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The Examination of the Relationship Between Scientific Literacy and Some Cognitively Based Individual Differences in Terms of Gender

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ABSTRACT

The aim of this study is to examine whether the structural model that Sahin and Ates (2020) put forward about the relationship among students' scientific literacy levels, logical thinking ability, cognitive styles, mental capacity, and mental rotation ability differ in terms of gender. A causal-comparative model approach was used in this study. The sample of the research was 823 seventh-grade students in the central districts of Ankara. This sample was created using the random stratified sampling method. In the study, it is seen that 64% of the variance in the scientific literacy scores of the females and 48% of the variance in the scientific literacy scores of the males are explained by the cognitively based variables. Comparing male and female students in the data analyses, the predictive effect of the mental rotation ability of female students on the logical thinking ability was not significant. In male students, when only the direct effects were examined, the effect of cognitive styles on scientific literacy was not significant. Based on the results of the study, it is thought that examining the interactions among the activities related to learning, teaching, and assessment process used in science classes, and cognitive styles will play an important role in the process of removing inequalities of opportunity arising from possible gender-cognitive style interaction in the process of raising scientifically literate individuals.

Keywords: cognitive styles, gender, logical thinking ability, mental capacity, mental rotation ability, scientific literacy

Introduction

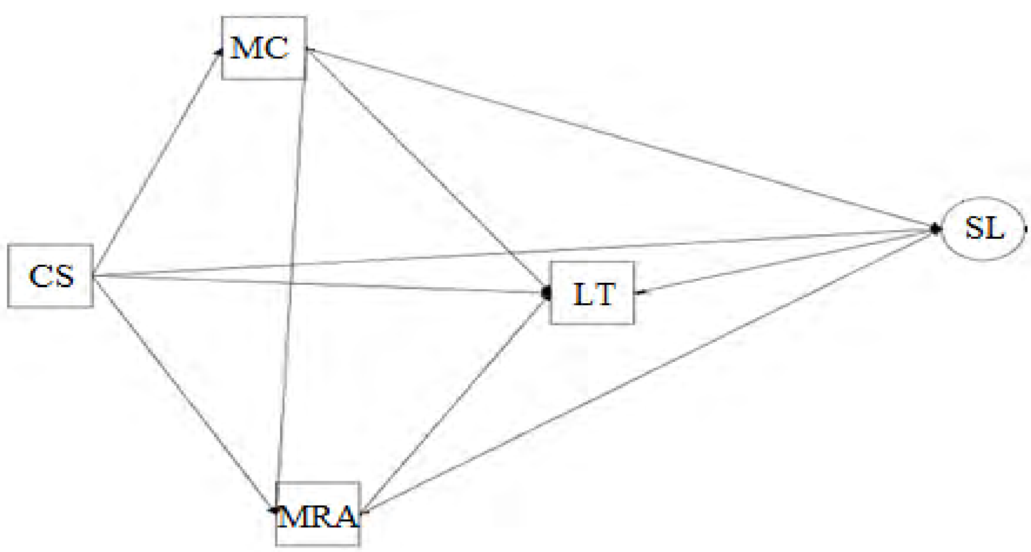
The vision of the Science Curriculum in Turkey is defined as educating all students as scientifically literate regardless of their individual differences (Turkish Ministry of Education [TME], 2017). Raising scientifically literate individuals is not only Turkey's aim but also many countries' (Pruitt, 2014). By determining the effect of various individual differences in the process of raising scientifically literate people, the activities to be carried out to reach the scientific literacy vision could be built on a more solid basis.

Many studies have been conducted on individual differences that are thought to affect science achievement from past to present (Schmeck & Grove, 1979; Schlatter et al., 2021). When these studies are examined, it is seen that the individual differences discussed may be in cognitive, affective, and psychomotor dimensions (Jonassen & Grabowski, 1993). Regarding the individual differences in cognitive characteristics, it is suggested that the variables of logical thinking ability, cognitive styles, spatial ability, mental capacity, locus of control, creativity, and fluent/crystallized intelligence are frequently mentioned in the literature. When the studies conducted between 1975 and 2017 in Web of Science and ERIC databases were examined using the keywords "individual difference" and "science achievement" in the field of science education, it was observed that cognitive-based individual differences, which are discussed in over 5% of the articles reviewed, include logical thinking ability, spatial thinking skills, cognitive styles and mental capacity (Sahin, 2018).

When the studies investigating the relationship between the above-mentioned cognitive-based individual differences and students' science achievement are addressed, it is seen that science achievement is mostly defined as the ability to solve end-of-units or chapter problems in science textbooks (Ates & Cataloglu, 2007). Although the main purpose of science education today is to raise scientifically literate individuals, the number of studies that define science achievement in the dimension of scientific literacy and reveal the interaction between these variables from a holistic perspective is quite limited. In their study in which they defined science achievement in the dimension of scientific literacy, Sahin and Ates (2020) revealed the relationship among those cognitively based individual differences and the scientific literacy level of students with a holistic model and tested the model seen in Figure 1.

Figure 1

The Theoretical Model of the Relationships Between Scientific Literacy Levels (SL), Logical Thinking Ability (LT), Cognitive Styles (CS), Mental Capacity (MC), and Mental Rotation Ability (MRA).



According to the model, the variable that directly predicts the scientific literacy levels of seventh-grade students is their logical thinking abilities. All other variables predict scientific literacy both directly and indirectly. When it comes to total effects in the study, it was found that field-dependent/field-independent cognitive styles had the highest predictive effect on scientific literacy, logical thinking abilities, mental capacities, and mental rotation abilities of seventh-grade students.

It is regarded that the proposed structural model is vital in terms of examining the interaction between various cognitive-based individual differences that may affect students' scientific literacy levels in a multifaceted manner. Besides, it is thought that it is also crucial to examine whether this model and findings differ in terms of gender, which is one of the other notable individual differences widely researched (Dimitrov, 1999; Scantlebury, 2011).

Conceptual Framework

In studies examining the relationship between science achievement and individual differences, it is seen that science achievement is mostly defined as the measurement of end of unit or chapter problem-solving ability related to subjects. Considering the 21st-century skills, the one-way approach to science achievement is quite limited and has some basic problems (Ates & Cataloglu, 2007; Pruitt, 2014). Evaluating students' science achievement in the context of scientific literacy, which emphasizes science education reforms in many countries, is necessary for realizing the visions of the curriculum.

In this study, science achievement was discussed in the dimension of scientific literacy. The historical development of the concept of scientific literacy suggests that there are many different definitions. According to the Project 2061 and Science for All Americans report, a scientifically literate individual is aware of the strengths and weaknesses of science, mathematics, and technology as well as interconnected human initiatives, comprehends basic science concepts and principles, knows the natural world, and recognizes both its diversity and unity. It is also a person who uses scientific knowledge in ways of scientific thinking for individual and social purposes. One of the most up-to-date definitions of scientific literacy that fits this definition is the one made by Fives et al. (2014). They define scientific literacy as the ability of individuals to have knowledge about the nature and processes of any field of science and thus to use science in daily life in a pragmatic and meaningful way.

