, it was determined that sampling adequacy was achieved on the basis of items with anti-image correlation categories (Measure of Sampling Adequacy-MSA) ranging from 0.875 to 0.941 (Sipahi, Yurtkoru, & Cinko, 2010). Significance of Barlett test showed that the data were sufficient. Levene test was used to determine the homogeneity of variances in the study. Since the Levene test result ( $F(1,461) = 0.133$ ;  $p = 0.752 > 0.05$ ) for GBT applications  $p > 0.05$ , it was determined that the variances were homogeneously distributed (Buyukozturk, 2016, p. 48-49). After the homogeneity of the variances, the skewness and kurtosis values were analyzed and it was determined that these values were between -2 and +2, and the z-skewness and z-kurtosis values were between -1.96 and +1.96. However, it was determined that the mode, median and arithmetic mean are also close to each other (Cameron, 2004, p. 544-545; Buyukozturk, 2016, p. 40-68). In addition, the Shapiro-Wilk test was used to determine whether the data was normally distributed, and the findings are given in **Table 2**.

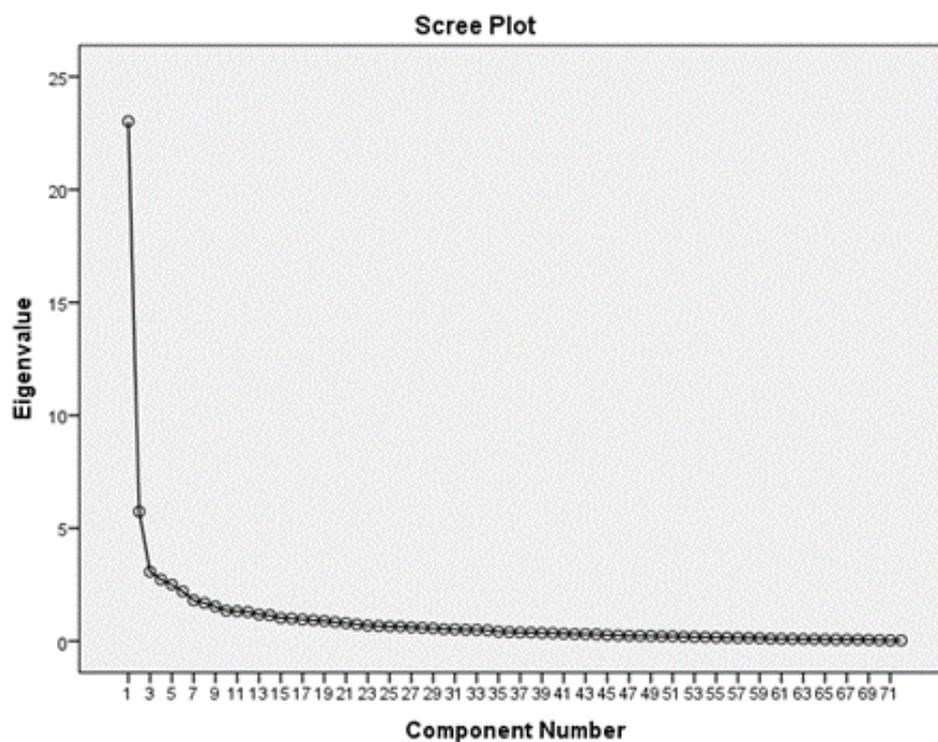
**Table 2.** MVPS Shapiro-Wilk test results

	Group	Statistics	Df	p
MVPS	Mathematics Teacher Candidates	0.833	461	0.240

\*Items whose ISCV value is less than 0.20 and excluded from the scale

Buyukozturk (2016, p. 42) stated that the Shapiro-Wilks test will be used to examine conformity to normality. For this reason, Shapiro-Wilk test was preferred in the study. As a result of the test, it was determined that MSTs applications were ( $p > 0.05$ ) and showed a normal distribution (Buyukozturk, 2016, p. 48-49). According to these findings, EFA procedure was initiated. Principal Component Analysis was preferred for EFA. Rotation techniques were used to make the results more understandable during the analysis (Pallant, 2011; Tabachnick & Fidell, 2013). During the analysis, it was determined that the correlation coefficients between the factors in the correlation matrix were  $r \geq 0.32$  and the analysis was continued with the Direct Oblimin oblique rotation technique (Tabachnick & Fidell, 2013). Factor load lower cut-off point was determined as 0.40 (Gable, 1986; Hatcher, 1994). Similarly, 0.40 value was taken as the criterion for the values of common factor variance (Costello & Osborne, 2005). In addition, in order to prevent an item from having high load values in different factors, it was assumed that the difference between the amount of load that can be taken on two factors should be at least 0.10 (Menard, 2002). The following indicators used in the relevant literature

