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Research Article

A Structural Equation Model for Factors Affecting Eighth Graders' Geometry Achievement*

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Abstract

The aim of this study is to examine the predictor and explanatory relationships among eighth-grade students' affective factors of attitude toward geometry, geometry anxiety, and geometry self-efficacy, as well as the cognitive factor of spatial visualization skills, with geometry achievement. This relational survey study was conducted on 487 eighth-grade students during the 2012-2013 academic year. The tools used to collect data are the Attitude toward Geometry Scale, Geometry Anxiety Scale, and Geometry Achievement Test developed by the researchers; the Geometry Self-Efficacy Scale developed by Cantürk-Günhan and Başer; and the Spatial Visualization Test (adapted to Turkish by Yıldız). The researchers developed the model in consideration of the relevant literature. This model tests the direct and indirect relationships among the variables of affective factors, spatial visualization skills, and geometry achievement. The model's fit indices were calculated and these fit indices show the model to have good fit (x^2 = 106.226; x^2 / df = 2.47; RMSEA = 0.05; CFI = 0.97; NFI = 0.95; NNFI = 0.96). Research reveals the relationship between spatial visualization skills and affective factors, between affective factors and geometry achievement, and between spatial visualization skills and geometry achievement to be positive and significant. Affective factors directly explain 26% of the variance in spatial visualization skills and 35% of the variance in geometry achievement, while indirectly explaining 7% of geometry achievement.

Keywords

Geometry achievement • Attitude toward geometry • Self-efficacy in geometry • Anxiety towards geometry • Spatial visualization skills • Structural equation model

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Geometry is an important branch of mathematics that explores the characteristics and relationships of angles, lines, and shapes (Üstün & Ubuz, 2004). Students learn geometric shapes and structures, their basic properties, and their relationship to each other in geometry lessons, which is very important for school mathematics (National Council of Teachers of Mathematics [NCTM], 2000). This course also develops their decision-making and judgment skills. Moreover, students who master the concepts of geometry and possess strong spatial awareness are ready to learn advanced mathematical subjects as well as subjects on numbers and measurement (Cantürk-Günhan, 2006). Though geometry as a discipline has rather great importance, the research reveals students' geometry achievement to be generally low and the students unable to sufficiently succeed in geometry-related topics (Battista & Clements, 1988; Carroll, 1998).

Thirty-eight countries participated in the 1999 Trends in International Mathematics and Science Study (TIMSS); Turkey came in 34th place on the geometry test, which had 21 questions (Toluk-Uçar, 2005). While Turkey's mean score for geometry was 418 in 1999, it was 411 in 2007 (Şişman, Acat, Aypay, & Karadağ, 2011). Additionally, 42 countries participated in the 2011 TIMSS, in which Turkey came in 21st place this time on the geometry test. Eighth-grade students correctly answered 39% of the questions on the geometry test (Büyüköztürk, Çakan, Tan, & Atar, 2014). While Turkey's mean score for geometry was 411 in the 2007 TIMSS, it increased to 454 in the 2011 TIMSS and 463 in the 2015 TIMSS (Polat, Gönen, Parlak, Yıldırım, & Özgürlük, 2016). This increase could be a result of the new education programs put into effect in 2005 and 2013. However, given that scores of 475 and lower are at the bottom level of math competency, achievement is not being seen at its desired level. When examining the statistics among all the sub-disciplines of mathematics, Turkish students are found to experience the most difficulty in geometry according to the 2007, 2011 and 2015 TIMSS results (Büyüköztürk et al., 2014; Polat et al., 2016; Şişman et al., 2011). The results from the 2003, 2006, 2009, 2012 Programme for International Student Assessment (PISA) resemble the TIMSS results (Anıl, Özer-Özkan, & Demir, 2015; PISA, 2003, 2006, 2009). Examining the reasons for this lack of success reveals geometry-related topics being placed at the end of the program, insufficient importance being attached to them, not enough time being given to the program for teachers to cover all these topics, and teachers encouraging rote learning when teaching geometry (Olkun & Aydoğdu, 2003).

One of the reasons for this failure in teaching geometry appears as the negative affective factors students have toward learning geometry (Yenilmez & Uygan, 2010). In consideration of the reasons for the lack of success in geometry instruction, more importance was attached to geometry in the 2005 Middle School 6th-8th Grade Mathematics Education Program, more room was spared for visual units and activities in the program, and many new subjects such as fractals, transformation

geometry, and spatial visualization were included in the new program (Ministry of National Education of Turkey [MoNE], 2005). In the Middle School 5th-8th Grade Mathematics Education Program (revised in 2013), Geometry and measurement education were incorporated into the mathematics curriculum for all grades. The mathematics education program includes geometric topics such as basic geometric concepts and shapes, lines and angles, polygons, circles, congruence and similarity, right triangles and the Pythagorean Theorem, different views of geometric objects, transformation geometry, and geometric objects (MoNE, 2013).

Success in geometry has been the subject of much research in recent years. Particularly remarkable is the amount of research focusing on the effect of learning environments using different designs (Altın, 2012; Apaçık, 2009; Arıcı, 2012; Başaran-Şimşek, 2012; Bayram, 2004; Boakes, 2009; Cantürk-Günhan, 2006; Duatepe, 2004; Kaya, 2013; Marangoz, 2010; Öz, 2012; Özdemir, 2006; Sarı, 2010; Terzi, 2010; Yahşi-Sarı, 2012; Zenginobuz, 2005). The manipulations made to the learning environments were concluded to have impacted cognitive and affective factors; however, geometry achievement is not just related to changes made in learning environments. While trying to improve geometry achievement, students' affective factors need to be considered as much as cognitive factors (Ma, 1999; McLeod, 1992; Sherman, 1979; Reyes, 1984; Utley, 2004).

