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Examination of the Relationship Between Seventh-Grade Students' Scientific Literacy among Certain Cognitive Variables *

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Abstract

The aim of this study was to model the possible relationships between the seventh-grade students' scientific literacy and their logical thinking abilities, cognitive styles (field-dependent/field-independent), functional mental capacities and mental rotation abilities. To that end, a theoretical model, which is believed to explain the relationship between the specified variables, was proposed and then tested by using the Structural Equation Modeling (SEM) techniques. The sample of the study consisted of 823 seventh-grade students who were sampled by using the stratified random sampling method from the central districts of Ankara. The analysis of the data collected in the study supported the proposed theoretical model in the study. Based on the model, the logical thinking ability of the seventh-grade students was the only variable that directly affected the scientific literacy of the students. Field-dependent/field-independent cognitive styles affected the scientific literacy both directly and through all other cognitive variables indirectly. The functional mental capacity affected the scientific literacy both directly and through the mental rotation ability and the logical thinking ability indirectly. Mental rotation abilities affected scientific literacy both directly and through the logical thinking ability indirectly. Finally, the findings obtained from the study were compared with the research studies in the relevant field, and recommendations were presented for the researchers and practitioners of science education.

Keywords

Cognitive Individual Differences
Field-dependent/Field-independent Cognitive Styles
Logical Thinking Ability
Mental Capacity
Mental Rotation Ability
Scientific Literacy
Structural Equation Modeling

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Introduction

It has been one of the main goals of science education for many years to be able to educate students as scientifically literate individuals (Milli Eğitim Bakanlığı [MEB], 2006, 2013, 2017; National Research Council, 1996, 2012; Osborne, 2007). Raising scientifically literate individuals is of importance both to the society and to the individual himself/herself, however, fulfilling this aim is quite challenging (Laugksch, 2000). Fulfilling the scientific literacy vision gets difficult due to the structure of the scientific literacy with multiple components, instruction and measurement-evaluation approaches used in courses, individual differences between teachers and students and the interaction of these variables with each other (Lipuma, 2008). Therefore, researching on the relationships and interactions between individual differences which are thought to have effect on the development of scientific literacy levels of the societies has importance to the science education.

It is important that program developers and teachers know individual differences of students so that they can plan an effective teaching–learning process (Kubat, 2018). Therefore, individual differences and the impact of such differences on the educational process are one of the topics broadly researched in educational research in recent years.

Individual differences can occur in cognitive, affective and psychomotor dimensions. In this study, how students' individual cognitive differences affect their scientific literacy was investigated. To that end, in order to identify the individual differences in the cognitive dimension that are likely to influence this process, the research studies carried out in the field of science education between 1975 and 2017 were listed by searching the "science achievement" and "individual difference" keywords in the ERIC and Web of Science databases. Based on the search, it was seen that 31% of the research on individual differences in the cognitive dimension were about the logical thinking ability, 27% about cognitive styles, 22% about mental capacity (working memory capacity), 8% about spatial ability, 6% about fluent and crystallized intelligence, 5% about the locus of control, and 1% were about creativity. In the light of these results, how certain cognitive variables affect students' scientific literacy was addressed. These cognitive variables, namely, are the logical thinking ability, cognitive styles, mental capacity and spatial ability that are frequently discussed in the literature and also have causal and correlation relationships with each other.

One of the variables most researched among individual differences in the cognitive dimension is the logical thinking ability (Ersanlı, Gencoglu, & Duran, 2018). The logical thinking ability is addressed within the framework of Theory of Cognitive Development by Piaget. The most widely researched dimension of the theory in terms of the level of students who constitute the sample of this study is the characteristics of the stage of concrete and formal operations and how they relate to science achievement (Ateş & Çataloğlu, 2007; Lawson, 1982; Özarslan & Bilgin, 2016; Vadapally, 2014; Valanides, 1996). The logical thinking abilities which students are supposed to have in the abstract operations stage and the development of these abilities are placed at the center of the research on science education. Research conducted in this field indicates that this ability is one of the most crucial predictors of the success in science (Cheng, She, & Huang, 2018; Lawson, 1992a, 1992b; Shayer & Adey, 1992; Vadapally, 2014; Yüksel & Ateş, 2017). Research in this field shows that logical thinking abilities are one of the most important predictors of science achievement (Araz & Sungur, 2007; Lawson, 1985; Shayer & Adey, 1992, 1993; Stender, Schwichow, Zimmerman, & Härtig, 2018; Vadapally, 2014).

Even if several aspects of the Theory of Cognitive Development by Piaget are well-acknowledged, there are certain points which are criticized in the theory. One of the key criticisms on the theory is that individual differences are not taken into consideration as individuals are defined as 'epistemic subjects'. Pascual-Leone is a scientist associated with the neo-Piagetian group of scientists accepting the assumptions of the theory as a basis and trying to respond to the criticisms. He has developed the Theory of Constructive Operators (TCO). In the theory, a particular emphasis is placed on a different variable which is likely to affect the logical thinking ability that is a significant variable to predict the success in science. Pascual-Leone states that mental capacity is a significant variable affecting the student success (Pascual-Leone & Goodman, 1979). There are several studies which explain the effect of mental capacity on the success in science (Pascual-Leone & Johnson, 2005, 2011; Tsaparlis, 2005; Stamovlasis, 2010). The mental capacity refers to a limited resource which enables the activation of schemes in the mind in relation to the activity. This capacity both grows along with age and differs across individuals of the same age (Pascual-Leone & Johnson, 2005, 2011). Theoretically, this capacity which individuals have is called as structural mental capacity, however, this capacity is affected by various motivational factors and cognitive factors such as cognitive styles and cannot be fully utilized during cognitive tasks. The form of structural mental capacity which can be utilized as a consequence of the effect of these factors is called as functional mental capacity (Pascual-Leone, 1970). Functional mental capacity can be minimum zero and can reach the value of the structural mental capacity at most (Niaz, 1992).

Cognitive styles are one of the variables which affect the structural mental capacity usage of individuals (Niaz, 1992; Pascual-Leone, 1970). It is asserted that cognitive styles exist within the foundation of all activities performed by individuals and thus affect their orientations (Witkin, Moore, Goodenough, & Cox, 1977). According to Morgan (1997), cognitive styles are a characteristic property that an individual uses to obtain or learn information. Even if there are several categorizations in the literature on cognitive styles, the most acknowledged categorization is the one which groups cognitive styles as the field-dependent and field-independent (Witkin et al., 1977). Field-dependent individuals are affected by external stimuli in analyzing the complex structure of the field and in finding a specific element in a complex whole and extracting it from this complex whole while field-independent individuals are more under the influence of internal stimuli (Jonassen & Grabowski, 1993). In previous research conducted in relation to cognitive styles of field dependence/field independence, it is asserted that this structure is one of the key predictors of academic achievement, and field-independent individuals are more successful than field-dependent individuals (Terrell, 2002; Tinajero & Paramo, 1998). Similar results are obtained also in studies performed on science education (Ateş & Çataloğlu, 2007; Çataloğlu & Ateş, 2014; Idika, 2017; Morris, Farran, & Dumontheil, 2019; Özarslan & Bilgin, 2016). When the research on the relevant literature is examined, it is seen that field-dependent/field-independent cognitive styles are related significantly not only to students' science achievement, but also to their logical thinking abilities, functional mental capacities and spatial abilities (Ahmar, Rahman, & Mulbar, 2018; Hindal, Reid, & Badgaish, 2009; Schmidt & Scerbo, 2004; Stamovlasis & Papageorgiou, 2012; Stamovlasis, 2010; Yazıcı, 2014).