There are other tools in the literature for the measurement of students' scientific literacy levels. One of these measurement tools is the Test of Basic Scientific Literacy developed by Laugksch and Spargo (1996). This scale includes questions about content knowledge, the nature of science, science-technology-society, and environment sub-dimensions. In addition to this scale, the Test of Scientific Literacy Skills developed by Gormally et al. (2012) is another scale used to measure the level of scientific literacy. This scale measures the skills of understanding research methods that provide access to scientific information, and the ability to organize, analyze, and interpret quantitative data, and scientific information. Another scale frequently used in the literature is Fives et al.'s (2014) Scientific Literacy scale. Fives et al. (2014) evaluated scientific literacy in terms of the role of science, scientific thinking, and acting, science and society, science media literacy, mathematics in science, motivation, and beliefs towards science.

In addition to these tools used in the measurement of scientific literacy are the Trends in International Mathematics and Science Study (TIMSS) and Program for International Student Assessment (PISA) exams conducted by the International Association for the Evaluation of Educational Achievement (IEA) and Organisation for Economic Co-operation and Development (OECD). PISA is international research conducted by the OECD in three-year cycles that evaluates the knowledge, and skills of 15-year-old students in certain fields. PISA research is carried out to measure the mathematical literacy, science literacy, and reading skills of students in the 15-age group who continue their formal education. In each cycle of the research, an area is selected as a weighted area, and in-depth analyzes are carried out in that area (TME, 2016). In the PISA 2015 research, the field of scientific literacy was chosen as the predominant field. The difference between gender groups among students' scientific literacy levels determined in PISA exams varies from country to country. When the scientific literacy performance of the PISA 2015 application is analyzed according to the gender variable, the average score of female students in all participating countries is higher than that of male students. But this difference is not statistically significant.

The same results are valid for the sample in Turkey; the difference between the mean scores of male, and female students in favor of females is not statistically significant (Tas et al., 2016). Similar results for Turkey were also seen in PISA scientific literacy measurements made in 2009 and 2012. In the PISA scientific literacy measurements conducted in 2015, the average of female students is higher than that of male students, but when the effect of other variables (economic, social, and cultural status, grade level, grade repetition) is controlled, it is seen that the average of boys is higher than that of females (Üstün et al., 2020).

Although individuals need to be scientifically literate both individually and socially, this is a challenging process. This situation may be caused by the functional definition of scientific literacy, teachers, teaching materials used, assessment and evaluation approaches, characteristics of the teaching environment, and the effects of individual differences, as well as the interaction of these variables with each other (Lipuma, 2008). Therefore, it is of paramount importance to investigate the effect of various variables such as individual differences on the development of scientific literacy.

Logical thinking ability is one of the variables frequently examined among individual differences in cognitive characteristics. (Ersanlı et al., 2018). According to Lawson (2004), logical thinking ability is the mental plans, strategies, or rules used to process information, and draw conclusions beyond directly observable experiences. Kuhn and Dean (2004) define logical thinking ability as the strategies, and rules that individuals use to ensure coordination between evidence, and theoretical hypotheses, and to create causal inferences. In both definitions, control of variables, proportional reasoning, correlation reasoning, and probabilistic reasoning, and hypothetical deductive reasoning are used as logical mathematical skills that assist scientific reasoning (Lawson, 2004; Zimmerman, 2000). Past studies in this field indicate that this ability begins to develop during adolescence and is a crucial factor affecting learning scientific concepts (Acar et al., 2015, Cheng et al., 2018, Lawson, 1995; Shayer & Adey 1992, Stender et al., 2018). When the change in the logical thinking ability of students in terms of gender groups was examined, it was found that in some studies there was a difference in favor of females (Demirtaş, 2011), in some studies in favor of boys (Valanides, 1996; Yenilmez et al., 2005), and in some studies, no difference was observed between the groups (Al-Zoubi et al., 2009; Piraksa et al., 2014; Talib et al., 2018; Yüzak, 2012).

Logical thinking ability is a concept related to the cognitive development of individuals, and one of the most accepted theories of cognitive development is Piaget's Theory of Cognitive Development (Lawson, 1995). The propositions of this theory have been prevalently used in many fields (Flavell, 1996). However, as a result of some studies to test Piaget's ideas, criticisms of the theory were put forward. One of the biggest criticisms of the theory is that it ignores the effect of individual differences on cognitive development. The theory cannot explain why some individuals progress faster during the cognitive development periods than others (Greenberg, 1995). Due to these findings, some studies preferred to examine and reinterpret Piaget's theory with new experimental findings. These researchers are called Neo-Piagetians (Knight & Sutton, 2004). Pascual-Leone's Constructivist Theory of Operators, the first Neo-Piagetian theorist, attributes the inability to perform activities with similar logical structures by students at the same developmental stage to the differences in students' mental capacities. Mental capacity refers to a limited resource that increases with age from childhood and can show variability within the age, enabling the activation of the schemas in mind related to the activity (Pascual-Leone & Johnson, 2005; 2011).

The science education literature review suggests that mental capacity is a cognitive variable that affects students' science achievement (Tsaparlis, 2005; Stamovlasis, 2010). In studies examining the difference between the mental capacities of different gender groups, it is seen that there is no statistically significant difference between the mental capacity scores of the gender groups (Hindal, 2007; Hindal et al., 2013). Pascual-Leone expresses that individuals' structural mental capacity cannot be used entirely during cognitive tasks, and various factors can affect their use of it. One of these factors is the cognitive styles of individuals (Pascual-Leone, 1970). According to Morgan (1997), cognitive styles are specific features that an individual uses in acquiring or learning information and can affect all individual activities. Although there are different classifications for cognitive styles in the literature, the most researched cognitive style in educational research is field-dependent/field-independent cognitive style classification (McKeachie & Svinicki, 2013). Field-independent learners are less affected by external stimuli in analyzing the complex structure of the field they are in and in the process of finding and extracting a particular element from a complex whole, compared to dependent learners who receive it from external stimuli. While field-dependent individuals give importance to external stimuli that affect their perceptions, field-independent individuals are more affected by internal stimuli rather than external stimuli (Jonassen & Grabowski, 1993).

When the literature on field-dependent/field-independent cognitive styles is examined, it is concluded that this variable is one of the strongest predictors of academic achievement (Terrell, 2002). Additionally, it is observed that field-independent students studying in some disciplines are more successful (Cataloğlu & Ates, 2014, Morris et al., 2019; Özarslan & Bilgin, 2016). In some studies, the tendency to have field-dependent/field-independent cognitive styles in terms of gender were examined, and no statistically significant difference was observed based on the scores obtained (Horzum & Alper, 2006; Maghsudi, 2007; Witkin et al., 1977). While in a few studies, it was found that male learners tended to be field-independent (Kirk, 2000; Onyekuru, 2015).