One factor that affects geometry achievement is spatial ability (Battista, 1990; Battista & Clements, 1991; Karaman, 2000). Lohman (1988, p. 319) defined this as the ability to "generate, retain, retrieve, and transform well-structured visual images." The components of spatial ability vary among researchers. McGee (1979, p. 3) stated spatial ability to have two components: spatial visualization and spatial orientation. While Linn and Petersen (1985) classified spatial ability as spatial perception, mental rotation, and spatial visualization, Maier (1996) classified it as mental rotation, spatial perception, spatial orientation, spatial relations, and spatial visualization. Among researchers' varying components of spatial ability, consensus has been seen provided for spatial visualization. Spatial visualization is defined by Ekstrom, French, and Harman (1976, p. 173) as "mental visualization of the new form taken by an object after it has been moved or rotated." Spatial visualization skills are particularly necessary for interpreting geometric shapes, creating connections between parts, and imagining certain changes (as cited in Kösa, 2011). The NCTM (2000) stated that 2-D and 3-D spatial visualizations are skills students should develop. Spatial visualization skills affect achievement in many scientific disciplines such as math, science, art, and engineering (Ben-Chaim, Lappan, & Houang, 1988; Delialioğlu & Aşkar, 1999; Olkun & Altun, 2003). Research reveals spatial skills to relate more to geometry than to algebra (Bishop, 1983). Some studies have reported a positive correlation between spatial visualization skills and geometry achievement (Battista,

1990; Kakmacı, 2009). In light of all this research, spatial skills in general and spatial visualization skills in particular can be argued as cognitive factors that influence geometry achievement.

Sherman (1979) stated that even though cognitive factors are known to have great influence on mathematics and geometry achievement, not enough emphasis has been placed on affective factors (as cited in Işık, 2008). Affective factors have as much impact as cognitive factors on students' formation of knowledge (Utley, 2004). The 2005 Middle School 6th-8th Grade and 2013 Middle School 5th-8th Grade Mathematics Education Programs stated that students' affective factors should be taken into account while developing their mathematical conceptualizations and skills (MoNE, 2005, 2013). Researchers have stated different opinions about what these affective factors are. Reyes (1984) explained affective characteristics related to mathematics as being confidence in learning mathematics, mathematics anxiety, attributions of success and failure in mathematics, and perceived usefulness of mathematics while McLeod (1992) stressed them as being belief, attitude, emotion, confidence, Self-concept, self-efficacy, and anxiety. Meanwhile, DeBellis and Goldin (2006) explained affective systems to involve emotions, attitudes, beliefs, morals, values, and ethics.

One affective factor impacting geometry achievement is attitude. According to Aiken (1970, p. 551), attitude is "an individual's tendency to positively or negatively respond to an object, state, concept, person, or learned affiliation" (as cited in Tavşancıl, 2002). Attitudes are formed as a result of the mutual interaction of affection and cognition, standing balanced between them (Kandemir & Gür, 2011). Attitudes towards mathematics represent opinions about mathematics and learning math (Reyes, 1980). Attitude toward geometry on the other hand is "a tendency to include an individual's opinions, emotions, and behaviors regarding geometry; activities related to topics in geometry; geometry teachers; and their personal impact on students" (Bindak, 2004, p. 38). Students' attitudes toward math that stem from emotions related to their math course have an important place in mathematics instruction (Nazlıçiçek & Erktin, 2002). Though a main course, many students consider math difficult to learn, and this perception leads students to develop negative attitudes towards it. Accordingly, their course achievement falls (Kurbanoğlu & Takunyacı, 2012). Only when students find a math course interesting can they develop positive attitudes towards math (Bergeson, Fitton, & Bylsma, 2000). In turn, students' attitudes towards math affect their interest and success in math courses (Aiken, 1976; Ekizoğlu & Tezer, 2007; Kulm, 1980; Ma, 1997; Ma & Kishor, 1997; Minato & Yanese, 1984; Özdoğan, Bulut, & Kula 2005; Peker & Mirasyedioğlu, 2003; Tağ, 2000; Yıldız, 2006; Yücel & Koç, 2011).

Another affective factor on geometry achievement is self-efficacy. Developed from Bandura's Social Learning Theory, self-efficacy is defined as "an individual's judgment about their capacity to demonstrate a certain performance by organizing required activities" (Bandura, 1977, p. 3). Individuals with high self-efficacy beliefs have higher motivations for overcoming difficulties. Possessing a strong perception of self-efficacy is a factor that positively contributes to achievement. People with high self-confidence in their competencies can more easily accomplish tasks assigned to them; however, those not aware of their hidden talents or doubtful of their abilities exhibit a tendency to avoid difficult tasks (Bandura, 1994). Hackett and Betz (1989, p. 262) defined mathematics self-efficacy as "an individual's situational or problem-based evaluation of his/her self-confidence in accomplishing a mathematical task or problem." Geometry self-efficacy can be defined as an individual's perception of his/her knowledge, skills, and capacities acquired through direct or indirect experiences in terms of coping with a geometric problem or task. Research that has investigated individuals' mathematical self-efficacy beliefs report a significant correlation between students' mathematics achievement and mathematics self-efficacy beliefs (Ayotola & Adedeji, 2009; Hackett & Betz, 1989; Kloosterman, 1991; Migray, 2002; Moore, 2005), as well as between geometry achievement and geometry self-efficacy beliefs (Çağırgan-Gülten & Soytürk, 2013; Erdoğan, Baloğlu, & Kesici, 2011; Erkek & Işıksal-Bostan, 2015).

Sources of self-efficacy are mastery experiences, vicarious experiences, social persuasions, and psychological states. Psychological states are composed of the results of individuals' anxiety and stress (Bandura, 1997). On the other hand, people's belief in their abilities affects their stress and anxiety. In this context, if people see themselves as inadequate regarding a certain context, they feel anxiety toward being unsuccessful (Bandura, 1997; Pajares, 1997). Additionally, people who believe they cannot manage danger or difficult situations feel anxious (Bandura, 1993). Students' math anxiety also occurs because of self-efficacy levels being less than desired (Alkan, 2011). Previous research has also indicated a negative relationship to exist between mathematics anxiety and mathematics self-efficacy (Doruk, Öztürk, & Kaplan, 2016; Hoffman, 2010; Meece, Allan, & Jacquelynne, 1990; Pajares & Kranzler, 1995). In other words, individuals with low math self-efficacy beliefs have more math anxiety (Hackett & Betz, 1989).