Another cognitive individual difference which is commonly studied is the spatial ability (Harle & Towns, 2011). This ability is one of the key predictors of student success in science courses (Ganley, Vasilyeva, & Dulaney, 2014). Mental rotation ability is one of the components of the spatial ability and a variable which is significant to the student success in the fields of science, technology, engineering and mathematics (Castro-Alonso & Uttal, 2019; Harle & Towns, 2011; Langlois, Bellemare, Toulouse, & Wells, 2019; Uttal & Cohen, 2012; Peters, Lehmann, Takahira, Takeuchi, & Jordan, 2006; Wai, Lubinski, & Benbow, 2009). When the research in this field is examined, studies indicate that the mental rotation ability is a significant predictor of not only science achievement but also of logical thinking abilities of students, and that it has a significant and positive correlation with the mental capacity and cognitive styles variables (Hacıömeroğlu & Hacıömeroğlu, 2017; Idris, 1998; Schmidt & Scerbo, 2004). It is seen in a number of research studies that spatial abilities of individuals are also considered as a function of the working memory capacity (Hegarty & Waller, 2006; Miyake, Friedman, Rettinger, Shah, & Hegarty, 2001). Considering that the mental capacity that is addressed in this study is a component of the working memory, it is predicted that the causal relationship between the working memory and the spatial ability will also be seen between the mental capacity and the spatial ability. It has also been demonstrated by research how the structure of cognitive styles influencing the activities of individuals in all areas affects the spatial ability.

As mentioned above, there are several studies in the field of science education examining the relationships between individual differences and science achievement. In these studies, science achievement is usually defined as the measurement of the ability to solve classical science problems at the end of a chapter or a unit, related to the subjects in science courses. When the literature on individual differences such as the logical thinking ability, mental capacity, field-dependent/field-independent cognitive styles, and mental rotation ability is examined, it is seen that there is a positive correlation between these variables and the science achievement defined in the specified structure. It is also seen that these variables are essential variables that predict science achievement. But today, it is suggested that students' science achievement should be measured not only as problem-solving skills, but also in terms of scientific literacy or the components of scientific literacy, and the relationships mentioned should be reinterpreted (Ateş & Çataloğlu, 2007; Lawson et al., 2000; Sencar & Eryılmaz, 2004). There is a very limited number of research studies in the literature that examine the possible relationships between the science achievement that is defined as scientific literacy and the specified cognitive variables. Moreover, no study could be found in the literature that systematically reviewed, through a model, the possible direct and indirect relations between scientific literacy and the specified cognitive individual differences. Yet, scientific literacy is the main goal of contemporary education (Laugksch, 2000). Students' being raised as scientifically literate individuals is a common emphasis made by science education reforms in many countries (Liu, 2009). For this reason, it is seen that there is a need for studies where the relationships between the specified individual differences and science achievement are reexamined in terms of the scientific literacy dimension. In this study, as defined in the study of Fives, Huebner, Birnbaum, and Nicolich (2014), science achievement was defined as individuals' being knowledgeable about the nature and processes of any field of science and, in this way, their ability to use science in daily lives pragmatically and in a meaningful way. According to this definition, scientific literacy is quite different from the problem-solving skills that require mathematical calculations. In this study, it was aimed to put forward the possible relationships between the individual differences in the cognitive dimension which have been specified to have a significant relationship with science achievement and students' science achievement levels that are defined as scientific literacy through a theoretical model, and to test this model using a powerful statistical method (SEM). Figure 1 shows the proposed model. All the directional relationships in the proposed model were created based on earlier research results.

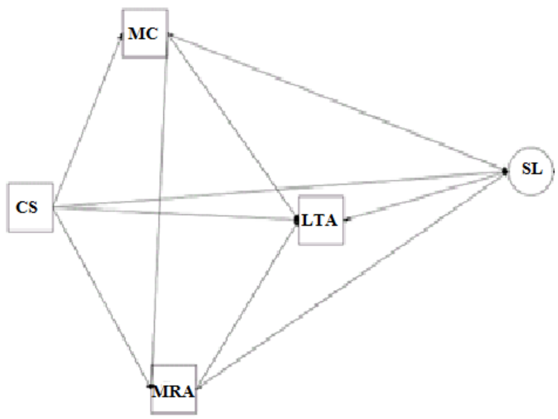

Figure 1. The Theoretical Model on the Relationships between Scientific Literacy (SL), Logical Thinking Ability (LTA), Cognitive Styles (CS), Mental Capacity (MC) and Mental Rotation Ability (MRA)

The research questions established for the purpose of the study are listed below.

1: Does the logical thinking ability of students have a statistically significant predictive effect on scientific literacy scores?

2: Does the field-dependent/field-independent cognitive styles of students have a statistically significant predictive effect on scientific literacy scores?

3: Does the mental capacities of students have a statistically significant predictive effect on scientific literacy scores?

4: Does the mental rotation abilities of students have a statistically significant predictive effect on scientific literacy scores?

5: Does the field-dependent/field-independent cognitive styles of students have a statistically significant predictive effect on their logical thinking ability?

6: Does the mental capacities of students have a statistically significant predictive effect on their logical thinking ability?

7: Does the mental rotation abilities of students have a statistically significant predictive effect on their logical thinking ability?

8: Does the field-dependent/field-independent cognitive styles of students have a statistically significant predictive effect on their mental capacities?

9: Does the field-dependent/field-independent cognitive styles of students have a statistically significant predictive effect on their mental rotation abilities?

10: Does the mental capacities of students have a statistically significant predictive effect on their mental rotation abilities?

Method

Research Design and Sample

Because structural equation modeling (SEM) is a multivariate statistical method based on the definition of observable and latent variables in a causal and relational model, as well as being a model to analyze direct and indirect relationships between variables (Byrne, 2010), this study was based on a causal-comparative research model. This model is also frequently used in studies on individual differences. This is because it is one of the recommended models for identifying the causes or consequences of previously existing differences between groups formed by individuals or between individuals (Fraenkel, Wallen, & Hyun, 2012).

This study was based on a causal-comparative research model. The research population was determined to be approximately 49,867 seventh-grade students studying at schools in the central districts of Ankara province. The sample of the study consisted of 823 seventh-grade students selected using the stratified random sampling method. The sample of the study was selected by using the stratified random sampling method. In this method, the population is divided into subunits that will represent itself. Next, elements are sampled from each of these subunits. The elements in the subunits are sampled in direct proportion to the ratio of subunits to the total population (Fraenkel et al., 2012). In this study, the central districts of Ankara were selected as the subunits of the population. By considering the proportions of the numbers of students in the central districts of Ankara, the number of students to be included in the sampling from each central district was determined. Based on the calculations made, it was decided to include approximately 1000 students in the sample consisting of 90–100 students from the secondary schools in Altındağ district, 120–130 from Çankaya district, 80–90 from Etimesgut district, 190–200 from Keçiören district, 120–130 from Mamak district, 70–80 from Pursaklar district, and 120–130 from Yenimahalle district. The schools where the implementation would be carried out were determined by drawing lots from the list of public secondary schools in the central districts of Ankara. In this study, data were collected from approximately 1000 students, but as a result of the analysis carried out to test the assumptions of SEM and to identify missing data in the data set, a total of 823 students were included in the data set.

The students in the sample consisted of 446 females and 377 males. According to Fowler's (2009) calculation method, the ratio of the sample to the population should be minimum 0.01. The value for this study is 0.02 (as cited in Creswell & Creswell, 2017, p.159).

Instruments

Scientific Literacy Assesment (SLA)

In this study, a measurement instrument developed by Fives et al. (2014) was used to identify the level of scientific literacy of students. This measurement instrument was preferred both because it was for secondary school students and because it consisted of questions that did not require content knowledge, and it was compatible with the population and purpose of the research. This measurement instrument consisted of a one-factor Demonstrated Scientific Literacy Assessment (SLA-D) and a three-factor Motivation and Beliefs Scale (SLA-MB).