Mental rotation ability, another individual difference discussed in this research, is one of the vital components of spatial ability and is used extensively both in daily life and in courses such as biology, physics, chemistry, and geometry (Ganley et al., 2014). Meta-analysis and review papers also infer that mental rotation is an important factor for student success not only in science, but also in technology, engineering and mathematics (Castro-Alonso & Uttal, 2019; Maeda & Yoon, 2013; Langlois et al., 2019).In terms of the gender variable, it is stated that the difference between the scores obtained by gender groups is higher in favor of male learners (Hirnstein et al., 2009; Maeda & Yoon, 2013; Pietsch & Jansen, 2012; Titze et al., 2010). However, in all the studies examining the effect of individual differences mentioned above, it is seen that science achievement mainly focuses on specific dimensions of scientific literacy, such as knowledge or skill. In this paper, science achievement was defined in the dimension of scientific literacy, and its relationship with the specified variables was reexamined in terms of gender.

The Present Study

Gender has been one of the most widely researched variables for many years, considering that it affects achievement in science education research (Kahle & Meece, 1994; Scantlebury & Baker, 2007; Scantlebury, 2011). To this end, in order for countries to progress socially and economically, it is a fundamental requirement to prevent inequalities of opportunity in terms of gender in the education and training process (National Research Council [NRC], 1996; Next Generation Science Standards [NGSS] Lead States, 2013). One of the main purposes of research on gender is expressed as to reveal the performance differences/similarities between male and female students, and their reasons, and prevent inequalities of opportunity among students by attempting to understand the learning ways of students (OECD, 2009). By examining whether the model, as mentioned earlier, differs in terms of gender groups, this study aims to serve the main purpose of preventing possible inequalities of opportunity that may occur between groups. In this context, the research question and sub-problems of this study are stated below:

> Are the paths specified in the proposed theoretical model statistically significant in the samples formed by students of different genders?

In the context of this research question, the sub-problems related to the model are as follows:

a. Are the paths specified in the proposed theoretical model statistically significant in the sample of female students?
b. Are the paths specified in the proposed theoretical model statistically significant in the sample of male students?

Method

Research Model

A causal-comparative design was used in this study. This model is used to describe the causes or consequences of pre-existing differences between or among groups of individuals (Fraenkel et al., 2012).

Sample

The research population includes seventh-grade students studying in central districts of Ankara. Using the stratified random sampling method, 823 seventh-grade students studying in Ankara constitute the research sample. In this method, the population is divided into sub-units to represent itself. Elements are then sampled from each of these subunits. The inclusion of the elements in the subunits into the sample is made in proportion to the ratio of the subunits to the total population (Fraenkel et al., 2012). In the application of this sampling method, Ankara central districts were determined as sub-units. Considering the ratio of the number of students in the central districts of Ankara to the total number of students in the population, the number of students in each central district was determined. The students participating in the study consisted of 446 (52%) females and 377 (46%) males.

Data Collection Tools

Demonstrated Scientific Literacy (SL)

In this study, the Demonstrated Scientific Literacy Test, developed by Fives et al. (2014) for secondary school students, was used to determine the students' scientific literacy levels. The test was translated and adapted to Turkish by Sahin and Ates (2018). The test is an assessment tool consisting of multiple-choice questions, including items about the role of science, scientific thinking and doing, science and society, science media literacy, and mathematics in science. In the relevant study, the chi-square value (χ^2= 178.41, N=823, df=135, p=0.00) as a result of the CFA analysis performed to test the construct validity of the test, was statistically significant. The values of (χ^2/df) =1.32; RMSEA= 0.02; CFI= 0.97; TLI= 0.96; WRMR= 0.94 were obtained. These values show that the data fit the model well (Kline, 2005). In this study, the KR-20 reliability coefficient of the test was found to be 0.66. These results show that the measurement is valid and reliable (Alpar, 2013; Kline, 2005).

Test of Logical Thinking (TOLT)

The Test of Logical Thinking developed by Tobin and Capie (1981) was used to measure the logical thinking abilities of secondary school students in this study. The test consists of 10 items. The test was translated and adapted to Turkish by Geban et al. (1992) and the Cronbach α reliability coefficient was found to be 0.77. As a result of the CFA analysis performed to test the construct validity of the test in the relevant study, it is seen that the chi-square value (χ^2=43.55, N=790, df=31, p=0.00) was statistically significant. The values of (χ^2/df) =1.40; RMSEA= 0.02; CFI= 0.99; TLI= 0.98; WRMR= 0.77 were obtained. These values indicate that the data fit the model well. In this study, the KR-20 reliability coefficient of the test was found to be 0.63. These results show that the measurement is valid and reliable (Alpar, 2013; Kline, 2005).

The Group Embedded Figures Test (GEFT)

In this study, the Group Embedded Figures Test was used to determine students' field-dependent/field-independent cognitive styles (Witkin et al., 1971). The test consists of 18 items. The test was adapted to Turkish by Çakan (2003). In the relevant study, the chi-square value (χ^2= 396.83, *N*=804, *df*=135, *p*=0.00) was statistically significant in the CFA analysis performed to test the construct validity of the test. In addition to that, the values of (χ^2/df)=2.93; RMSEA= 0.05; CFI= 0.98; TLI= 0.97; WRMR= 1.28 were obtained. These values suggest that the data fit the model well. In this study, the KR-20 reliability coefficient of the test was found to be 0.89. These results show that the measurement is valid and reliable (Alpar, 2013; Kline, 2005).

Figural Intersection Test (FIT)

In this study, the Figural Intersection Test was used to determine the functional mental capacity of the students (Pascual-Leone & Johnson, 2011). The test consists of 36 items. The test was adapted to Turkish by Sahin (2018). As a result of the CFA analysis performed to test the construct validity of the test in this study, the chi-square value (χ^2=1099.38, *N*=785, *df*=594, *p*=0.00) was found to be statistically significant. Additionally, the values of (χ^2/df)=1.85; RMSEA= 0.03; CFI= 0.94; TLI= 0.94; WRMR= 1.34 were obtained. These values infer that the data fit the model well. In this study, the KR-20 reliability coefficient of the test was found to be 0.89. These results show that the measurement is valid and reliable (Alpar, 2013; Kline, 2005).

Mental Rotation Test (MRT)

The basic format of the Mental Rotation Test developed by Peters et al. (1995) was used to determine mental rotation abilities, a dimension of students' spatial abilities. The test consists of 24 items. The test was translated and adapted to Turkish by Yildiz and Tüzün (2011). In the relevant study, the chi-square value (χ^2= 482.69, *N*=759, *df*=252, *p*=0.00) was statistically significant in the CFA analysis performed to test the construct validity of the test. The values of (χ^2/df)=1.91; RMSEA= 0.04; CFI= 0.91; TLI= 0.90; WRMR= 1.15 were obtained. These values show that the data fit the model well. In this study, the KR-20 reliability coefficient of the test was found to be 0.77. These results show that the measurement is valid and reliable (Alpar 2013; Kline, 2005).