Anxiety is an important affective factor on learning (Delice, Ertekin, Aydın, & Dilmaç, 2009) and achievement (Ma & Qu, 2004). According to Aiken (1976), "anxiety is a state of arousal manifesting itself in the form of physical, emotional, and cognitive changes when an individual confronts a stimulus" (as cited in Aydın & Dilmaç, 2004, p. 235). Individuals with high levels of anxiety feel more stringent and tense and overtly focus on pleasing others, even when coming across simple tasks. A moderate level of anxiety tends to arouse, protect, and motivate an individual. In

some cases, anxiety serves as a vehicle that motivates an individual to work harder to be successful and to take precautions in the face of situations where failure is likely (Akgün, Gönen, & Aydın, 2007). Mathematical anxiety is "a sense of worry and stress that hinders using numbers and solving mathematical problems in daily life and academic environments" (Richardson & Suinn, 1972, p. 51). Mathematical anxiety includes feelings of worry about and fear and avoidance of mathematics; with increasing levels of anxiety, individuals start to strongly believe that they cannot deal with the source of anxiety (Baykul, 2009). Anxiety towards geometry can be defined as a sense of distress or worry felt in social or academic life by an individual when learning geometry, solving geometric problems, or taking a geometry exam. Researchers have investigated the causes of anxiety under three categories: environmental, cognitive, and personal (Deniz & Üldaş, 2008). Mathematical anxiety is maintained to be a state of anxiety rather than an anxiety trait (Baloğlu, 2001; Reyes, 1984; Spielberger, 1972). Though the causes of mathematical anxiety cannot be precisely explained, this anxiety is thought to be closely related to the attitudes of teachers and families towards mathematics, a lack of confidence in dealing with disappointments experienced in mathematics, and superficial teaching of mathematical concepts by teachers (Norwood, 1994). Research has revealed a negative correlation to exist between mathematics anxiety and mathematics achievement (Keşan, Yetişir, & Kaya, 2011; Ma & Qu, 2004; Peker & Şentürk, 2012; Yenilmez & Özbey, 2006).

In terms of developing geometry instruction, determining the factors that affect geometry achievement is of great importance. Research on geometry has revealed that, aside from spatial visualization, one cognitive factor that also affects achievement are affective factors such as attitude, self-efficacy, and anxiety (Bishop, 1983; Ben-Chaim et al., 1988; Çağırgan-Gülten & Soytürk, 2013; Özkan, 2010; Özkeleş-Çağlayan, 2010). However, most research has focused on mathematics. One of the most important branches of mathematics is geometry. A rather limited number of studies have explored geometry-oriented affective characteristics together with spatial visualization. The current study investigates the extent to which spatial visualization together with affective characteristics affect geometry achievement. In this respect and in consideration of the relevant literature, variables thought to be related to geometry achievement are tested using a model developed within the framework of the theoretical knowledge base; furthermore, all variables' inter-relationships are analyzed.

Understanding the relationship between affective and cognitive learning in mathematics instruction is of great importance for developing mathematics education. Significant correlations are found as a result of the research review on testing the correlation between spatial visualization and geometry achievement (Bishop, 1983; Ben-Chaim et al., 1988; Pandiscio, 1994) and between affective characteristics and

geometry achievement (Cansız-Aktaş & Aktaş, 2012; Çağırgan-Gülten & Soytürk, 2013; Erdoğan et al., 2011; Özkan, 2010; Özkeleş-Çağlayan, 2010). Moreover, the teaching methods adopted in class and students' socio-economic levels, computer and technology usage, gender, and spatial visualization skills have been reported to have certain impacts on geometry achievement. Some research has also shown how the experimental activities conducted in a geometry class impact affective characteristics and spatial visualization (Battista, 1990; Delgado & Prieto, 2004; Dursun, 2010; Fennema & Tartre, 1985; McGee, 1979; Pandiscio, 1994; Tartre, 1990). While some research has focused on the effect of computer-assisted perspective drawings and/or the use of concrete models on students' spatial visualization skills and attitudes towards mathematics, technology, and geometry (Drickey, 2000; İça-Turhan, 2010; Sarı, 2012; Turğut, 2010; Yıldız, 2009; Yolcu, 2008), other studies have investigated the effects of teaching using origami on spatial ability and achievement, reporting these variables to be affected by the independent variables (Arıcı, 2012; Boakes, 2009; Çakmak, 2009).

Given the delineations above, determining the factors that affect geometry achievement are clearly important for enhancing geometry instruction. The current study is believed important as it attempts to elicit the correlations of certain affective factors (attitude, self-efficacy, and anxiety) and the cognitive characteristic of spatial visualization skills with geometry achievement, attempting to reveal the relationships among these variables using structural equation models. These variables are seen in the literature to normally be investigated separately. No study has dealt with forming a model to explain the correlation of affective characteristics and spatial visualization skills with geometry achievement or their ability to predict geometry achievement. Furthermore, as the results of the current study will reveal the relationships among variables that predict geometry achievement, it will contribute to determining the reasons for students' low performance in geometry. The current study is believed to help fill this void in the literature and shed light on the research teachers, mathematics educators, and researchers conduct for improving geometry achievement. More effective mathematics instruction programs can be developed by taking these variables into consideration.

The purpose of this study is to investigate the impact of affective characteristics and the cognitive factors of spatial visualization skills on eighth-grade students' geometry achievement. This study also aims to examine predictor and explanatory relationships of eighth-grade students' attitude toward geometry, geometry self-efficacy, and anxiety toward geometry (affective factors) and spatial visualization skills (cognitive factor) on geometry achievement.

Method

Research Design

The current study aims to determine predictive relationships of certain variables that affect middle-school eighth-grade students' geometry achievement using structural equation models. For this reason, the relational survey model is used as the research design. Relational survey models aim to investigate the relationships among two or more variables and obtain clues on cause-and-effect relationships (Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz, & Demirel, 2011).

Procedure

The first model in Figure 1 was developed in light of the related theory and research in order to examine the direct and indirect relationships among the cognitive and affective variables. Attitude, self-efficacy, and anxiety explain the geometry-related affective factors in this model. Affective factors have a direct effect on geometry achievement, and geometry achievement has a direct effect on affective factors. Spatial visualization skills have a direct effect on geometry achievement, and geometry achievement has a direct effect on spatial visualization skills. Affective characteristics have indirect effects on geometry achievement, and this effect is mediated through spatial visualization skills. In addition spatial visualization skills have an indirect effect on geometry achievement. The model is shown in Figure 1.

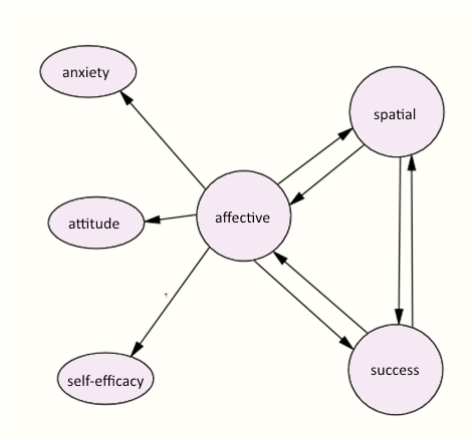

Figure 1. The first structural equation model that was tested.