SLA-D is a single-factor measurement instrument consisting of multiple-choice questions that include the role of science, scientific thinking and doing, science and society, science media literacy, and mathematics in science dimensions. SLA-D was adapted to Turkish by the researchers (Şahin & Ateş, 2018). The fit indices of the final version of the test were examined using the Confirmatory Factor Analysis (CFA) carried out during the adaptation study. The Chi-squared value ($\chi2$=178.41, N=823, SD=135, p=.00) was found to be statistically significant based on the analysis that was carried out. In addition to that, the following values were obtained: ($\chi2$/SD)=1.32, RMSEA=.02, CFI=.97, TLI=.96, WRMR=.94. These values revealed that the data fitted well to the model (Hu & Bentler, 1999; Kline, 2005; Schermelleh-Engel, Moosbrugger, & Müller, 2003; Yu, 2002). The KR-20 reliability coefficient of the test was found to be .66.

Group Test of Logical Thinking (GTLT)

In this study, the Group Test of Logical Thinking developed by Tobin and Capie (1981) was used to measure the logical thinking abilities of the students who were in the 11–18 age range. The test was adapted to Turkish by Geban, Askar, and Özkan (1992), and the reliability coefficient of the test was reported as .77. The test consisted of 10 questions. The first eight questions included 2 stages. The first stage was composed of multiple-choice questions, and in the second stage, the reason of the answer given in the first stage was asked. In these eight questions, the student who responded correctly to both the question and the reason of the answer was given a point. The last two questions of the test consisted of open-ended questions, each with one point. A maximum of 10 points could be taken from the test. The CFA analysis to test the construct validity of the test using the data collected in this study showed that the Chi-squared value ($\chi2$=43.55, N=790, SD=31, p=.00) was statistically significant. In addition to that, the following values were obtained: ($\chi2$/SD)=1.40, RMSEA=.02, CFI=.99, TLI=.98, WRMR=.77. These values revealed that the data fitted well to the model. The KR-20 reliability coefficient of the test was found to be .63.

Group Embedded Figures Test (GEFT)

In this study, the Group Embedded Figures test was used to determine the field-dependent/field-independent cognitive styles of the students (Witkin, Oltman, Raskin, & Karp, 1971). This test is one of the most commonly used tests in this field. The test consisted of 3 sections. The first section consisted of seven questions, and the other two sections, nine questions. The first section of the test had to be completed in 2 minutes. The other two sections had to be completed in 5 minutes. The first section consisted of questions that targeted to have students do practice exercises. Only the points received from the questions in the second and third sections were included in the total score. A maximum of 18 points could be taken from the test. The test was adapted to Turkish by Çakan (2003), and its reliability coefficient was reported as .82. The CFA analysis to test the construct validity of the test using the data collected in this study showed that the Chi-squared value ($\chi2$=396.83, N=804, SD=135, p=.00) was statistically significant. In addition to that, the following values were obtained: ($\chi2$/SD)=2.93, RMSEA=.05, CFI=.98, TLI=.97, WRMR=1.28. These values revealed that the data fitted well to the model. The KR-20 reliability coefficient of the test was found to be .89.

Figural Intersections Test (FIT)

In this study, the Figural Intersections Test developed by Pascual-Leone and Burtis was used to determine the functional mental capacity of the students (Pascual-Leone & Johnson, 2011). The test consisted of 36 questions. On the right side of each question, there were a number of geometric shapes, and on the left side, there was a complex shape formed by overlapping of these geometric shapes. For each question, students were expected to mark the geometric intersection areas on the right side, from within the complex shape on the left side. A maximum of 36 points could be taken from the test. The test was adapted to Turkish by the researchers. The fit indices of the final version of the test were examined using the CFA during the adaptation study. The Chi-squared value ($\chi 2$=1099.38, N=785, SD=594, p=.00) was found to be statistically significant based on the analysis that was carried out. In addition to that, the following values were obtained: ($\chi 2$/SD)=1.85, RMSEA=.03, CFI=.94, TLI=.94, WRMR=1.34. These values revealed that the data fitted well to the model. The KR-20 reliability coefficient of the test was found to be .89.

Mental Rotation Ability Test (MRAT)

In this study, the basic type of the Mental Rotation Ability test developed by Peters et al. (1995) was used to determine the ability of the students to rotate things in their minds, which is a dimension of their spatial abilities. The test consisted of 24 questions. In each question, two of the four options were correct. The total score to be taken from the test was 48. In each of the questions in the test, it was asked to find the appearance from different angles of the new version of a shape created using units of cubes when the shape was rotated at different angles. The test was adapted to Turkish by Yıldız and Tüzün (2011), and its reliability coefficient was reported as .71. The CFA analysis to test the construct validity of the test using the data collected in this study showed that the Chi-squared value ($\chi 2$=482.69, N=759, SD=252, p=.00) was statistically significant. In addition to that, the following values were obtained: ($\chi 2$/SD)=1.91, RMSEA=.04, CFI=.91, TLI=.90, WRMR=1.15. These values revealed that the data fitted well to the model. The KR-20 reliability coefficient of the test was found to be .77.

Procedure

The data collection process of the study took place during the spring semester of the 2015–2016 school year. After the necessary permissions had been obtained, a detailed planning was made since five measurement instruments would be used in the study.

Certain issues were taken into consideration during the planning. The first of these was that the implementation period of 5 measurement instruments in a school was planned to be 2 weeks in total. This arrangement was made to prevent test fatigue that may occur in students. The second issue was to make sure that the implementation in each school was completed within 2 weeks. The purpose of this arrangement was to minimize performance differences that could arise from seasonal changes throughout the implementation. The third issue was that the planning was carried out by taking into account the exam schedules of the students. The implementation was carried out in weeks outside of the students' exam weeks. This arrangement was made to prevent performance differences that could arise from exam stress in the students. The fourth issue was related to the time of completion of the implementation. The data collection process was planned to last a total of 2.5 months and end at the end of May. This arrangement was intended to prevent the decrease in the students' motivations from reflecting on the test performance due to the warming of the weather and end-of-term fatigue. The final issue that was taken into account during the planning was to avoid doing implementation during the Physical Education lessons. The reason for this arrangement was to try to prevent the negative attitude that may result from the use of this course, which students love very much, from being used for different purposes, to affect student test performance. After the planning made taking into account the specified issues, the implementation was carried out by going to the schools at the specified times. Before starting the implementation, all participants were informed about the purpose and importance of the study, and they were given the necessary information about the implementation. They were also told that the data obtained from them would not be used anywhere other than the research and that the scores that they would receive as a result of the research would not affect their course grades. During the implementation, the participants were not forced, and only the volunteers were included in the implementation. During the implementation, the scales of the participants who did not wish to continue the implementation were deemed invalid.

After the data collection process, the tests were coded by the researchers, and the scores were entered into the computer environment.