Application

The data collection process for this study was carried out by the researchers in the spring term of the 2015-2016 academic year. Before the implementation, official permissions regarding the implementation had been obtained from institutions affiliated with the TME and detailed planning was made. In the planning, the issues that may reduce student motivation regarding the implementation were taken into consideration. For example, no implementation was made during the exam weeks of the students or in their favorite sports lessons. For the same purpose, the data collection process was planned to last for 2.5 months, and the process was completed before the air temperatures increased. In addition, five measuring instruments were not applied one after the other to avoid test fatigue. Completion of implementation in a school was spread over two weeks. After the planning, the implementation was made in the schools at the specified times. Before the application, all participants were informed of the purpose and importance of the study. During the application, the participants were not forced, and only voluntary participants were included in the application. The scales of the participants who did not want to continue the application were deemed invalid. The tests used in the research were applied in the same order in all schools. The researcher took care to have the same attitude in all classes where data was collected. After the data collection process, the scoring of the tests was done by the researcher using pre-prepared answer keys. In this way, the threat of instrumentation, scoring, and participant attitude has been tried to be prevented.

Data Analysis

In this study, the SPSS 23 package program was used for descriptive analysis, while the Mplus 7.0 program was used to test the structural model in both gender groups.

Findings

Descriptive Analysis

Table 1 shows the descriptive statistics of the total scores obtained from the tests used in this study. When the skewness and kurtosis coefficients in the table are examined, it is seen that these coefficients are within the limits of ±1, indicating that the total scores show a normal distribution (Mertler & Vannatta, 2005).

Table 1

Descriptive Analysis of Tests

Variable	Group	*n*	Min	Max	Mean	Std.Dev	Skewness	Kurtosis
SL	Total	823	1	17	8.23	3.31	0.16	-0.60
	Female	446	2	17	9.01	3.21	0.13	0.23
	Male	377	1	17	8.05	3.36	0.27	-0.61
LT	Total	823	0	10	5.43	2.23	0.13	-0.59
	Female	446	1	10	5.50	2.21	0.11	-0.51
	Male	377	0	10	5.33	2.25	0.16	0.25
CS	Total	823	0	18	7.78	4.93	0.22	-0.98
	Female	446	0	18	8.07	4.91	0.14	-0.97
	Male	377	0	18	7.41	4.93	0.34	0.25
MC	Total	823	0	34	19.77	6.17	-0.34	-0.09
	Female	446	0	34	19.49	6.43	-0.37	0.01
	Male	377	1	32	20.06	5.81	-0.29	-0.38
MRA	Total	823	14	44	27.21	5.15	0.89	0.85
	Female	446	14	44	26.85	4.67	0.95	1.45
	Male	377	15	44	27.67	5.61	0.81	0.25

When Table 1 is examined, while female students have a higher mean score than male students in terms of scientific literacy, logical thinking ability, and cognitive styles, it is seen that the mean scores of male students are higher than female students in terms of mental capacity and mental rotation ability variables. Some of these differences between mean scores are statically significant, whereas the others are statistically insignificant.

Table 2

ANOVA Results of Test Means by Gender

Variable	Source	Sum of Squares	*df*	Mean Square	*F*	**p*
SL	Inter-group	190.69	1	190.69	17.73	.000*
	Intra-group	8831.18	821	10.76		
	Total	9021.87	822			
LT	Inter-group	6.66	1	6.66	1.34	.248
	Intra-group	4093.71	821	4.99		
	Total	4100.37	822			
CS	Inter-group	95.78	1	95.78	3.95	.047*
	Intra-group	19900.30	821	24.24		
	Total	19996.08	822			
MC	Inter-group	60.25	1	60.25	1.58	.209
	Intra-group	31253.12	821	38.07		
	Total	31313.36	822			
MRA	Inter-group	147.57	1	147.57	5.59	.018*
	Intra-group	21688.34	821	26.42		
	Total	21835.91	822			

As seen in Table 2, there was no significant difference between the mean scores of male and female students in terms of mental capacity scores (F (1, 821) =1.58; $p \geq 0.05$); there is a significant difference in favor of male students in terms of mental rotation ability (F (1, 821) =5.59; $p<0.05$). While the mean score difference between male and female students is significant in favor of female students in terms of scientific literacy (F (1, 821) =17.73; $p<$ 0.05) and field-dependent/field-independent cognitive styles scores (F (1,821) =3.95; $p<$ 0.05), there is no statistically significant difference between the mean scores in terms of logical thinking ability (F (1,821) =1.34; $p \geq 0.05$).

Testing the Structural Model on Male and Female Students

The structural model was tested using the Mplus software. In the analysis, it was seen that the chi-square value (χ^2= 212.46, N=377, df=203, p=0.31) was not significant in the sample of male students. Additionally, the values of (χ^2/df) =1.05; RMSEA= 0.01; CFI= 0.99; TLI= 0.99; WRMR= 0.79 were obtained. These values suggest that the data fit the model well. The chi-square value (χ^2= 262.79, N=445, df=203, p=0.00) was found to be significant in the sample consisting of female students. The values of (χ^2/df) =1.29; RMSEA= 0.03; CFI= 0.96; TLI= 0.95; WRMR= 0.91 were obtained and conclude that the data fit the model well. The direct, indirect, and total effects obtained as a result of the analyzes for both samples, and the percentages of variance explained by other variables for dependent and mediator variables in the model, are given in Table 3.

Table 3

Direct, Indirect, and Total Effects in the Model and Effect Sizes (Male and Female Students)