After testing this model, no paths were found meaningful nor were the model's fit indices found acceptable, so an alternative model was developed (see Figure 2). In this model, attitude, self-efficacy, and anxiety explain geometry-related affective factors. Affective factors have direct effects on geometry achievement. Spatial visualization

skills have a direct effect on geometry achievement. Affective characteristics have indirect effects on geometry achievement, and this effect is mediated through spatial visualization skills.

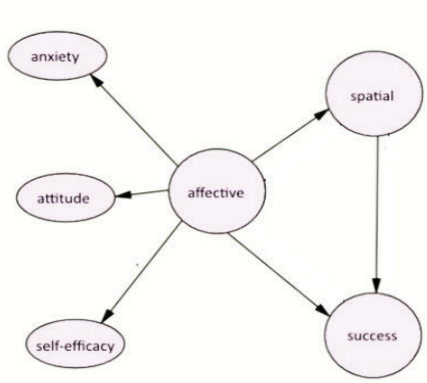

Figure 2. The main structural equation model.

Participants

The pilot application of the scales was conducted with the participation of 317 students attending five different middle schools randomly selected from among the middle schools located in a city in Turkey's Central Anatolia. Of the participants, 157 are girls, 160 are boys and their ages range from 11 to 14 years old. A total of 340 students participated in the study, but 23 were excluded for giving the same response (or no response) to all the items. According to Tavşancıl (2002), the number of the participants in the sampling must to be at least five times greater than the number of items. The number of participants is ten times greater than the number of items. The distribution of pilot study participants according to gender and school are given in Table 1.

Table 1
The Distribution of Pilot Study Participants According to Gender and School

	School	Female	Male	Total
1	Middle School A	41	45	86
2	Middle School B	24	23	47
3	Middle School C	21	34	55
4	Middle School D	54	42	96
5	Middle School E	17	16	33
	Total	157	160	317

After the scales' pilot study, the main sample of the study became 487 eighth-grade students from five different schools in a Central Anatolian city during the 2013 spring semester. The schools where the main application was conducted were selected using simple random sampling, a method in which equal opportunity is given to each sampling unit in terms of being selected (Büyüköztürk et al., 2010). The scales, spatial

visualization test, and geometry achievement test were conducted on 564 students. When the researchers examined the questionnaires, some were found to be half-complete while others were double marked; some students were also found to have not participated in certain applications. After excluding these questionnaires, data was collected from 487 (238 female, 249 male) students and subjected to analysis. The distribution of students according to gender and school is given in Table 2.

Table 2
Distribution of Students According to Gender and School

	School	Female	Male	Total
1	Middle School F	89	106	195
2	Middle School G	53	45	98
3	Middle School H	25	39	64
4	Middle School I	54	43	97
5	Middle School K	17	16	33
	Total	238	249	487

Data Collection Tools

The Attitude toward Geometry Scale, Geometry Anxiety Scale, and Geometry Achievement Test (developed by the researchers); the Geometry Self-Efficacy Scale (developed by Cantürk-Günhan & Başer, 2007); and the Spatial Visualization Test (adapted to Turkish by Yıldız, 2009) were used as data collection tools. Information on the reliability and validity studies of the scales developed by this study's researchers and the reliability and validity about the other scale and test are presented under relevant scale's heading.

Geometry Self-Efficacy Scale. The Geometry Self-Efficacy Scale was developed by Cantürk-Günhan and Başer (2007) for middle school students. Factor analysis determined the five-point Likert-type scale to consist of three factors and 25 items. Geometry self-efficacy has three dimensions: positive self-efficacy, negative self-efficacy, and using geometry knowledge. The dimension of positive self-efficacy has Twelve items and its Cronbach alpha is .88; the dimension of negative self-efficacy has seven items and its Cronbach alpha is .70; and the dimension of using geometry knowledge has six items and its Cronbach alpha is .70. The results of the reliability analysis find Cronbach's alpha for the whole scale to be .90 (Cantürk-Günhan & Başer, 2007). In this research, Cronbach's alpha is .89.

The statement "I can remember the features of a geometrical figure I see" can be given as an example for the dimension of positive self-efficacy. "I think I will be successful if I select a job requiring the use of geometry knowledge in future" can be given as an example for the dimension of using geometry knowledge. "I cannot

explain the relationships among geometrical figures" can be given as an example for the sub-dimension of negative self-efficacy.

Attitude toward Geometry Scale. This scale was developed by the researchers for determining middle school students' geometry attitudes. While developing the Attitude toward Geometry Scale, a comprehensive literature review was first conducted on attitudes and their dimensions, in addition to existing mathematics and geometry attitude scales (Bindak, 2004; Bulut, Ekici, İşeri, & Helvacı 2002; Duatepe, 2004; Duatepe & Çilesiz, 1999; Karakaş-Türker & Turanlı, 2008; Nazlıçiçek & Erktin, 2002; Turanlı, Karakaş Türker, & Keçeli, 2008; Utley, 2004). As a result of the literature review and in line with the study's aim, items were formed and expert opinion was sought in order to establish the content validity of the scale. The items are designed using a 5-point Likert scale ranging from Strongly Disagree (1), to Disagree (2), Undecided (3), Agree (4), and Strongly Agree (5). Furthermore, the scale items were analyzed by a linguistic expert to check them in terms of grammar and comprehensibility. In order to determine the response time for the scale items and their comprehensibility, the scale was administered to 10 middle school students. As a result, the average response time for 41 scale items was found to be 20 minutes; the students found the 42nd item difficult to comprehend, and as such was discarded from the scale, thus leaving 41 items. Afterwards the pilot study was conducted with the participation of 340 students attending 5 different middle schools. After factor analysis, the five-point Likert-type scale was determined to consist of four factors and 24 items. The variance explained by each of the factors in the determined four-factor structure is 17.5%, 14.9%, 11.3%, and 8.9%. The total variance explained by these four factors is 52.63%. Geometry attitudes include four dimensions: confidence, benefit, interest, and love. After confirmatory factor analysis, fit indices were calculated (χ^2 / df = 1.87; $p < .001$; NFI = 0.94; $RMSEA$ = 0.05; $NNFI$ = 0.97; $AGFI$ = 0.85; $S\text{-}RMR$ = 0.06). The results of the reliability analysis show Cronbach's alpha to be .90. Cronbach's alpha for the sub-dimension of interest was calculated as .83; of love, .84; of benefit, .73; and of confidence, .70. The Attitude toward Geometry scale in the present study can be argued as valid and reliable.