In this study, a number of measures were taken to prevent the internal validity threats that could occur during both data collection and analysis of data (participant characteristics, loss of participants, location, instrumentation, scoring, implementation time, maturation, participant attitude, regression and implementation). This study was conducted only on the seventh-grade students studying in public schools in the central districts of Ankara, and thus, attempts were made to control the characteristics of the participants (age and socio-economic level) and the threats related to the location. In order to avoid the threat of participant loss, the implementation was carried out by reaching a larger sample. The multiple imputation technique, which is a type of regression test, was used as a technique for the assignment of missing data. The implementation time threat was one of the most important threats in this study. To eliminate the threats of implementation time and maturation, the implementation in each school was planned to be completed in 2 weeks. In this way, the data collection process took a total of 2.5 months. For the same purpose, the implementation was not carried out during the students' exams and during the hours of their physical education classes. The tests used in the study were administered in the same order in all schools. The SLA-D test, which was the dependent variable of the study, was administered on the first day in all schools. Before the tests were administered, the researchers informed the students about the purpose, importance, benefits of the study for the community and for the students. The researchers paid attention to have the same attitude in all classes where data were collected. After the data collection process, the tests were scored using pre-made answer keys. In this way, the threat of instrumentation, the threat of scoring, and the threat of participant attitude were tried to be avoided.

Data Analysis

The analysis of the data consists of three main parts. These are the pre-data analysis, the descriptive analysis, and the measurement and testing of the structural model using structural equation modeling techniques.

In this study, the variables of the study were coded appropriately during the data analysis process. At this stage, correct responses were coded 1, and incorrect responses were coded 0 in the scientific literacy, cognitive styles, mental capacity, and logical thinking ability tests. In the mental rotation test, each response was scored between 0 and 2 as the minimum and maximum scores. SPSS 23 package program was used to determine mean, mode, minimum and maximum values, standard deviations, and the frequency and percentages of responses to each item in each data sets. The SPSS 23 package program was also used to check for incorrect data entries and outlier values in the data sets for each test, to examine whether variables were normally distributed, and to find the Cronbach α reliability coefficients of the tests. In the study, the measurement and structural models were tested using the Mplus 7.0 program

Effect Size and Power

Kline's (2005) classification was used in this study to assess the value of the f^2 index showing the effect size of the rates of the explained variance for each endogenous variable and the effect sizes related to the size of the standardized regression coefficients. These results are presented in the Results section.

Moreover, in this study, the approach proposed by Saris and Satorra (1993) was used to calculate the power of the theoretical model (as cited in Schumacker & Lomax, 2010, p. 94). Accordingly, the noncentrality parameter (NCP= $\chi^2 - df$model) value was calculated and power of the hypothesis test for the model was analyzed by using the G*Power 3 program. The power value obtained as a result of the analyses was approximately 0.99. This result shows that the power of the hypothesis test was quite high.

Results

Preliminary Data Analysis

During the preliminary data analysis, data were analyzed for missing values. The multiple imputation technique was used for the assignment of missing data. After this stage, a univariate and multivariate outlier analysis was carried out. For the univariate outlier analysis, the total scores that the students received from the tests were converted to Z scores. A total of 19 participantswhose score range was outside of the +3.29 and-3.29 range were removed from the data set. For the multivariate outlier analysis, the mahalanobis distance (m_i^2) was calculated, and $\chi^2_{p(0,001)}$ value was found for the α = 0.001 significance level; observations with a m_i^2 value greater than this value were considered as multivariate outliers (Alpar, 2013, p. 132). As a result of this analysis, 1 participant identified as an outlier was removed from the data set. Additionally, the normality assumptions of the continuous variables were tested. To that end, the skewness and kurtosis coefficients of all continuous variables were calculated. As a result of the analyses, these coefficients were found to be in the range of +1 to -1 and were considered to meet the assumptions of normal distribution. In order to investigate linearity and homoscedasticity between pairs of variables, scatter plots were examined, and the plots were found to be oval (Tabachnick & Fidell, 2015, p. 83). The correlation coefficients between variables were calculated to investigate the multi-collinearity problem. These correlation coefficient values were observed to be in the range of .60 to .01. Since the resulting values were smaller than .80, it was concluded that there was no multi-collinearity problem (Kline, 2005). Kline (2005) has stated that the sample size between 10 and 20 times the number of free parameters is sufficient in order to be able to carry out analyses in SEM studies. The number of free parameters in this study was 55. It is seen that a sufficient sample size was achieved when it is considered that the sample of the study was composed of 823 people.

Descriptive Analysis

Table 1 shows the descriptive statistics of the scores received from the tests used in the study. Descriptive analyses were carried out using the SPSS 23 package program. When the skewness and kurtosis coefficients of the distribution of the total scores were examined, it was seen that these coefficients fell within the boundaries of ±1, and that the total scores were not excessively deviated from the normal distribution (Mertler & Vannatta, 2016).

Table 1. Descriptive Statistics of the Scores Received from the Tests

Variable	Group	n	Min	Max	Mean	Std.Dev	Skewness	Curtosis
SLA-D	Total	823	1	17	8.23	3.31	0.16	-0.60
	Girl	445	2	17	9.01	3.21	0.13	0.23
	Boy	377	1	17	8.05	3.36	0.27	-0.61
GTLT	Total	823	0	10	5.43	2.23	0.13	-0.59
	Girl	445	1	10	5.50	2.21	0.11	-0.51
	Boy	377	0	10	5.33	2.25	0.16	0.25
GEFT	Total	823	0	18	7.78	4.93	0.22	-0.98
	Girl	445	0	18	8.07	4.91	0.14	-0.97
	Boy	377	0	18	7.41	4.93	0.34	0.25
FIT	Total	823	0	34	19.77	6.17	-0.34	-0.09
	Girl	445	0	34	19.49	6.43	-0.37	0.01
	Boy	377	1	32	20.06	5.81	-0.29	-0.38
MRAT	Total	823	14	44	27.21	5.15	0.89	0.85
	Girl	445	14	44	26.85	4.67	0.95	1.45
	Boy	377	15	44	27.67	5.61	0.81	0.25

In this study, all variables other than the scientific literacy were considered as the observed variable. Correlation coefficients between variables were calculated to make a preliminary assessment of the complex relationship between the variables. Correlation values of the variables in the model are shown in Table 2.

Table 2. Pearson Correlation Coefficients Among Variables (n= 823)

	SL	LTA	CS	MC	MRA
SL	1				
LTA	0.58**	1			
CS	0.46**	0.49**	1		
MC	0.40**	0.46**	0.56**	1	
MRA	0.32**	0.32**	0.40**	0.41**	1

**p≤0.01

When Table 2 is examined, it is seen that all variables have a moderately positive and statistically significant relationship among themselves.

Testing of the Model

The Multiple Indicators and Multiple Causes (MIMIC) model approach, which is a type of structural equation modeling, suggests that the process of testing a theoretical model should be started by testing the measurement model. Therefore, the structural model was tested after the measurement model was tested.

Testing of the Measurement Model

The analysis of the measurement model of this study included the analysis of SLA-D, which was the only latent variable in the model as well as the dependent variable of the model. The KR-20 reliability coefficient of the SLA-D, consisting of 18 multiple-choice questions, was calculated, and it was found to be .66. The construct validity of the scale was examined through CFA by using the Mplus program. The Chi-squared value ($\chi 2$=178.41, N=823, SD=135, p=.00) was found to be statistically significant based on the analysis that was carried out. In addition to that, the following values were obtained: ($\chi 2$/SD)=1.32, RMSEA=.02, CFI=.97, TLI=.96, WRMR=.94. These values revealed that the data fitted well to the model. In addition to the goodness of fit criteria, the path coefficient of each question was found to be statistically significant. The path diagram is shown in Figure 2.