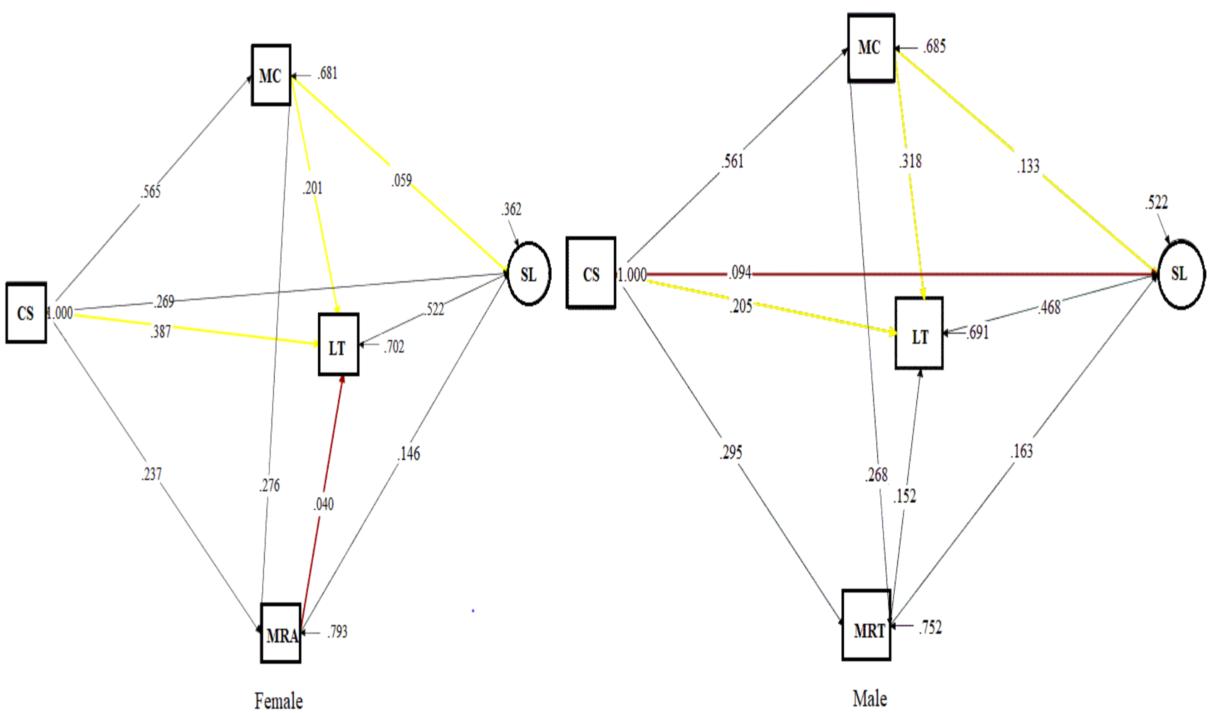
Dependent Variable	Independent Variable	Standardized Regression Coefficients					
		Direct		Indirect		Total	
		Male	Female	Male	Female	Male/ Effect size	Female/ Effect size
SL	LT	0.47*	0.52*	-	-	0.47*/Big	0.52*/Big
R^2=0.48	CS	0.09	0.27*	0.36*	0.36*	0.45*/Big	0.63*/Big
(Male)	MRA	0.16*	0.15*	0.07*	0.02	0.23*/Medium	0.17*/Medium
R^2=0.64	MC	0.13*	0.06	0.21*	0.15*	0.34*/Medium	0.21*/Medium
(Female)							
LT	CS	0.20	0.39 *	0.25*	0.13*	0.45*/ Big	0.52*/ Big
R^2=0.31	MC	*	0.20*	0.04*	0.01	0.36*/Medium	0.21*/Medium
(Male)	MRA	0.32*	0.04	-	-	0.15*/Small	0.04/ Small
R^2=0.30		0.15*					
(Female)							
MRA	CS	0.30*	0.24*	0.15*	0.15*	0.45*/ Big	0.39*/Medium
R^2=0.25	MC	0.27*	0.28*	-	-	0.27*/Medium	0.28*/Medium
(Male)							
R^2=0.21							
(Female)							
MC	CS	0.56*	0.57*	-	-	0.56*/ Big	0.57*/ Big
R^2=0.32							
(Male)							
R^2=0.32							
(Female)							

When the variables in Table 3 are considered in terms of the total predictive effect, it can be inferred that only the mental rotation skills of female students have no statistically significant effect on logical thinking ability (β=0.04, p>0.05). Apart from this, the predictive effects of scientific literacy, logical thinking ability, mental rotation ability, and mental capacity variables on total prediction by other variables in both samples are statistically significant. When Table 3 is reviewed in terms of its direct predictive effect, the effect of cognitive styles on the direct prediction of scientific literacy in the sample formed by male students (β= 0.09, p>0.05), the effect of mental capacity to directly predict scientific literacy (β= 0.06, p>0.05) and the effect of mental rotation ability to directly predict logical thinking ability (β= 0.04, p>0.05) in the sample of female students were not statistically significant. When Table 3 is addressed in terms of indirect prediction effect, in the sample formed by female students, the effect of mental rotation ability to indirectly predict scientific literacy (β= 0.02, p>0.05) and the effect of mental capacity to indirectly predict logical thinking ability (β= 0.01, p>0.05) was not found to be statistically significant. Apart from these, the predictive effects of scientific literacy, logical thinking ability, mental rotation ability, and mental capacity variables on indirect prediction by other variables in both samples are statistically significant.

As seen in Table 3, a total of 4 variables that predict scientific literacy in male students can explain 48% of the variance in scientific literacy. This value is 64% for female students. Three variables that predict logical thinking ability in male students can explain 31% of the variance in logical thinking ability. This value is 30% for female students. Two variables predicting mental rotation ability in male students can explain 25% of the variance in mental rotation ability. This value is 21% for female students. One variable predicting mental capacity in male students can explain 32% of the variance in mental capacity. This value is 32% for female students. When Table 3 is analyzed in terms of effect size created by the effects of the variables on the total prediction made, it is seen that the effect sizes are in the same category for all variables in both samples (Kline, 2005). The values in Table 3 are summarized in Figure 2.

Figure 2

Structural Model of the Relationships Between Scientific Literacy (SL), Logical Thinking Ability (LT), Cognitive Styles (CS), Mental Capacity (MC), and Mental Rotation Ability (MRA) in Gender Groups



Note: → Path coefficients with no significant predictive effect, → Path coefficients differing in size in both samples

One of the main differences seen in the model, which was tested separately for male and female students, is related to the direct predictive effect of the cognitive style variable on scientific literacy. In the sample of female students, the effect on this prediction was found to be statistically significant, while in the sample formed by male students, the effect on this prediction is not statistically significant. Another significance is related to the direct predictive effect of mental rotation ability on logical thinking ability. While the effect on this prediction was statistically significant in the sample formed by male students, the effect on this prediction is not statistically significant in the sample formed by female students. The direct predictive effect of mental capacity on cognitive literacy in the model also differs in both groups. While the effect on this prediction was statistically significant in the sample formed by male students, the effect on this prediction is not statistically significant in the opposite gender.

Discussion

In this study, the structural model that Sahin and Ates (2020) proposed with regards to the interaction between scientific literacy level and logical thinking ability, field-dependent/field-independent cognitive styles, mental capacities, and mental rotation abilities of seventh-grade students was examined in terms of male and female students. As a result of the research, 64% of the variance in the scientific literacy scores of the females and 48% of the variance in the scientific literacy scores of the male are explained by logical thinking ability, cognitive style, mental capacity, and mental rotation ability. As stated by Sahin and Ates (2020), this value was found to be 55% in the study in which male and female students were assessed together and all the predictive effects in the theoretical model were found to be statistically significant.

When both models were examined to explain the difference in the variance values that explain scientific literacy in gender groups in the research, it is noteworthy that there is a significant difference between the groups in terms of the effects of students' cognitive styles and mental capacities to directly or indirectly predict scientific literacy levels. This remarkable difference is also observed in terms of the predictive effect of mental rotation abilities on logical thinking abilities. When the direct effects were analyzed in the study, it was found that the cognitive styles of male students did not have a statistically significant effect on predicting scientific literacy. In contrast, in female students, it is seen that the effect of mental capacity to predict scientific literacy is not statistically significant. At the same time, the effect of mental rotation ability to predict logical thinking ability is not statistically significant. Besides these, there is no significant difference between gender groups.

The most notable result of those observed among gender groups in the study is that the effect of cognitive styles on the direct predictor of scientific literacy is not statistically significant in males but significant in females. The difference between field-dependent/field-independent cognitive styles of females and males is frequently mentioned in the relevant literature. In some of these studies, the difference between the scores of males and females in cognitive styles measurements was quite minor and not significant (Horzum & Alper, 2006; Idika, 2017; Maghsudi, 2007; Witkin et al., 1977), while in others this difference was stated to be higher in favor of males (Kirk, 2000; Onyekuru, 2015).