were taken into account in determining the number of factors: original structure criterion (priori criterion), Kaiser criterion ( $\geq 1$  eigenvalue), Line graph and Horn's parallel analysis (Hair, Black, Babin, & Anderson, 2014; Pallant, 2011). The EFA of 47 items was collected under 6 factors with an eigenvalue greater than 1 and explained 54,521% of the variance related to the scale. In the context of the content and conceptual structure of the study, the number of factors found is more than expected, so this number is considered to be reduced. At this point, the fact that the first six factors with high eigen values included 2/3 of the total variance of the scale indicated that the scale could have six factors (Buyukozturk, 2016, p.127). In addition, this factor structure is clearly seen in the Scree Plot graph in **Figure 1** drawn according to eigen values.



**Figure 1.** Scree Plot Graph of the Scale

In the graph in **Figure 1**, the interval between the two points shows a factor (Secer, 2015, p. 86). Accordingly, as of the seventh point, it has been observed that the curve proceeds in the direction close to the horizontal, in other words the additional variances of the subsequent factors are very close to each other. Thus, it was decided that the number of important factors should be six. This finding showed that the scale could be multidimensional. Therefore, in the exploratory factor analysis after this process, vertical rotation is selected and the number of factors is limited to six. In the obtained matrix; firstly, the overlapping items (m17, m26) with a difference between their relationship with different factors less than 0.1 were removed. Subsequently, items with a load value less than 0.40 (m1, m12) were removed from the scale (Buyukozturk, 2016, p. 135; Secer, 2015, p. 87).

While the reliability analysis of each factor is made, the reliability coefficient should be greater than 0.70 (Durmus, Yurtkoru, & Zinko, 2013, p. 89). In reliability analyzes; m60 (0,456) was removed from the scale since the reliability coefficient of the item remained below 0.70. After all these procedures, the reliability coefficients of the factors obtained were higher than the expected limit values. In addition, there was no inconsistent value from internal consistency values. Thus, item-scale correlations, factor loads and variance ratios of the final scale that were formed after EFA were calculated.

**Table 3.** EFA Results of the Scale

Items	Factors and Load Values					
	AD	ST	DC	RDL	TAG	TGA
m <sub>2</sub> If there is more than one additional drawing in a question, I <b>believe</b> I can solve it.	0.896					
m <sub>4</sub> If a triangle needs to be drawn as auxiliary elements such as height and bisector, I <b>will not</b> have any problem solving the question.	0.934					
m <sub>5</sub> I'm <b>not anxious</b> about solving questions that require additional drawing.	0.891					
m <sub>6</sub> If a test contains questions that require additional drawings, I <b>will</b> solve them first.	0.892					
m <sub>7</sub> I'm <b>interested</b> in questions that require additional drawing because it is the product of reason.	0.878					
m <sub>8</sub> I <b>can guess</b> the auxiliary element to be drawn for questions that require additional drawing.	0.937					
m <sub>9</sub> If additional drawing is required to solve a problem, I <b>care about</b> solving the question.	0.887					
m <sub>10</sub> I <b>can</b> solve geometry questions that require additional drawing without difficulty.	0.903					
m <sub>13</sub> I <b>can visualize</b> the shape of a three-dimensional object formed by the rotation of a triangle.		0.953				
m <sub>15</sub> I <b>can imagine</b> how the position of the water changes when the cone is reversed.		0.958				
m <sub>16</sub> I <b>can geometrically express</b> the maximum area that a bird tied to a rope can scan while flying.		0.903				
m <sub>21</sub> I <b>can draw</b> a cross-section of a prism with a plane		0.923				
m <sub>22</sub> I <b>can imagine</b> the right triangular prism in my mind		0.951				
m <sub>23</sub> I <b>can draw</b> a given geometric shape itself.		0.939				
m <sub>24</sub> I <b>can estimate</b> the volume of a cylindrical jar.		0.934				
m <sub>30</sub> I <b>can find</b> the location of the vehicle that it provides transportation outside or I parked before			0.981			
m <sub>31</sub> I <b>can interpret</b> the direction star on a map.			0.969			
m <sub>36</sub> I <b>can describe</b> an address I've been to before.			0.980			
m <sub>37</sub> I <b>can use</b> what I have learned in geometry to solve problems in everyday life.				0.917		
m <sub>38</sub> I <b>can</b> relate everyday life to geometry.				0.925		
m <sub>39</sub> I <b>can associate</b> the geometric objects around me with the shapes I learned in geometry.				0.926		
m <sub>41</sub> I'm <b>interested in</b> geometric objects used in everyday life.				0.938		
m <sub>43</sub> I <b>immediately notice</b> the geometric shapes in my environment.				0.918		
m <sub>45</sub> I <b>like</b> making tools that make my life easier by using geometric shapes.				0.927		
m <sub>46</sub> Geometry <b>has</b> an important place in my life.				0.927		
m <sub>47</sub> Geometry <b>helps me</b> solve the problems I face in everyday life.				0.931		
m <sub>49</sub> I <b>have no difficulty</b> in solving verbal geometry questions.					0.980	
m <sub>50</sub> In Geometry, it is <b>easier to</b> solve drawn questions.					0.959	
m <sub>55</sub> When I see the third power of number, I <b>think of</b> a cube.					0.970	
m <sub>57</sub> I <b>immediately understand</b> that an equation with two unknowns is the correct equation.					0.961	
m <sub>58</sub> I <b>can guess</b> the geometric shape of an area when its property deeds are given					0.944	
m <sub>59</sub> I <b>can express</b> decimal numbers in number line.					0.951	
m <sub>61</sub> I <b>like</b> the algebraic processes in solving geometry questions.						0.933
m <sub>62</sub> I <b>can algebraically express</b> the volume of a geometric object.						0.938
m <sub>63</sub> I <b>can</b> write the equation of a line whose graph is given.						0.941
m <sub>64</sub> I <b>can</b> write the algebraic relation between the bases and heights of two triangles with equal area.						0.947
m <sub>66</sub> When I see a quadratic field, a second-order algebraic expression <b>comes to my mind</b> .						0.952
m <sub>67</sub> I <b>can prove</b> the identity of two square differences by using the field fragmentation method.						0.960
m <sub>68</sub> With the help of volume I <b>can formulate</b> how many cups of tea can come out of a teapot.						0.929
m <sub>69</sub> I <b>can make a general correlation</b> with cubes whose surface area is equal in number to volume.						0.949
m <sub>70</sub> I <b>can express</b> a quadratic equation using square and rectangular fields.						0.935
m <sub>72</sub> I <b>can algebraically express</b> the relationship between the area and volume of a geometric shape.						0.956
Variance ratios of factors	31.592	16.148	14.054	10.785	9.345	6.578
Total variance value	88,502					