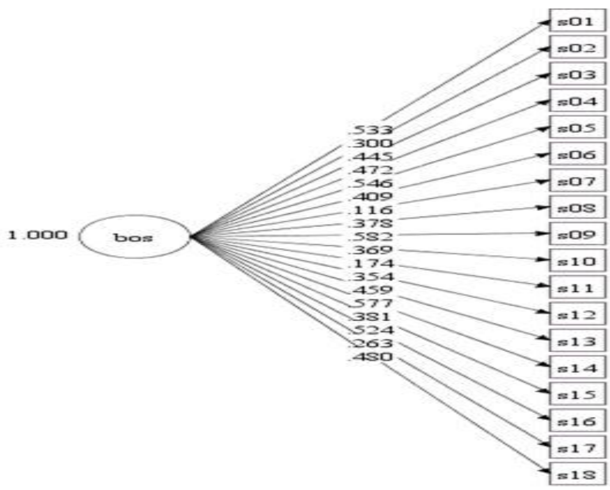

Figure 2. SLA-D Confirmatory Factor Analysis (Standardized Regression Coefficients)

Testing of the Structural Model

The structural model was tested using the Mplus program.

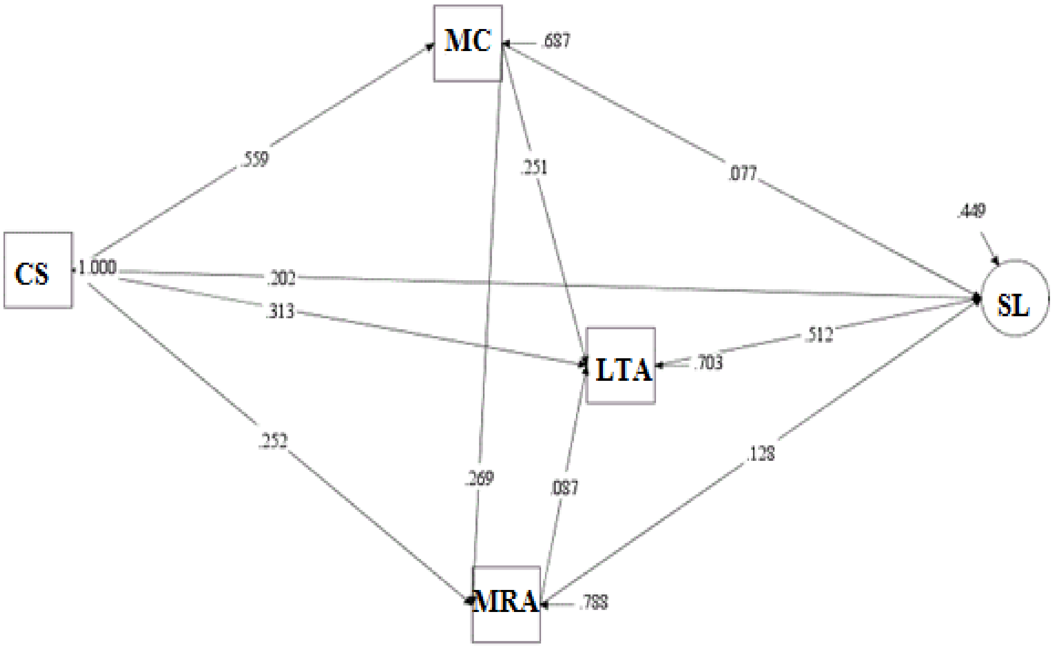

Figure 3. Structural Model

The fit indices as a result of the analyses are shown in the table below.

Table 3. Recommended Model Fit Indices for Seventh-Grade Students' Scientific Literacy Levels

Fit Index	Good Fit	Acceptable Fit	Fit Values Obtained in the Study
p value	.05 ≤ p ≤ 1	.01 ≤ p ≤ .05	0.00
$\chi 2$/sd	0 ≤ χ2/sd ≤ 2	2 ≤ χ2/sd ≤ 5	1.38
RMSEA*	0 ≤ RMSEA ≤ .05	.05 ≤ RMSEA ≤ 1.00	.02
CFI	.95 ≤ CFI ≤ 1.00	.90 ≤ CFI ≤ .95	.97
TLI	.95 ≤ TLI ≤ 1.00	.90 ≤ TLI ≤ .95	.97
WRMR	WRMR ≤ .95	.95 ≤ WRMR ≤ 1.00	.93

* RMSEA value is between 0.015 and 0.027 in the 90% confidence interval.

Considering the values obtained from the fit indices, it can be said that the data fitted well to the model (Hu & Bentler, 1999; Wheaton, Muthen, Alwin, & Summers, 1977; Kline, 2005; Schermelleh-Engel et al., 2003; Yu, 2002). However, this alone is not enough; the values of the path coefficients defined between the variables must be statistically significant. The results of the analysis carried out for this purpose are shown in Table 4. The research questions in this table are explained in previous sections.

Table 4. Unstandardized and Standardized Regression Coefficients of Model Parameters

Research Question	Parameter			Unstandardized Regression Coefficient	SE	Standardized Regression Coefficient
1	LTA	→	SL	0.12*	0.01	0.51
2	CS	→	SL	0.02*	0.00	0.20
3	MC	→	SL	0.01*	0.00	0.08
4	MRA	→	SL	0.01*	0.00	0.13
5	CS	→	LTA	0.14*	0.02	0.31
6	MC	→	LTA	0.09*	0.02	0.25
7	MRA	→	LTA	0.04*	0.01	0.09
8	CS	→	MC	0.70*	0.04	0.56
9	CS	→	MRA	0.26*	0.04	0.25
10	MC	→	MRA	0.23*	0.03	0.27

*$p \leq .05$

As shown in the table above, the predictive effect of the logical thinking ability on the level of scientific literacy ($\beta = .51$, $p \leq .05$), the predictive effect of cognitive styles on the level of scientific literacy ($\beta = .20$, $p \leq .05$), the predictive effect of mental capacity on the level of scientific literacy ($\beta = .08$, $p \leq .05$), and the predictive effect of mental rotation on the level of scientific literacy ($\beta = .13$, $p \leq .05$) were statistically significant. The predictive effect of cognitive styles on the logical thinking ability ($\beta = .34$, $p \leq .05$), the predictive effect of mental capacity on the logical thinking ability ($\beta = .25$, $p \leq .05$), and the predictive effect of mental rotation on the logical thinking ability ($\beta = .09$, $p \leq .05$) were also statistically significant. Moreover, the predictive effect of cognitive styles on mental capacity ($\beta = .56$, $p \leq .05$), the predictive effect of cognitive styles on the mental rotation ability ($\beta = .25$, $p \leq .05$), and the predictive effect of the mental capacity on the mental rotation ability ($\beta = .27$, $p \leq .05$) were also statistically significant.

In structural equation modeling studies, it is of importance to calculate indirect effects and the total effects formed by direct and indirect effects, in addition to direct effects. The total, indirect and direct effects in the model and the variance percentages explained by the other variables for predictive and mediator variables in the model are given in Table 5.

Table 5. Direct, Indirect, and Total Effects in the Model

Dependent Variables	Independent Variables	Standardized Regression Coefficients		
		Direct	Indirect	Total
Scientific Literacy (SL) (R^2= 0.55)	LTA	0.51*	-	0.51*
	CS	0.20*	0.35*	0.55*
	MRA	0.13*	0.04*	0.17*
	MC	0.08*	0.17*	0.25*
Logical Thinking Ability (LTA) (R^2=0.30)	CS	0.31 *	0.18*	0.49*
	MC	0.25*	0.03*	0.28*
	MRA	0.09*	-	0.09*
Mental Capacity (MC) (R^2=0.31)	CS	0.56*	-	0.56*
Mental Rotation Ability (MRA) (R^2=0.21)	CS	0.25*	0.15*	0.40*
	MC	0.27*	-	0.27*

*$p \leq 0.05$

As shown in the table above, the direct effect of logical thinking ability on the scientific literacy (β=.51, p≤.05), the direct effect of cognitive styles on the scientific literacy (β=.20, p≤.05), the direct effect of mental capacity on the scientific literacy (β=.08, p≤.05), and the direct effect of mental rotation ability on the scientific literacy (β=.13, p≤.05) were statistically significant. The direct effect of cognitive styles on the logical thinking ability (β=.34, p≤.05), the direct effect of mental capacity on the logical thinking ability (β=.25, p≤.05), and the direct effect of mental rotation ability on the logical thinking ability (β=.09, p≤.05) were also statistically significant. Moreover, the direct effect of cognitive styles on the mental capacity (β=.56, p≤.05), the direct effect of cognitive styles on the mental rotation ability (β=.25, p≤.05), and the direct effect of the mental capacity on the mental rotation ability (β=.27, p≤.05) were also statistically significant.