In the analysis of variance in the study, although the difference observed between field-dependent/field-independent cognitive styles scores between females and males was found to be significant in favor of females, this result, obtained through testing the theoretical model, provides information beyond whether there is a significant difference between the cognitive style scores of both genders. The result obtained by testing the structural model in this study proposes that the predictive effect of the increase in field-independent cognitive style tendencies of female students on the level of scientific literacy is higher and more significant than that of males. It is a key point to interpret this situation in terms of scientific literacy vision. To this end, the result of the research shows that the increase in cognitive styles scores of female students affects scientific literacy achievement more, thanks to the fact that the teaching environment and materials are designed according to the characteristics of different cognitive styles by being aware of the cognitive styles structure of learners.

In this respect, there are studies implying that planning strategies to be used in lessons mediate the effect of cognitive style on achievement (Tinajero et al., 2012). Hence, science teachers need to be aware of the barriers to learning arising from field-dependent/field-independent cognitive styles and consider this issue when presenting teaching materials to learners. Organizing the teaching materials to be used during teaching, and simplifying the irrelevant or complex contexts in the activities in order of importance, can facilitate the learning of dependent students. It is tough for field-dependent students to distinguish the important ones among the many pieces of information presented in the lectures in which the lecture method is applied. Using teaching methods with much social interaction, such as in-class discussion and collaborative teaching methods, could help prevent this disadvantage of field-dependent students (Jonassen & Grabowski, 1993). Although it is hard for teachers to apply the appropriate teaching method to each student in the classroom, it is thought that the disadvantages arising from the field-dependent/field-independent cognitive style could decrease with the diversification of the teaching and assessment techniques used.

Another remarkable finding in the study is related to the direct predictive effect of mental rotation ability on logical thinking ability. The results obtained by testing the structural model in this study show that the predictive effect of mental rotation ability in the theoretical model on logical thinking ability is not statistically significant for female students. Although this effect is significant for male students, it is categorized as a minor effect. In the analysis of variance in the study, it was found that the difference in performance between genders was significant in favor of males. These findings are consistent with the relevant literature (Hirnstein et al., 2009; Maeda & Yoon, 2013; Pietsch & Jansen, 2012; Priest, 2019; Titze et al., 2010). The result obtained by testing the structural model in the research provides information beyond whether there is a significant difference between the groups. The result obtained by testing the structural model in this study suggests that the predictive effect of the increase in male students' mental rotation ability performance on logical thinking ability is greater and more significant than that of the female students. It is reported in the literature that the difference observed between gender groups in mental rotation ability may be due to the learning opportunities that individuals had in the past and biological, environmental, and sociocultural factors (Schoning et al., 2007; Sundberg, 1994). Sorby (1999) asserts that playing with toys, playing with three-dimensional computer games, and doing some sports activities in childhood contribute to developing spatial ability. Although a difference was observed between gender groups in terms of mental rotation ability, students can develop this skill through appropriate activities (Miller & Halpern, 2013; Sanchez, 2012). Studies conclude that participation in spatial activities, especially at an early age, can affect students' performance in spatial activities. As reported in two meta-analysis studies (Baenninger & Newcombe, 1989; Uttal et al., 2013) conducted on the ability to improve mental rotation ability with teaching, while education focused on spatial activities and materials allow the development of mental rotation ability, this development also positively affects other components of spatial ability. Researchers also indicate that it is vital to start activities to develop spatial ability at an early age before the gender gap in spatial ability widens (Newcombe & Frick, 2010).

Another finding obtained among gender groups is related to the direct predictive effect of mental capacity on scientific literacy. While this effect is statistically significant for male students, it is insignificant for female students. Meanwhile, in the analysis of variance for mental capacity, it was found that the mean score difference in favor of male students between both genders was not significant. This result shows parallelism with studies in this field (Hindal, 2007; Hindal et al., 2013). One of the main results obtained by testing the structural model in this study is related to the predictive effect of mental capacity on scientific literacy rather than the differentiation found between gender groups. This result obtained from the research shows that the increase in functional mental capacity of students affects the scientific literacy performance of male students more than female students, thanks to the strategies that increase the functional mental capacity by removing unnecessary information from the activities organized for students and increasing the motivation of the students. An individual's mental capacity is explained as a cognitive variable that defines the ability to process many phenomena or concepts simultaneously (Pascual-Leone, 1970). According to the Constructivist Operators Theory, the more complex the activity, the greater the demand for mental capacity. As a matter of fact, studies tried to reduce the field effect by removing unnecessary information from the activities, and it was observed that there is an increase in student performance in this way (Boujaoude et al., 2004; Danili & Reid, 2004; Niaz, 1988a, b; Niaz & Robinson, 1992; Tsaparlis, 1998; Tsaparlıs et al., 1998). It is thought that the spatial effect could be reduced by alleviating unnecessary or extra information through the context or life-based activities in the lessons. In addition, by increasing the social context, there could be an increase in student motivation. In this way, it is thought that there may be an increase in student performance. As can be seen in the research results, although the structural mental capacity cannot be interfered, a functional mental capacity area can be created with the above-mentioned strategies. For this reason, it is thought that the concept of functional mental capacity can be known by the teachers and the implementation of the aforementioned strategies can contribute to the development of scientific literacy levels of all students.

Conclusions and Suggestions

This research concluded that cognitive styles and mental capacity variables differ according to gender groups in terms of their predictive effect on scientific literacy. Therefore, it is expressed that the preparation of the teaching materials (written, visual, and interactive) be used in the lessons by considering how these two variables play a key role in preventing inequalities of opportunity in terms of gender. For this purpose, field experts should examine the effects of textbooks and other teaching materials in terms of these variables and cross-check their efficiency.

Since this research was conducted in the central districts of Ankara, to generalize the research results to Turkey, it can be tested in model gender groups with students from different regions and at different grade levels. In the study, a model was created by considering only certain cognitive variables. To examine the scientific literacy levels of students in-depth, it is regarded as important to test new models in which only affective variables take place, or that cognitive and affective variables take place together in different gender groups.

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References

Acar, Ö., Türkmen, L., & Bilgin, A. (2015). Examination of gender differences on cognitive and motivational factors that ınfluence 8th graders' science achievement in Turkey. *Eurasia Journal of Mathematics, Science & Technology Education*, *11*(5) 1027-1040. https://doi.org/10.12973/eurasia.2015.1372a

Alpar, R. (2013). *Uygulamalı çok değişkenli istatistiksel yöntemler*. Detay.

Al-Zoubi, T., El-shar'a, I., & Al-Salam, M.K. (2009). The scientific reasoning level of students' in the faculty of science in Al-Hussein Bin Talal University and its affection of gender, teaching level, and specialization. *An-Najah University Journal for Research Humanities*, *23*(2), 401-437. https://journals.najah.edu/article/357/

Ates, S., & Cataloglu, E. (2007). The effects of students' reasoning abilities on conceptual understandings and problem-solving skills in introductory mechanics. *European Journal of Physics*, *28*(6), 1161. http://dx.doi.org/10.1080/02635140701250618.