**Table 3** shows that the 42 items remaining in the scale are grouped under six sub-factors. The sub-factors obtained are named by the researchers as Additional Drawing (AD), Spatial Thinking (ST), Direction Concept (DC), Relation with Daily Life (RDL), Transition from Algebra to Geometry (TAG) and Transition from Geometry to Algebra (TGA) according to related themes. Factor load values of the items ranged from 0.878 to 0.981. The total variance rate explained by the scale factors is 88,502% and the variance rates provided by each sub-factor are 31.592%, 16.148%, 14.054%, 10.785%, 9.345% and 6.578%, respectively.

### Confirmatory Factor Analysis (CFA)

After the exploratory factor analysis, a 42-item 6-factor structure was tested to confirm the validity of the model. The fit indicator values of the scale were  $\chi^2 / sd = 0.211$ , GFI = 0.910, AGFI = 0.999, CFI = 0.944, NFI = 0.960, NNFI = 0.989, IFI = 0.971, RMSEA = 0.061. In order to demonstrate the adequacy of the model, acceptable or excellent fit values for the fit indices and the results of the analysis are shown in **Table 4** (Cokluk, Sekercioglu, & Buyukozturk, 2012, p. 271; Kazu & Demiralp, 2017, p. 455).

**Table 4.** CFA Values

Goodness of fit value	Before modification	After modification
$p^*$	.0000	.0000
$\chi^2/sd$	1323.354/804=1.646	1286.658/801=1.606
RMSEA	.053	.051
RMR	.035	.035
SRMR	.031	.031
GFI	.79	.80
CFI	.97	.97
NFI	.92	.92
IFI	.97	.97
TLI	.96	.97

Values of goodness of fit were examined to verify the model. When **Table 4** is examined, it is seen that the GFI value is below 0.90, however, considering that the GFI values increase with the number of samples (Hooper, Coughlan, & Mullen, 2008), it can be said that the value of 0.80 is acceptable. RMSEA, RMR, SRMR, CFI, NFI, TLI,  $\chi^2/sd$  and IFI values were found to be at perfect levels. In order to improve the model, 3 covariance assignments were made between items 36-39, 41-42 and 29-31 by examining the modification suggestions proposed by the AMOS program. In addition, the average explained variance (AVE) values were examined to determine the concordance validity.