As seen in the table, 4 variables that are thought to affect scientific literacy explained 55% of the variance in scientific literacy. When the total (direct and indirect) effects of the variables on the scientific literacy were examined in terms of effect sizes, it was seen that the logical thinking ability (β=.51) and cognitive styles (β=.55) had a great effect, and the mental capacity (β=.25) and the mental rotation ability (β=.17) had a moderate effect. It was seen that the indirect effect of cognitive styles on scientific literacy was moderate (β=.35) (Kline, 2005). A total of 3 variables that affected the logical thinking ability in the model described 30% of the variance in the logical thinking ability. When the variables were assessed in terms of the total effects that they had caused, the effects caused by all variables were statistically significant. When the total effects of the variables on the logical thinking ability were examined in terms of effect sizes, it was seen that the cognitive styles had a major effect (β=.49), that the mental capacity had a moderate effect (β=.28), and that the mental rotation ability had a minor effect (β=.09) (Kline, 2005). The cognitive styles that affected the mental capacity variable in the model explained31% of the variance in the mental capacity. The total effect this variable caused (β=.57) was at a level of major effect. The cognitive styles and mental capacity that affected the mental rotation ability in the model could explain 21% of the variance in the mental rotation ability. When the variables were assessed in terms of the total effects that they had caused, the effects caused by all variables were statistically significant. When the total effects of the variables on the mental rotation ability in terms of effect sizes were examined, it was seen that the cognitive styles (β=.40) and the mental capacity (β=.27) had a moderate effect (Kline, 2005).

Effect Size

In this study, the values of the f^2 index showing the effect size of the rates of the explained variance for each endogenous variable and the category of this effect size are shown in Table 6.

Table 6. Effect Sizes of the Structural Equations in the Model

Structural Equation	R^2	f^2	Category of the Effect Size
SL	0.55	1.22	Large
LTA	0.30	0.43	Large
MC	0.31	0.45	Large
MRA	0.21	0.27	Moderate

As shown in Table 6, the structural equations describing the students' scientific literacy (R^2 = .55, f^2 = 1.22), logical thinking abilities (R^2 = .30, f^2 = 0.43) and mental capacities (R^2 = .31, f^2 = 0.45) fell into the large effect category, whereas the structural equations describing their mental rotation abilities (R^2 = .21, f^2 = 0.27) fell into the moderate effect category.

Discussion

Unlike in previous studies, in this study, an analysis technique was used in which indirect relationships between variables could be examined in addition to direct relationships. Upon taking the total effects into consideration, it was found that cognitive styles of field dependence/field independence were the variable with the highest power to predict students' scientific literacy levels, logical thinking abilities, mental capacities and mental rotation abilities. These findings have parallels with results of other research conducted on cognitive styles in the field of science education. In previous studies, it is noted that field-independent individuals were more successful than field-dependent individuals even when the success in science was defined as the skill in solving classical science problems at the end of each chapter or unit (Ateş & Çataloğlu, 2007; Bahar & Hansell, 2000; Bahar, 2003; Çataloğlu & Ateş, 2014; Danili & Reid, 2006; Hindal et al., 2009; Karaçam & Ateş, 2010; Roth, 1990; Morris et al., 2019; Özarslan & Bilgin, 2016; Sarı, Altıparmak, & Ateş, 2013; Tsaparlis, 2005). In the context of variables which affect the scientific literacy level, this result supports the explanations by Witkin et al. (1977) that highlight that cognitive styles exist within the foundation of all activities performed by individuals and thus affect individuals' orientations. Previous research carried out in relation to this field identified this structure of cognitive styles with Information Processing Model, and asserted that cognitive styles were associated with the perception filter which was deemed as the beginning of information processing operation (Hindal et al., 2009). There was an increase in the students' scientific literacy performance as their field-independence levels increased in this study, as well. The GEFT used in the study is thought to measure an indicator of the extent to which students can find the stimulus (information) that is needed and desired for learning in an environment where there are too many and complex stimuli. In this test, independent students are performing better than field-dependent students. This feature, which is measured by the test, plays a critical role in the process of re-structuring information of individuals in the education and training process. For example, within the scientific process skills, which is one of the basic components of scientific literacy, the mental abilities that are easily used by individuals, who have an independent cognitive style are needed. These capabilities are used in the process of successfully identifying and controlling variables that are appropriate from multiple and complex independent variables. Likewise, similar characteristics are needed to identify the types of problems that can be solved through scientific research and to identify more reliable sources of information on social media. Perhaps, the most important thing is that the characteristic that is reported to be widely used by field-independent cognitive styles is needed in a crucial stage like finding and using the information that is really necessary for learning in complex contexts where many necessary and unnecessary stimuli are used in the instructional process.

It was also found in this study that cognitive styles were the strongest predictor of students' logical thinking abilities, mental capacities and mental rotation abilities. This result is consistent with both the explanations of the Theory of Constructivist Operators and the results of the studies that have been carried out. It has been revealed in other studies that there is a significant relationship between field-dependent/field-independent cognitive styles and students' logical thinking ability (Kwon & Lawson 2000; Kypraios, Papageorgiou, & Stamovlasis, 2014; Lawson, 1983; Niaz, 1989, 1996; Papageorgiou, Markos, & Zarkadis, 2016; Stamovlasis, 2010; Stamovlasis & Papageorgiou, 2012; Stamovlasis, Tsitsipis, & Papageorgiou, 2012; Tsitsipis, Stamovlasis, & Papageorgıou, 2010). Moreover, it has been stated that there are significant relationships between field dependent/field-independent cognitive styles and students mental capacities (Bahar & Hansell, 2000; Hindal et al., 2009; Johnstone & Al-Naeme, 1991; Kwon & Lawson 2000; Niaz, 1996; Roth, 1990; Tsaparlis, 2005; Stamovlasis, 2010) and their spatial abilities (Hindal et al., 2009; Idris, 1998; MacLeod, Jackson, & Palmer, 1986; Piburn, 1980; Schmidt & Scerbo, 2004). As per the Theory of Constructive Operators (TCO), individuals fail to use their mental capacities efficiently due to the effect of certain individual differences such as the cognitive styles (Pascual-Leone, 1970). In this respect, if a student is confronted with a complex problematic situation or context, information not essential to the solution of the problem occupies a part of the mental capacity and so a smaller capacity is left out for processing the information essential to the solution of the problem. In this situation, as field independent students are capable of easily differentiating information essential to the problem from unessential information, they have higher functional mental capacities left for use (Johnstone & Al-Naeme, 1991). In this study, the predictive effect of cognitive styles on the mental rotation ability was also found to be significant. This result is consistent with the results of previously conducted research (Hindal et al., 2009; Idris, 1998; MacLeod et al., 1986; Schmidt & Scerbo, 2004). In the previous research, it was elucidated that students employed holistic and analytical strategies while performing activities which required the mental rotation (Harle & Towns, 2011; Lohman, 1984; Janssen & Geiser, 2010). Individuals who generally use the holistic strategy perceive the object as a whole as they rotate it in mind. Individuals who utilize the analytical strategy try to rotate the object in parts. Previous research demonstrates that individuals who used the holistic strategy in mental rotation activities were faster whereas individuals who used the analytical strategy needed longer time for completing the rotation process due to concentrating on details in the environment (Hirnstein, Bayer, & Hausmann, 2009; Janssen & Geiser, 2010). It is thought that the mental rotation process will be completed sooner if an object is rotated in mind upon being dissociated from the environment (context) surrounding it and from the unessential environmental stimuli. That is why, it is considered that individuals' cognitive styles of field dependence/field independence will affect their achievements in mental rotation activities by shaping their strategy selections. Findings of this research are also in support of this explanation.