Baenninger, M., & Newcombe, N. (1989). The role of experience in spatial test performance: A meta-analysis. *Sex Roles*, *20*(5), 327–344. https://doi.org/10.1007/BF00287729

BouJaoude, S., Salloum, S., & Abd-El-Khalick, F. (2004). Research report: Relationships between selective cognitive variables and students' ability to solve chemistry problems. *International Journal of Science Education*, *26*(1), 63-84. https://doi.org/10.1080/0950069032000070315

Cakan, M. (2003). Cross-cultural aspect of the group embedded figures test: Norms for Turkish eighth graders. *Perceptual and Motor Skills*, *97*(2), 499-509. https://doi.org/10.2466/pms.2003.97.2.499

Castro-Alonso, J. C., & Uttal, D. H. (2019). Science education and visuospatial processing. In C. A. Juan (Ed.), *Visuospatial processing for education in health and natural sciences* (pp. 53-79). Springer.

Cataloglu, E., & Ates, S. (2014). The effects of cognitive styles on naive impetus theory application degrees of pre-service science teachers. *International Journal of Science and Mathematics Education*, *12*(4), 699-719. https://doi.org/10.1007/s10763-013-9430-z

Cheng, S. C., She, H. C., & Huang, L. Y. (2018). The impact of problem-solving instruction on middle school students' physical science learning: Interplays of knowledge, reasoning, and problem solving. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(3), 731-743. https://doi.org/10.12973/ejmste/80902

Danili, E., & Reid, N. (2004). Some strategies to improve performance in school chemistry based on two cognitive factors. *Research in Science and Technological Education,* 22, 203–23. https://doi.org/10.1080/0263514042000290903

Dimitrov, D. M. (1999). Gender differences in science achievement: Differential effect of ability, response format, and strands of learning outcomes. *School Science and Mathematics, 99*(8), 445-450. https://doi.org/10.1111/j.1949-8594.1999.tb17507.x

Ersanlı, E., Gencoglu, C., & Duran, V. (2018). A meta-synthesis study on investigations of dissertations on education regarding reasoning skills in Turkey. *International Online Journal of Educational Sciences*, *10*(5). http://dx.doi.org/10.15345/iojes.2018.05.015

Fives, H., Huebner, W., Birnbaum, A. S., & Nicolich, M. (2014). Developing a measure of scientific literacy for middle school students. *Science Education*, *98*(4), 549-580. https://doi.org/10.1002/sce.21115

Flavell, J.H. (1996) Piaget's legacy, *Psychological Science*, *7*, 200–203. https://www.jstor.org/stable/pdf/40062945.pdf.

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to design and evaluate research in education*. McGraw-Hill.

Ganley, C. M., Vasilyeva, M., & Dulaney, A. (2014). Spatial ability mediates the gender difference in middle school students' science performance. *Child development*, *85*(4), 1419-1432. https://doi.org/10.1111/cdev.12230

Geban, Ö., Askar, P. & Özkan, I. (1992). Effects of computer simulated experiment and problem solving approaches on students' learning outcomes at the high school level. *Journal of Educational Research*, *86*(1), 5-10. https://doi.org/10.1080/00220671.1992.9941821

Gormally, C., Brickman, P., & Lutz, M. (2012). Developing a test of scientific literacy skills (TOSLS): Measuring undergraduates' evaluation of scientific information and arguments. *CBE—Life Sciences Education*, *11*, 364-377. https://www.researchgate.net/publication/233880797

Greenberg, D. (1995). *Free at last: The Sudbury Valley School*. Sudbury Valley School.

Hindal, H. S. (2007). *Cognitive characteristics of students in middle schools in State of Kuwait, with emphasis on high achievement* [Doctoral dissertation, Glasgow University]. Glasgow University Theses and Dissertations Archive. https://theses.gla.ac.uk/5717/1/2007hindalphd.pdf

Hindal, H., Reid, N., & Whitehead, R. (2013). Gender and learner characteristics. *European Journal of Educational Research*, *2*(2), 83-96. https://doi.org/10.12973/eu-jer.2.2.83

Hirnstein, M., Bayer, U. & Hausmann, M. (2009). Sex-specific response strategies in mental rotation. *Learning and Individual Differences*, *19*, 225-228. https://doi.org/10.1016/j.lindif.2008.11.006.

Horzum, M. B., & Alper, A. (2006). Fen Bilgisi dersinde olaya dayalı öğrenme yöntemi, bilişsel stiller ve cinsiyetin öğrenci başarısına etkisi. *Ankara Üniversitesi Eğitim Bilimleri Fakültesi Dergisi*, *39*(2), 151-175. https://app.trdizin.gov.tr/makale/TnpRNU16TXo/fen-bilgisi-dersinde-olaya-dayali-ogrenme-yontemi-bilissel-stilin-ve-cinsiyetin-ogrenci-basarisina-etkisi

Idika, M. I. (2017). Influence of cognitive style and gender on secondary school students' achievement in and attitude to chemistry. *Advances in Social Sciences Research Journal*, *4*(1), 129-139. https://doi.org/10.14738/assrj.41.2585

Jonassen, D. H., & Grabowski, B. (1993). *Handbook of ındividual difference learning, and ınstruction*. Routledge.

Kahle, J.B & Meece, J. (1994). Research on gender issue in the classroom. In D. L. Gabel (Eds). *Handbook of Research on Science Teaching and Learning*, (pp.542-558). Macmillan.

Kirk, G. R. (2000). *The relationship of attitudes toward science, cognitive style and self-concept to achievement in chemistry at the secondary school level* [Doctoral dissertation, Florida International University]. Florida International University ProQuest Dissertations Publishing. https://www.proquest.com/openview/ac0e6532411650cdeed81f4b17185c83/1?pq-origsite=gscholar&cbl=18750&diss=y

Kline, R.B. (2005). *Principles and practice of structural equation modeling*. The Guilford.

Kuhn, D. & Dean, D. (2004). Connecting scientific reasoning and causal inferences. *Journal of Cognition and Development, 5*(2), 261–288. https://doi.org/10.1207/s15327647jcd0502_5

Langlois, J., Bellemare, C., Toulouse, J., & Wells, G. A. (2019). Spatial abilities training in anatomy education: A systematic review. *Anatomical Sciences Education*. *13*(1), 71-79. https://doi.org/10.1002/ase.1873

Laugksch, R. C., & Spargo, P. E. (1996). Development of a pool of scientific literacy test-items based on selected AAAS literacy goals. *Science Education*, *80*(2), 121-143. https://doi.org/10.1088/0963-6625/5/4/003

Lawson, A. E. (1995). *Science teaching and the development of thinking: Stages in the development of procedural knowledge*. Wadsworth.