**Table 5.** Average Variance Extracted values

Sub dimensions	Average Variance Extracted (AVE)
AD	0.832
ST	0.880
DC	0.952
RDL	0.857
TAG	0.927
TGA	0.894

In the study, Average Variance Extracted values for goodness of fit were examined and it was found that the AVE value for each dimension was above 0.50 (Fornell & Larcker, 1981). Discriminant validity and cross loading values were calculated to examine the discrimination validity. The findings obtained are given in **Table 6** and **Table 7**.

**Table 6.** Discriminant Validity Values

	CGG	AD	GCG	RDL	ST	DC
TAG	0.963					
AD	0.312	0.912				
TGA	0.283	0.378	0.946			
RDL	0.077	0.147	0.095	0.926		
ST	0.293	0.235	0.182	0.121	0.938	
DC	0.004	-0.051	-0.076	0.030	0.097	0.976

**Table 7.** Cross Loading Values

	<b>EÇ</b>	<b>UD</b>	<b>YK</b>	<b>GHİ</b>	<b>CGG</b>	<b>GCG</b>
m2	<b>0.940</b>	0.271	-0.040	0.133	0.309	0.415
m4	<b>0.911</b>	0.180	-0.095	0.094	0.249	0.316
m5	<b>0.904</b>	0.225	-0.050	0.169	0.287	0.336
m6	<b>0.912</b>	0.220	-0.012	0.162	0.286	0.362
m7	<b>0.912</b>	0.225	-0.083	0.164	0.326	0.359
m8	<b>0.899</b>	0.187	-0.053	0.069	0.214	0.311
m9	<b>0.902</b>	0.233	0.002	0.156	0.332	0.316
m10	<b>0.915</b>	0.147	-0.045	0.103	0.249	0.322
m13	0.199	<b>0.945</b>	0.088	0.120	0.269	0.156
m15	0.226	<b>0.953</b>	0.056	0.128	0.265	0.185
m16	0.222	<b>0.918</b>	0.094	0.130	0.298	0.197
m21	0.225	<b>0.931</b>	0.128	0.132	0.263	0.182
m22	0.254	<b>0.953</b>	0.081	0.088	0.269	0.176
m23	0.217	<b>0.934</b>	0.100	0.091	0.260	0.161
m24	0.189	<b>0.933</b>	0.092	0.111	0.310	0.131
m30	-0.065	0.093	<b>0.988</b>	0.010	0.019	-0.078
m31	-0.040	0.103	<b>0.968</b>	0.039	-0.016	-0.073
m36	-0.028	0.088	<b>0.972</b>	0.058	-0.003	-0.066
m37	0.135	0.099	0.032	<b>0.923</b>	0.072	0.104
m38	0.183	0.158	0.022	<b>0.946</b>	0.111	0.123
m39	0.162	0.131	0.029	<b>0.941</b>	0.110	0.131
m41	0.105	0.099	0.008	<b>0.929</b>	0.047	0.071
m43	0.081	0.080	0.031	<b>0.900</b>	0.030	0.081
m45	0.109	0.060	0.037	<b>0.914</b>	0.016	0.039
m46	0.147	0.124	0.045	<b>0.932</b>	0.073	0.079
m47	0.103	0.101	0.014	<b>0.919</b>	0.054	0.028
m49	0.286	0.251	0.003	0.072	<b>0.963</b>	0.244
m50	0.313	0.276	0.017	0.073	<b>0.965</b>	0.282
m55	0.293	0.278	0.018	0.084	<b>0.968</b>	0.272
m57	0.292	0.287	0.001	0.077	<b>0.964</b>	0.283
m58	0.292	0.300	0.002	0.088	<b>0.950</b>	0.273
m59	0.324	0.302	-0.019	0.052	<b>0.967</b>	0.283
m61	0.384	0.159	-0.083	0.083	0.260	<b>0.945</b>
m62	0.398	0.203	-0.065	0.084	0.295	<b>0.960</b>
m63	0.374	0.173	-0.068	0.117	0.265	<b>0.950</b>
m64	0.365	0.182	-0.045	0.110	0.275	<b>0.953</b>
m66	0.353	0.185	-0.041	0.078	0.243	<b>0.946</b>
m67	0.335	0.162	-0.067	0.081	0.209	<b>0.939</b>
m68	0.365	0.166	-0.084	0.068	0.285	<b>0.940</b>
m69	0.330	0.181	-0.079	0.091	0.282	<b>0.944</b>
m70	0.349	0.124	-0.113	0.079	0.298	<b>0.939</b>
m72	0.308	0.187	-0.072	0.109	0.261	<b>0.939</b>

When **Table 7** is examined, it is concluded that the values in the intersecting dimension are greater than the others, thus providing discrimination validity. In addition, the results of the cross-correlation loads were entered in the SmartPLS program and the results were examined, and the higher correlation values of the expressions of each variable than the correlation values with the others indicate that there is discrimination validity (See **Table 7**). It was determined that the correlation values of each scale expression were higher than the others. In this context, it has been concluded that the research model has discrimination validity.