Geometry Anxiety Scale. This scale was developed by the researchers for determining middle school students' geometry anxiety. While developing the geometry anxiety scale, a comprehensive literature review was first conducted on mathematics (Bindak, 2005; Deniz & Üldaş, 2008; Özdemir & Gür, 2011) and geometry anxiety scales (Sağlam, Türker, & Umay, 2011), then the items were formed. The items were designed using a 5-point Likert scale. In order to establish the scale's content validity, expert opinion was sought. Furthermore, the scale items were analyzed by a linguistic expert. After factor analysis, the scale was determined to consist of three factors and 17 items. Geometry anxiety has three dimensions: anxiety towards

social environment, anxiety towards assessment, and anxiety towards learning. The variances explained by each factor in the determined three-factor structure are 19.7%, 18.4%, and 17.12%. The total variance explained by these three factors is 55.28%. After confirmatory factor analysis, fit indices were calculated (χ^2 / *df* = 1.44; *RMSEA* = 0.038; *S-RMR* = 0.0046; *CFI* = 0.99; *NNFI* = 0.99; *NFI = 0.97)*. The results of the reliability analysis show Cronbach's alpha to be 0.906. Cronbach alpha for the dimension of anxiety towards social environment was calculated to be .80; of anxiety towards assessment, .81; and anxiety towards learning, .81.

The statement "I worry that my geometry achievement is compared with my friends'' can be given as an example of the dimension of anxiety towards social environment. "I worry I won't be able to learn geometry" can be given as an example of the dimension of anxiety toward geometry learning. "I panic even in geometry exams I think I can pass" can be given as an example of the dimension of anxiety toward geometry assessment.

Spatial Visualization Test. This test is used to measure students' spatial visualization skills. The 15-item test was developed for the project Middle Grades Mathematics Project carried out in the US by Winter, Lappan, Philips, and Fitzgerald (1989), and adapted to Turkish by Yıldız (2009). Each item has five answer choices. The test includes questions related to isometric images of structures made up of cubic units and their views from the left, right, back, and front. In addition to these, it has questions on math plans, which are a special coding of a bird's eye view of the cubic structures in the test. Cronbach's alpha of reliability was found to be .97 (Yıldız, 2009). The required permissions were granted for administering the test, which takes 40 minutes to complete.

Geometry Achievement Test. This test was developed by the researchers to measure middle school eighth graders' geometry achievement. First, 60 learning outcomes included in the scope of geometry learning for sixth, seventh, and eighth graders in the Middle School 6th-8th Grade Mathematics Education Program were determined. Each sub-learning area involved in the scope of geometry learning and the ratio of each sub-learning area in the program was determined; moreover, by forming patterns between the learning outcomes, a total of 25 learning outcomes were taken into consideration. In order to establish the content validity of the scale, expert opinion was sought. The suitability of the prepared questions for students' levels and whether they included mathematical errors were examined by math teachers and math education specialists. The suitability of the piloting form in terms of measurement was evaluated by a measurement and evaluation expert. The pilot form of the test was determined to include 50 questions and then was administered to 250 eighth-grade students. As the number of questions was high, The Geometry

Test Pilot Form was arranged into two separate forms (each including 25 questions) and administered to students on two different days during an hour of class. The pilot form was conducted under the supervision of the researcher and the class teachers from the schools participating in the pilot; but teachers made no interventions. Prior to administering the test, all necessary explanations were made to the students, who were informed about the purpose of the test and how the coding would be performed.

The response papers obtained from the pilot study for selecting items were scored in such a way that 1 point was given to each correct answer and a zero was scored for each wrong, blank, or incomplete answer; the scores obtained in this way were subjected to item analysis using Microsoft EXCEL. The tests consist of 25 multiple-choice questions. Formed after item analysis, the geometry achievement tests' mean score was calculated as 12.66. The mean difficulty index was found to be .51, and the mean discrimination index was found to be .39. These values show that the test is good and at the required difficulty level. After reliability analysis, the Kuder-Richardson Formula 20 reliability value was found to be .81. The test takes 40 minutes to complete.

Data Collection

Path analysis is employed to test whether the collected data confirm the theoretical model built by the researcher (Meydan & Şeşen, 2011). Within the context of the current study, the researchers conducted a literature review related to these variables and their relationships; on the basis of this review and with expert opinions, a model was designed to represent the relationships among the variables. Following the model's construction and validity-reliability studies, the process of data collection began. Prior to collecting the data, the required permissions were received for conducting the study in the five schools selected using convenience sampling. The directors of these five schools located in a Central Anatolian city were met with individually, informed about the study, and decided on a date for applying it. Further validity and reliability studies were conducted and the collected data were subjected to exploratory factor analysis, thus determining the structures of the scales. Confirmatory factor analysis was then conducted on the data, giving the scales their final form.

The Geometry Self-Efficacy Scale, Attitude toward Geometry Scale, Geometry Anxiety Scale, Spatial Visualization Test, and Geometry Achievement Test were administered to collect the research data. During the data collection process, contact was made with the mathematics teachers in the schools to inform them about the application and to seek their opinions about when to administer the data collection instruments. In line with the school directors' and mathematics teachers' opinions, the data collection instruments were decided to be administered in three stages so as not to bore the students. The researcher visited the schools on the predetermined dates,

informed the students about the application, and explained the goals of the study. While administering the scales, students were told how to fill them in, how to answer the questions on the Geometry Achievement and Spatial Visualization Tests, and how they would be graded. The class teachers remained in class during the administration but were asked not to interfere in the process. Enough time was given to the students to complete the scales and tests.

Data Analysis

AMOS 19.0 was used to conduct confirmatory factor analysis on the data from the scales and for testing the model. Data analysis was conducted in three stages. The first stage included preparing the data before analysis. For this purpose, missing data analyses were carried out, extreme values were determined, and univariate/multivariate normality tests were performed. The data were found to be non-normally distributed. When the multivariate normality coefficient is not satisfied, an attempt is made to normalize the data. This was attempted here, but the data could not be normalized. In cases where the data cannot be normally distributed, either the robust-likelihood or weighted-least-squares is used. In this research, robust-maximum-likelihood was used. In the second stage, confirmatory factor analysis and descriptive statistics were performed. In the third stage, the theoretical model was tested. For this purpose, a measurement model was constructed between the related variables, and according to suggested modifications, the model's fit indices were re-evaluated. In line with the direct and indirect impacts between observed and latent variables, data analysis was performed using the structural equation model to examine the fit indices among the variables in the model.