In the case of total effects, it was found in the study that the variable that ranked second in predicting the seventh-grade students' scientific literacy was the logical thinking ability. This result shows that the concept teaching dimension of scientific literacy can be supported as well as improving the scientific literacy of students when logical thinking abilities, which are some of the components of scientific literacy, are improved. It is something expected that the logical thinking ability (involving processes such as control and diagnosis of variables, and proportional, probabilistic, relational and combinational reasoning) is a variable that predicts scientific literacy (containing the dimensions: using scientific methods, the role of science, scientific thinking and doing, the relationships between science and society, and the use of mathematics in science) (Holbrook & Rannikmae, 2009). It is also thought that students should be able to use the reasoning processes defined within the context of logical thinking ability in the following processes: using scientific knowledge and scientific methods to cope with the problems faced in everyday life, to understand the role of science in deciding on any subject, to evaluate the validity of scientific reports, and to use mathematics in scientific thinking.

An examination of studies on the relationship between logical thinking ability and science achievement shows that there is a positive correlation between science achievement and logical thinking ability. The way in which the success in science is defined differs in these studies. In certain studies, it is discerned that the success in science is defined in terms of end-of-semester grades obtained from the science course (Mwamwenda, 1993) or accomplishments in science attained in exams organized at national level (Hinojosa, 2015; Vadapally, 2014; Valanides, 1996) or problem-solving skills in topics of science (Ateş & Çataloğlu, 2007; Cavallo, 1996; Cheng et al., 2018; Niaz ve Lawson, 1985; Niaz ve Robinson, 1992, 1993) or levels of conceptual comprehension (Ateş & Çataloğlu, 2007; Coletta & Phillips, 2005; Kwon & Lawson, 2000; Niaz & Robinson, 1992, 1993; Özarslan & Bilgin, 2016; Stender et al., 2018, Tekkaya & Yenilmez, 2006; Yenilmez, Sungur, & Tekkaya, 2006) or scientific process skills in science (Lawson, Nordland, & Devito, 1975; Tobin & Capie, 1982). Upon the examination of these studies, it is viewed that the logical thinking ability, cognitive styles and mental capacity differed on the basis of their powers to predict the success in science, and the logical thinking ability was in general one of the best predictors of success in science (Niaz & Robinson, 1992, 1993). It was identified that, if the success was defined as the problem-solving skill instead of the level of conceptual comprehension, the predictive power of the logical thinking ability would be higher (Cavallo, 1996; Lawson, 1983; Niaz & Robinson, 1992, 1993).

Even if the logical thinking ability is asserted in the literature to be the most powerful predictor variable, it is thought that there are some reasons for cognitive styles to be the most powerful predictor of scientific literacy in this study. One of them is that SEM (Structural Equation Modeling) techniques are different and powerful vis-à-vis other statistical techniques in certain respects. By enabling the interpretation of indirect effects as well as direct effects, SEM techniques differ from other statistical analysis techniques. As such that, considering only the direct effects in this study, it is seen that the strongest predictor of scientific literacy was logical thinking ability. However, through the SEM analyses, we were able to see the indirect effects in addition to the direct effects, so our results were differentiated. Based on that, it is seen that cognitive styles were the strongest variable predicting scientific literacy. In this research, the manner in which the success in science is defined can be another explanation for cognitive styles to be the most powerful predictor of the scientific literacy level. As mentioned above, if the success in science is defined as the problem-solving skill, it is discerned that the most powerful predictor of success is the logical thinking ability (Cheng et al., 2018; Cavallo, 1996; Lawson, 1983; Niaz & Robinson, 1993). In this study, as defined in the study of Fives et al. (2014), science achievement was defined as individuals' being knowledgeable about the nature and processes of any field of science and, in this way, their ability to use science in daily lives pragmatically and in a meaningful way. Upon the examination of this definition, it is discerned that the scientific literacy is quite different from the problem-solving skill. Both the statistical advantages of the SEM techniques and the definition of science achievement as scientific literacy caused the extent of power to which logical thinking ability predicts scientific literacy to rank second.

Considering the total effects, the functional mental capacity is ranked as the third most powerful predictor of the seventh-grade students' scientific literacy levels. This result displays the significance of functional mental capacity to students' achievements in scientific literacy. In TCO, it is emphasized that the mental capacity is a significant variable for student success (Pascual-Leone & Goodman, 1979). The results of this research study are consistent with the explanations of TCO as well as a number of other studies that have been carried out in this field (Boujaoude, Salloum, & El-Khalick, 2004; Hindal et al., 2009; Johnstone & Al-Naeme, 1991; Kwon & Lawson, 2000; Lawson, 1983; Niaz, 1988a, 1996; Roth, 1990; Tsaparlis, 2005; Stamovlasis, 2010; St Clair-Thompson & Botton, 2009). Upon the review of previous studies, it is discerned that students' mental capacities affect their achievements in science, logical thinking abilities and spatial ability performances. There are also certain studies arguing that the mental capacity has no positive effect on the success in science (BouJaoude et al., 2004; Chandran, Treagust, & Tobin, 1987). In previous studies, it is indicated that the predictive power of mental capacity generally had a greater effect on tests containing sophisticated questions or on open-ended questions demanding high mental capacity rather than simple questions requiring low mental capacity (Niaz, 1988a; Overton & Potter, 2011; Roth, 1990; St Clair-Thompson & Botton, 2009). The results of Boujaoude et al. (2004) and Chandran et al. (1987) contradict the relevant literature. Chandran et al. (1987) asserts that this situation was associated with the insufficient sample size whilst Boujaoude et al. (2004) states that it was associated with the fact that students were supposed to learn the sophisticated strategies for the solution of algorithmic problems as the exam system in the country required.

The functional mental capacity is also a predictor of students' logical thinking abilities and mental rotation abilities. Upon the review of literature on the mental rotation ability, it is discerned that there is a functional relationship between this ability and the working memory (Hegarty & Waller, 2006; Miyake et al., 2001). In this respect, if the individual has a large working memory, there will be more space in memory for processing and storing spatial data, and hence the individual with large working memory will also have a better spatial ability performance (Miyake et al., 2001). As the mental capacity was a component of the working memory (Pascual-Leone & Johnson, 2005, 2011), it was projected that the relationship between working memory and spatial ability would also exist between mental capacity and spatial ability. Results of this current research are supportive of this projection. The association observed in the research between the logical thinking and mental capacity is in conformity with the relevant literature (Boujaoude et al., 2004; Kwon & Lawson, 2000). It is thought that properties referred to in the definition of functional mental capacity are of importance so that a person can use reasoning based on likelihoods which are components of logical thinking ability, address the association between variables and reason by considering all combinations. When judged from this perspective, the result obtained through this current research is in compliance with the theoretical framework of these two structures.