#### **Findings Related to the Reliability of the Scale**

Cronbach alpha and composite reliability coefficient values calculated to determine the reliability of the measurement tool are presented in **Table 8**.

**Table 8.** Cronbach alpha, Guttman split half and composite reliability coefficient values

	<b>Cronbach Alpha</b>	<b>Composite reliability</b>
AD	0,971	0,975
ST	0,977	0,981
DC	0,976	0,984
RDL	0,976	0,980
TAG	0,984	0,987
TGA	0,987	0,988
MVPS	0,938	0,942

The Cronbach's Alpha coefficients related to the reliability of the data obtained from the MVPS in terms of internal consistency in the study were calculated as 0.971 for the AD factor, 0.977 for the ST factor, 0.976 for the DC factor, 0.976 for the RDL factor, 0.984 for the TAG factor, 0.987 for the TGA factor, and 0.938 for the MVPS. In addition, composite reliability values were examined. It was calculated as 0.975 for the AD factor, 0.981 for the ST factor, 0.984 for the DC factor, 0.980 for the RDL factor, 0.987 for the TAG factor, 0.988 for the TGA factor, and 0.942 for the MVPS.

## CONCLUSION, DISCUSSION AND SUGGESTIONS

It is aimed to develop a valid and reliable scale that measures the level of mathematical visualization perception of mathematics teacher candidates. During the development of the scale of Mathematical Visualization Perception, the pool of items, testing the scope and appearance validity, performing the trial application, ensuring the construct validity, calculating the reliability and establishing the final scale were followed respectively as Buyukozturk (2016) stated. In order to establish the item pool, interviews were conducted with a group of mathematics teacher candidates outside the research sample, containing their feelings and thoughts about mathematical visualization and visualization perception. Some of the items that can be included in the scale have been determined with the help of the opinions of the teacher candidates about mathematical visualization and perception. In addition, the studies on mathematical visualization and perception in the literature were utilized. Thus, an item pool consisting of 80 items of 5-point likert type that was thought to be included in the scale was created. The pool of items was examined in terms of content validity, appearance validity, simplicity of the language used and spelling rules. The draft scale was applied to 462 mathematics teacher candidates in the Eastern Anatolia Region in the fall semester of the 2018-2019 academic year. Item analysis was conducted based on item-scale correlation value in order to examine whether the items of the scale were related to each other and to remove items that could not be included in the scale (Baykul, 2010, p. 371). How many structures the scale measures were examined by Exploratory Factor Analysis (Secer, 2015, p. 78). The confirmatory factor analysis was used to determine whether the structure obtained by Exploratory Factor Analysis was verified (Cokluk, Sekercioglu and Buyukozturk 2012, p. 275). Cronbach's alpha and Composite reliability coefficient was also calculated for additional evidence of reliability of the final scale. These values indicate the reliability of the scale with AD, ST, DC, RDL, TAG and TGA sub-dimensions and MVPS reliability values. After all these procedures, a valid and reliable "Mathematical Visualization Perception Scale 42 with 42 items and 6 factors was established. The reason for the improvement of this scale is that no valid and reliable scale was prepared to evaluate the mathematical visualization perception levels of mathematics teacher candidates when the literature review was performed. However, when the literature is reviewed, it is seen that questionnaire forms, tests or scales that evaluate the visualization levels of undergraduate students in general were developed. Sezen Yuksel and Bulbul (2014) developed a license level scale to measure spatial visualization ability. Also Delice and Sevimli (2014) developed a questionnaire and test related to the concept of spatial visualization and used them in their studies. As a result, valid and reliable Mathematical Visualization Perception Scale was developed to evaluate the visualization perception levels of mathematics teacher candidates. Within the framework of the findings obtained within the scope of the research, the following suggestions were given to the researchers who wish to work in this field in the future;

Mathematics teacher candidates';

1. Mathematical visualization perception levels can be analyzed in terms of different variables (gender, grade, parental education level, etc.).
2. The relationships between mathematical visualization perceptions and other cognitive characteristics can be examined using techniques such as correlation, regression or path analysis.
3. Determining mathematical visualization perception levels, their views on this subject can be analyzed and mixed-patterned researches can be conducted.

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