Results

The model developed within the context of the current study uses the variables of anxiety toward geometry, attitude toward geometry, and geometry self-efficacy, and the affective characteristics of spatial visualization skills and geometry achievement. Geometry achievement is explained by the scores from the Geometry Achievement Test and spatial visualization skills are explained by the scores from the Spatial Visualization Test. In the model, one-way arrows show causal relations. The structural equation model built using the collected data is shown in Figure 3.

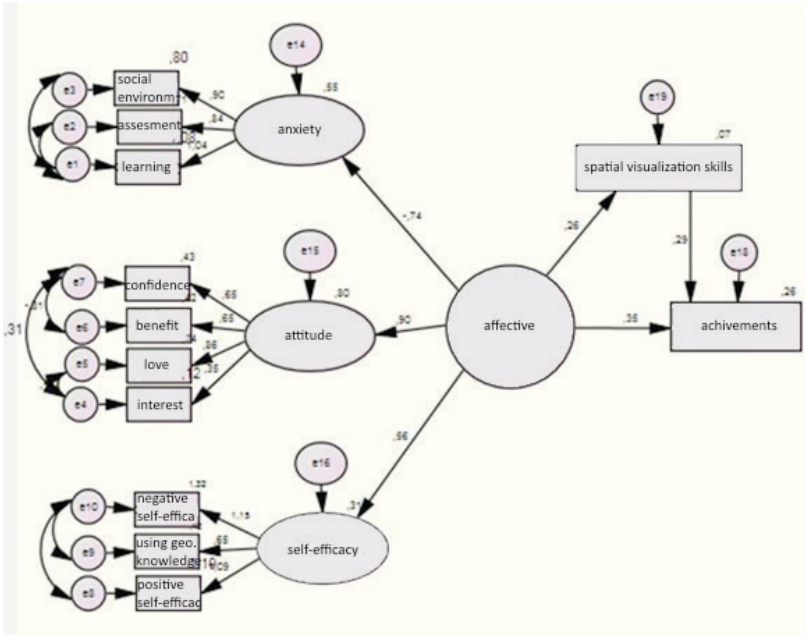

Figure 3. The structural equation model.

According to the model, affective characteristics include the variables of attitude toward geometry (β = 0.90), geometry self-efficacy (β = 0.56), and anxiety toward geometry (β = -0.74). Anxiety toward geometry has three dimensions: anxiety toward the social environment, anxiety toward assessment, and anxiety toward learning. Attitude toward geometry includes four dimensions: confidence, benefit, interest, and love. Geometry self-efficacy has three dimensions: positive self-efficacy, negative self-efficacy, and using geometry knowledge. The most important variable constituting the affective dimension is attitude toward geometry, followed by anxiety toward geometry, then geometry self-efficacy. Affective characteristics related to geometry are seen to directly explain geometry achievement (β = 0.35; p < .001) and spatial visualization skills (β = 0.26; p < .001) at a significant level. Spatial visualization skills directly explain geometry achievement at a significant level (β = 0.29; p < .001). Inter-variable relationships, their levels of significance, and explained variance values are presented in Table 3.

Table 3
Regression Coefficients and Variances of the Model

	ß	*p*	Explained Variance
Anxiety ← Affective	-0.74	***	.55
Attitude ← Affective	0.90	***	.80
Self-efficacy ← Affective	0.56	***	.31
Spatial Visualization ← Affective	0.26	***	.07
Achievement ← Affective	0.35	***	.26
Achievement ← Spatial Visualization	0.29	***	.26

*** $p < .001$.

According to Table 3, geometry-related affective characteristics' total power for predicting spatial visualization skills is .26, and .35 for predicting geometry achievement. When examining the standardized results belonging to indirect effects, geometry-related affective characteristics' power of indirectly predicting geometry achievement is seen to be .07. Thus, the affective characteristics can be argued to have an indirect effect on geometry achievement, and this effect is mediated by spatial visualization skills. Fit indices were examined after analyzing the significance of the standardized loading values and *t* values. These fit indices are the chi-square (χ^2), goodness-of-fit index (*GFI*), adjusted goodness-of-fit index (*AGFI*), root-mean-square error of approximation (*RMSEA*), standardized root-mean-square residual (*SRMR*), normed fit index (*NFI*), non-normed fit index (*NNFI*) and comparative fit index (*CFI*). Some fit indices are given in Table 4.

Table 4
Fit Indices

Fit Indices	Criteria	Value	Result
χ^2		106.22	
χ^2 / *df*	≤ 5	2.47	Good Fit
GFI	≥ 0.95	0.96	Very Good Fit
AGFI	0.90 ≤ *AGFI* ≤ 0.95	0.93	Good Fit
RMSEA	≤ 0.05	0.05	Very Good Fit
NFI	≥ 0.95	0.95	Very Good Fit
NNFI	≥ 0.95	0.96	Very Good Fit
CFI	≥ 0.95	0.97	Very Good Fit

According to Table 4, fit indices have been calculated as $\chi^2 = 106.226$ ($df = 43$; $p < .001$); $\chi^2 / df = 2.47$; $RMSEA = 0.05$; $CFI = 0.97$; $NFI = 0.95$; and $NNFI = 0.96$. Considering these values, the model can be concluded to exhibit good fit.

Mediation Effect

In the second stage, the tested model explores the mediating effect of the variable of spatial visualization skills between affective characteristics and geometry achievement. For this purpose, three-stage regression analysis as proposed by Baron and Kenny (1986) was tested using two different structural equation models in order

to be able to see direct and indirect effects simultaneously (as cited in Meydan & Şeşen, 2011). Accordingly:

1. The independent variable (affective factors) must have an effect on the mediating variable (spatial visualization skills).

2. The independent variable (affective factors) must have an effect on the dependent variable (geometry achievement).

3. When the mediating variable (spatial visualization skills) is included in the regression analysis of the second stage, while the effect of the independent variable (affective factors) on the dependent variable (geometry achievement) decreases, the mediating variable (spatial visualization skills) must have a significant effect on the dependent variable (geometry achievement).

Two different models have been constructed to investigate these effects. The first model is shown in Figure 4.