In the TCO, it is asserted that the interference with individual's structural mental capacity is impossible, however, individual's functional mental capacity can be enlarged through strategies to be developed (Pascual-Leone, 1970). The first of these strategies is to reduce the mental capacity which is required by activities to be offered to students. Previous studies performed in this field indicate that student's performance went down as the mental capacity required by activities (sophistication of the activities) which were offered to the students increased, and the interference with the mental capacity necessary for performing the activity without modifying the logical structure of the activity improved student's performance (Lawson, 1983; Johnstone & El-Banna, 1986; Niaz, 1988a, 1988b; Niaz & Robinson, 1992; Tsaparlis, Kousathana, & Niaz, 1998; Tsaparlis & Angelopoulos, 2000; Boujaoude et al., 2004; Danili & Reid, 2006). Another strategy is to have interferences with variables of student motivation and cognitive styles which are asserted in the theory to affect the amount of the structural mental capacity to be used. In studies carried out in this context, it was observed that the effect of field dependence was reduced and hence there were increases in student achievements by virtue of the removal of the unnecessary information from activities performed during courses (Danili & Reid, 2006). It was also observed that, by virtue of starting the activities with questions requiring low mental capacity, the student motivation went up and, in parallel, student achievements were enhanced (Tsaparlis & Angelopoulos, 2000). Therefore, it is thought that creating more space in the functional mental capacity thanks to teachers knowing about the concept of functional mental capacity and by means of contexts and life-oriented phenomena cleaned from unnecessary information will contribute both directly and indirectly to the improvement of students' scientific literacy levels.

In this research, mental rotation ability is the least powerful variable to predict the seventh-grade students' scientific literacy levels when total effects are taken into consideration. The spatial ability is one of the significant predictors of the student success in the science course along with its frequent use in this course (Uttal & Cohen, 2012). In longitudinal studies performed in this field, it is discerned that the spatial ability performance of seventh-grade students is a statistically significant predictor of their educational and professional performances after 20 years (Shea, Lubinski, & Benbow, 2001). In the meta-analysis, compilations and national reports published in this field, it is commonly stressed that the spatial ability which is the variable with the greatest effect on the exceptional success in STEM fields is neglected, however, the number of individuals who will specialize in STEM fields in the future can be raised through a science curriculum which includes spatial thinking activities (The National Science Board, 2010, p. 9; Uttal, Miller, & Newcombe, 2013a; Wai et al., 2009). It is asserted that this practice will also contribute to the enhancement of the science and math literacy of individuals (Khine, 2016). In this study, the mental rotation ability, which is one of the most important components of spatial ability, was discussed. The mental rotation ability which represents individuals' ability to imagine how objects appear when they rotate the objects in the plane or depth in which the objects are located is used in many activities in daily life. In addition to that, it is necessary to actively use this ability in many subjects that are covered within science courses. Indeed, many studies that have been carried out in this field have revealed the relationship of this ability with science achievement (Castro-Alonso & Uttal, 2019; Ganley et al., 2014; Kozhevnikov, Motes, & Hegarty, 2007; Langlois et al., 2019). The results obtained from this current research are compatible with the relevant literature. Individuals with high spatial ability are people with the ability to discern interdisciplinary relationships between different branches of science more easily as well as being successful in the solution of problems in STEM fields (Gardner, 1983). As is seen, it is important to improve this ability in terms of accomplishing achievement in the fields into which STEM practices are integrated. In conclusion, in order to successfully integrate STEM practices which have begun to become one of the fundamental components of scientific literacy into science education, it is considered that the mental rotation ability will occupy a significant place in this field.

Students' mental rotation abilities predict not only their scientific literacy but also their logical thinking abilities. As per the relevant literature, it is discerned that there was a statistically significant relationship between students' spatial ability performances and scores obtained by them from the logical thinking ability tests (Hacıömeroğlu & Hacıömeroğlu, 2017; Jiang, 2008; Kayhan, 2005; Tai, Yu, Lai, & Lin, 2003). It is ascertained that the result of the current research is compatible with the relevant literature. This result demonstrates that individuals who are capable of manipulating visual objects easily by keeping them in their minds will obtain higher scores in activities which require them to reason about both concrete and abstract cases.

Conclusion and Suggestions

In this study, a model has been established, demonstrating the effects of the individual differences in the cognitive dimension of the seventh-grade students both on scientific literacy and on each other. According to the results of the study, considering the total effects caused by the cognitive style tendencies of people on scientific literacy as well as on cognitive variables, it can be said that students' cognitive style characteristics are a variable that should not be overlooked. It is thought that it will contribute to the process of improving students' scientific literacy levels to be aware of the cognitive styles of students in the educational process and to design the context and materials used in the teaching environment to cater to the characteristics of students in different cognitive styles. For this purpose, science teachers can simplify the learning of field dependent students by simplifying stimulants that are not very relevant to the subject in activities or in complex contexts, while organizing teaching materials and contexts to be used during teaching. Because the field-dependent students are very much affected by stimuli in the environment when examining a case. For this reason, it is important for our teachers to make arrangements that will enable students to focus on the basic subject and concept. In addition, the use of teaching methods which have more social interaction such as discussion and cooperative teaching methods will also help in learning processes by providing a more comfortable learning environment for field dependent students.

As per the research results, cognitive styles are followed by the logical thinking ability as the second most powerful variable to predict the scientific literacy. In previous studies, it is asserted that the logical thinking ability which was important to students' scientific literacy performances could be developed through instructional activities (Daempfle, 2006; Engelmann, Neuhaus, & Fischer, 2016; Jensen, 2008; Marušić & Sliško, 2012; Shayer & Adey, 1992; Yüksel & Ateş, 2017). As per these studies, the application of questioning-oriented and cooperation-based approaches and the experiment technique which underline the act of writing has positive effect on students' logical thinking abilities (Blumer ve Beck, 2019; Daempfle, 2006; Van der Graaf, Van de Sande, Gijsel, & Segers, 2019; Yulianti, Mustikasari, Hamimi, Rahman, & Nurjanah, 2020).

In the research, it was found that the variable of mental capacity which was not very often addressed in studies performed in Turkey had both directly and indirectly significant effect on students' scientific literacy levels. This situation demonstrates that researchers, curriculum developers and teachers should attribute importance to this variable which is not often referred to in the national literature. It is thought that performance losses emanating from this variable will be lowered if the effect of this variable on the instruction method to be used during courses is taken into consideration by teachers and if the contents of materials used during courses are checked by researchers in terms of the required mental capacity.

In the literature on mental rotation ability which is another variable to predict students' scientific literacy levels in the research, it is asserted that this ability could be developed through goal-oriented education to be offered in early ages (Miller & Halpern, 2013; Uttal et al., 2013b). In early ages, the education which is offered through concrete materials such as jigsaw puzzles and board games, activities intended for the development of motor skills and digital games equipped with educational content contribute positively to the development of this ability (Nazareth, Herrera, & Pruden, 2013). That is why, it is thought that it is important to develop this ability which contributes positively to students' scientific literacy achievements through education programs which will be offered as of the early childhood.

The concept of scientific literacy addressed in this research was examined on the basis of the scientific literacy definition by Fives et al. (2014). The scientific literacy which is addressed in the research covers the skill and science-technology-society-environment dimensions which are referred to in the Instruction Program for the Science Course in Turkey. It is considered that, in the future research, the model can be tested in a way to include knowledge and sensation dimensions of the scientific literacy which were not covered within the scope of this research. Only cognitive variables existed in the model which was employed in this research. It is thought that, through a model including sensational variables besides these variables, the nature of the scientific literacy concept can be analyzed more deeply. The research population was comprised of the seventh-grade students studying in districts directly affiliated with Ankara city center. In order to generalize the research results to the entire country, the same model can be tested once again by using a sample to be selected from across the country. Moreover, by testing the model across different gender groups, class years and socio-economic groups, the relationships between variables in the study can be interpreted from different perspectives.

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