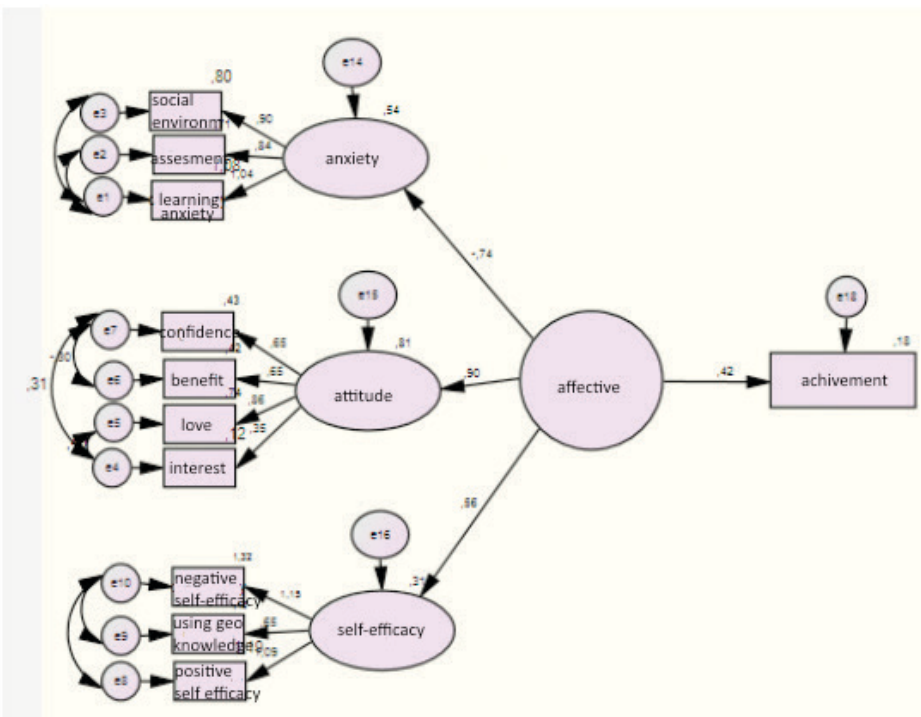

Figure 4. Structural equation model on the mediation effects.

In the first model (see Figure 4), geometry achievement is taken as the dependent variable and affective factors are taken as the independent variable, thus exploring the first effect mentioned by Baron and Kenny. Fit indices have been calculated as (χ^2

= 97.76; *df* = 34, $p < .001$), $\chi^2 / df = 2.87$; *RMSEA* = 0.06; *GFI* = 0.96; *AGFI* = 0.93; *CFI* = 0.97; *NFI* = 0.96; *NNFI* = 0.96). Considering these values, the model can be concluded to exhibit good fit. The standardized beta, standard error, and significance values belonging to the paths leading from affective factors to geometry achievement are shown in Table 5.

Table 5
Regression Coefficient and Variance of the Model

	B	Standard Error	*p*	Explained Variance
Achievement← Affective	0.42	0.05	***	.42

*** $p < .001$.

According to Table 5, the findings indicate that affective factors have an influence on geometry achievement. In the second stage, geometry achievement is taken as the dependent variable, affective factors are taken as the independent variable, and spatial visualization skills are taken as the mediating variable. Then the existence of the second and third effects mentioned by Baron and Kenny is investigated. This model is shown in Figure 3. Fit indices of the model shown in Figure 3 are calculated as $\chi^2 = 106.226$ (*df* = 43; $p < .001$); $\chi^2 / df = 2.47$; *RMSEA* = 0.05; *CFI* = 0.97; *NFI* = 0.95; *NNFI* = 0.96. Considering these values, the model can be concluded to exhibit good fit. The standardized beta, standard error, and significance values belonging to the paths are shown in Table 6.

Table 6
Regression Coefficients and Variances of the Model

	Regression Coefficient(β)	*p*	*Explained Variance*
Spatial Visualization ← Affective	0.26	***	.07
Achievement ← Affective	0.35	***	.26
Achievement ← Spatial Visualization	0.29	***	.26

*** $p < .001$.

Geometry-related affective factors' total power for predicting spatial visualization skills is 0.26 and for predicting geometry achievement is 0.35. When examining the standardized results belonging to indirect effects, geometry-related affective factors' power for indirectly predicting geometry achievement is seen to be 0.07. Moreover, the findings reveal that in the model formed by including spatial visualization skills, the impact of affective factors on geometry achievement decreases. Thus, spatial visualization skills play a partially mediating role as a variable forming the impact of affective factors on geometry achievement.

Effect Size

Effect sizes have been calculated by considering the structural equations obtained as a result of analysis, and the explained variances (r^2) and effect sizes (f^2) were

calculated based on the determining coefficients of the structural equations. Effect sizes of the equations have been calculated using the formula $r^2/(1 - r^2)$ formula (see Table 7).

Table 7
Explained Variances and Effect Sizes of Latent Variables

	r^2	f^2
Affective ← Spatial Visualization	0.07	0.07
Affective ← Achievement	0.26	0.35
Spatial Visualization ← Achievement	0.26	0.35

According to Table 7, while affective characteristics explain 7% of spatial visualization skills, they explain 26% of geometry achievement. Spatial visualization skills also explain 26% of geometry achievement. When evaluating the effect sizes calculated on the basis of the explained variance values, Cohen's (1988) classification was used. According to this classification, an f^2 of 0.02 indicates a small effect; of 0.15, a medium effect; and of 0.35 or greater, a large effect. Thus, affective characteristics can be argued to have a small effect size in explaining spatial visualization skills ($f^2 = 0.07$); spatial visualization skills have a large effect size in explaining geometry achievement.

Discussion

This study, which employs the survey model, aims to bring some of eighth-grade students' affective factors together with a cognitive factor (spatial visualization skills) to explain their direct and indirect relationships among them. In this context, a structural equation model has been constructed to show the relationship of middle-school eighth-grade students' geometry-related affective factors and spatial visualization skills to geometry achievement. The affective factors consist of attitude, anxiety, and self-efficacy. Geometry achievement is explained by the scores from the Geometry Achievement Test, and spatial visualization skills are explained by the scores from the Spatial Visualization Test. The model built on the related variables is concluded to be a convenient model (χ^2 / $df = 2.47$; $RMSEA = 0.05$; $CFI = 0.97$; $NFI = 0.95$; $NNFI = 0.96$). According to the findings derived from the model, the geometry-related affective factors' total power for predicting spatial visualization skills is .26; for predicting geometry achievement, .35; for predicting geometry-related self-efficacy, .55; for predicting geometry-related attitude, .89; and for predicting geometry-related anxiety, .74.

In many studies, students' spatial visualization skills have been found to highly correlate with geometry achievement (Bishop, 1983; Ben-Chaim et al., 1988). This parallels the findings of the current study. These findings reveal spatial visualization skills to be an important variable explaining geometry achievement. Dursun (2010)

reported a positive relationship between the students' spatial visualization test scores and their geometry self-efficacy scores. Kakmacı (2009) stated a significant difference to exist between the spatial visualization achievements of sixth-grade students according to the variable of interest in geometry. Much research has indicated a positive relationship between mathematics success and mathematics attitude (Aiken, 1976; Dungan & Thurlow, 1989; Ekizoğlu & Tezer, 2007; Hackett & Betz, 1989; Kulm, 1980; Ma, 1997; Ma & Kishor, 1997; Minato & Yanese, 1984; Nazlıçiçek & Erktin, 2002; Özdoğan et al., 2005; Peker & Mirasyedioğlu, 2003; Şentürk, 2010; Tağ, 2000; Uslu, 2006; Yenilmez & Özabacı, 2003; Yıldız, 2006; Yücel & Koç, 2011). In addition, a positive relationship has also been stated to exist between students' attitudes toward geometry and geometry achievement (Cansız-Aktaş & Aktaş, 2012). In addition, positive relationships exist between mathematics self-efficacy and mathematical achievement (Hackett & Betz, 1989; Pajares & Graham, 1999; Pietsch, Walker, & Cahpman, 2003) and geometry self-efficacy and geometry achievement (Çağırgan-Gülten & Soytürk, 2013; Erdoğan et al., 2011; Erkek & Işıksal-Bostan, 2015; Özkan, 2010; Özkeleş-Çağlayan, 2010). On the other hand, the findings in the literature also indicate a significant negative correlation between mathematics achievement and mathematics anxiety (Betz, 1978; Douglas, 2000; Dursun & Bindak, 2011; Ma, 1999; Meece, Wigfield, & Eccles 1990; Nazlıçiçek, 2007; Richardson & Suinn, 1972; Şentürk, 2010).

Geometry-related affective factors' power to indirectly predict geometry achievement is seen to be .07. Thus, affective factors can be concluded to have an indirect effect on geometry achievement, and this effect is mediated by spatial visualization skills. Moreover, the findings reveal that when the model includes spatial visualization skills, the impact of affective factors on geometry achievement decreases. Thus, spatial visualization skills play the role of a partially mediating variable in the formation of the impact of affective factors on geometry achievement. Affective factors can increase geometry achievement. In addition to individuals' affective attributes on geometry, their spatial visualization skills can positively improve their geometry achievement. On the basis of the findings derived from the model, the correlation between affective factors and spatial visualization skills, between affective factors and geometry achievement, and between spatial visualization skills and geometry achievement have been concluded to be positive and significant. Moreover, a positive and significant correlation has been found between the independent latent variable of spatial visualization skills and affective factors, between spatial visualization skills and geometry achievement as variables, between spatial visualization and geometry achievement as variables. Affective factors explain 26% of geometry achievement. This confirms Bloom's (1979) claim that 25% of the variance in learning outcomes is explained by affective factors.

When examining the model, the variables that directly or indirectly predict geometry achievement and spatial visualization skills are concluded to generally be an individual's affective factors, or in other words, self-efficacy, anxiety, and attitude. The most important affective characteristic in this regard is attitude, followed by anxiety and self-efficacy. This indicates that improving students' attitudes towards and self-efficacy in geometry will enhance both their geometry achievement and spatial visualization skills. Moreover, reducing their anxiety levels can also result in improving their geometry achievement and spatial visualization skills. This situation can be explained by the difficulty in changing self-efficacy beliefs because self-efficacy is a judgment of one's own abilities (Bandura, 1977). Because beliefs that affect the decisions individuals make throughout their lives are shaped at an early age and resistant to change (Pajares, 1992), the impact of beliefs on success may therefore be comparatively small. Özkeleş-Çağlayan (2010) maintained based on the research findings that self-efficacy beliefs about and attitudes towards a geometry course predict geometry achievement. Kalender (2010) stated that affective variables positively impact mathematics achievement.

Research has generally reported correlations ranging from .30 to .60 between spatial visualization and mathematics achievement (Ben-Chaim et al., 1988; Fennema & Tartre, 1985; Friedman, 1992; Harris, 1981; Johnson & Meade, 1987, as cited in Pandiscio, 1994). The findings of the current study reveal that spatial visualization skills explain 26% of geometry achievement. Thus, spatial skills clearly have an important role in geometry achievement. Spatial visualization skills are particularly necessary for interpreting geometric shapes, creating connections between their parts, and imagining certain transformations (Kösa, 2011). Battista (1990) conducted a study on high school students and found a positive correlation for spatial visualization skills with logical reasoning and geometry achievement. Battista, Wheatley, and Talsma (1989) reported the spatial visualization, formal logic, and problem-solving performances of pre-service elementary school teachers to be associated with geometry achievement. The findings of the current study also reveal spatial visualization skills to be an important variable directly affecting geometry achievement. These findings concur with those reported by Işık (2008), Sherman (1979), and Battista (1990). Işık (2008) stated field dependent/independent cognitive styles, spatial skills, and attitudes toward geometry to be variables that predict geometry achievement, with spatial visualization skills explaining 3.6% of geometry achievement. Thus, spatial visualization skills can be argued to be a statistically significant variable in explaining geometry achievement. Sherman (1979) addressed the issues of spatial visualization, verbal skills, ninth-grade mathematics achievement, and attitude towards mathematics, investigating whether these variables predict mathematics achievement. Sherman (1979) concluded these variables to predict tenth graders' geometry achievement, with spatial visualization being the third most

important variable following mathematics achievement and verbal skills in terms of predicting geometry achievement. Teachers need to be aware of the importance of affective factors and spatial visualization skills. They need to plan activities to help develop their students' affective factors and spatial visualization skills in order to enhance their students' geometry achievement.

Suggestions

This study was conducted on eighth-grade students from five different Central Anatolian schools. Future research conducted in different cities at different grade levels for investigating correlations among various variables with geometry achievement is also believed to be useful. The current study was conducted on middle school students. Repeating this study at the high school level and higher is believed able to make a contribution to the literature. In this study, spatial visualization skills play the role of a partially mediating variable in forming the impact of affective factors on geometry achievement. This mediation effect of spatial visualization skills can be researched in future studies. Longitudinal research can be conducted using the same variables and model as the current study. Qualitative research can be involved for a more in-depth analysis of the affective variables and their causes in the current study. How the model constructed in this study should be implemented can also be researched.

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