Lawson, A. E. (2004). The nature and development of scientific reasoning. *International Journal of Science and Mathematics Education, 2*(3), 307–338. https://link.springer.com/content/pdf/10.1007/s10763-004-3224-2.pdf

Lipuma, M., (2008, May 27). *Obstacles to science literacy.* https://webcache.googleusercontent.com/search?q=cache:_TTARK_WcvAJ:https://web.njit.edu/~lipuma/LipumaJMObstacles_to_Scientific_Literacy.doc+&cd=1&hl=tr&ct=clnk&gl=tr

Maeda, Y., & Yoon, S.Y. (2013). A meta-analysis on gender differences in mental rotation ability measured by the Purdue spatial visualization tests: Visualization of rotations (PSVT:R). *Educational Psychology Review, 25*, 69-94. https://doi.org/10.1007/s10648-012-9215-x

Maghsudi, M. (2007). The interaction between field dependent/independent learning styles and learners' linguality in third language acquisition. *Interactive Multimedia Electronic Journal of Computer-Enhanced Learning*, *7*(5), 1-23. http://ut.pr/biblioteca/Glossa2/Journal/dec2007/Linguality%20in%20Third%20Language%20Acquisition.pdf

McKeachie, W., & Svinicki, M. (2013). *Mckeachie's teaching tips: strategies, research, and theory for college and university teachers*. Wadsworth Cengage Learning.

Miller, D. I., & Halpern, D. F. (2013). Can spatial training improve long-term outcomes for gifted STEM undergraduates? *Learning and Individual Differences, 26, 141*–152. https://doi.org/10.1016/j.lindif.2012.03.012.

Morgan, H. (1997). *Cognitive styles and classroom learning*. Praeger.

Morris, S., Farran, E. K., & Dumontheil, I. (2019). Field-independence associates with mathematics and science performance in 5-to 10-year-olds after accounting for domain-general factors. *Mind, Brain, and Education*. *13*(4), 268-278. https://doi.org/10.1111/mbe.12214

National Research Council. (1996). *The national science education standards*. National Academy.

Newcombe, N. S., & Frick, A. (2010). Early education for spatial intelligence: Why, what, and how. *Mind, Brain, and Education, 4* (3), 102–111. https://doi.org/10.1111/j.1751-228X.2010.01089.x

NGSS Lead States. (2013). *Next generation science standards: For States, by states*. The National Academies Press.

Niaz, M. (1988a). The information processing demand of chemistry problems and its relation to Pascual-Leone's functional M-capacity. *International Journal of Science Education, 10*, 231–38. http://dx.doi.org/10.1080/0950069880100211.

Niaz, M. (1988b). Manipulation of M-demand of chemistry problems and its effects on students performance: A neo-Piagetian study. *Journal of Research in Science Teaching, 25*, 643–57. http://dx.doi.org/10.1002/tea.3660250804.

Niaz, M., & Robinson, W. R. (1992). Manipulation of logical structure of chemistry problems and its effect on student performance. *Journal of Research in Science Teaching, 29,* 211–226. https://doi.org/10.1002/tea.3660290303

OECD. (2009). *Equally prepared for life? How 15-year-old boys and girls perform in school.* http://www.pisa.oecd.org/dataoecd/59/50/42843625.pdf

Onyekuru, B. U. (2015). Field dependence-field ındependence cognitive style, gender, career choice and academic achievement of secondary school students in emohua local government area of rivers state. *Journal of Education and Practice*, *6*(10), 76-85. http://files.eric.ed.gov/fulltext/EJ1081668.pdf

Özarslan, M., & Bilgin, İ. (2016). Öğrencilerin alan bağımlı/bağımsız bilişsel stillerinin ve bilimsel düşünme yeteneklerinin maddenin doğası kavramlarını anlamalarına ve fen dersine yönelik tutumlarına etkisi. *Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *13*(33), 94-110. https://dergipark.org.tr/tr/pub/mkusbed/issue/19579/208938

Pascual-Leone, J. (1970). A mathematical model for the transition rule in Piaget's developmental stages. *Acta Psychologica*, *32*, 301-345. https://doi.org/10.1016/0001-6918(70)90108-3.

Pascual-Leone, J., & Johnson, J. (2005). A dialectical constructivist view of developmental intelligence. In O. Wilhelm & R. Engle (Eds.), *Handbook of understanding and measuring intelligence* (pp. 177-201). Sage.

Pascual-Leone, J., & Johnson, J. (2011). A developmental theory of mental attention: Its application to measurement and task analysis. In P. Barrouillet & V. Gaillard (Eds.), *Cognitive development and working memory: A dialogue between neoPiagetian theories and cognitive approaches,* (pp.13-46). Psychology.

Pietsch, S., & Jansen, P. (2012). Different mental rotation performance in students of music, sport and education. *Learning and Individual Differences, 22*(1), 159-163. https://doi.org/10.1016/j.lindif.2011.11.012

Piraksa, C., Srisawasdi, N., & Koul, R. (2014). Effect of gender on student's scientific reasoning ability: A case study in Thailand. *Procedia-Social and Behavioral Sciences*, *116,* 486-491. https://doi.org/10.1016/j.sbspro.2014.01.245

Priest, M. J. (2019). *Taking gender out of mental rotation: reexamining gender differences in mental rotation using virtual reality and 3d models* [Unpublished doctoral dissertation]. University of Wyoming.

Pruitt, S. L. (2014). The next generation science standards: The features and challenges. *Journal of Science Teacher Education*, *25*(2), 145-156. https://doi.org/10.1007/s10972-014-9385-0

Sahin, F. (2018). Yedinci sınıf öğrencilerinin bilimsel okuryazarlık düzeyi ile bazı bilişsel degişkenler arasındaki ilişkinin incelenmesi. [Doctoral dissertation, Gazi University]. Turkey Higher Education Council Thesis Center. https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

Sahin, F., & Ates, S. (2018). Ortaokul öğrencilerine yönelik bilimsel okuryazarlık ölçeği adaptasyon çalışması. *Gazi Eğitim Fakültesi Dergisi*, *38*(3), 1173-1205. https://doi.org/10.17152/gefad.406601

Sahin, F., & Ates, S. (2020). Examination of the relationship between seventh-grade students' scientific literacy among certain cognitive variables. *Education And Science*, *45*(203), 63-89. http://dx.doi.org/10.15390/EB.2020.8552

Sanchez, C. A. (2012). Enhancing visuospatial performance through video game training to increase learning in visuospatial science domains. *Psychonomic Bulletin & Review, 19* (1),58–65. https://doi.org/10.3758/s13423-011-0177-7

Scantlebury K. & Baker D. (2007). Gender issues in science education research: Remembering where the difference lies. In S. K. Abel, & N. G. Lederman (Eds). *Handbook of Research on Science Education,* (pp.257-286). Lawrence.

Scantlebury, K. (2011). *Still part of the conversation: gender ıssues in science education*. In B. J. Fraser, K. Tobin, & C. J. McRobbie (Eds). *Second International Handbook of Science Education*, (pp.499-512). Springer.

Schlatter, E., Lazonder, A. W., Molenaar, I., & Janssen, N. (2021). Individual differences in children's scientific reasoning. *Education Sciences*, *11*(9), 471. https://doi.org/10.3390/educsci11090471

Schmeck, R. R., & Grove, E. (1979). Academic achievement and individual differences in learning processes. *Applied Psychological Measurement*, *3*(1), 43-49. https://doi.org/10.1177/014662167900300106

Schöning, S., Engelien, A., Kugel, H., Schäfer, S., Schiffbauer, H., Zwitserlood, P., & ... Konrad, C. (2007). Functional anatomy of visuo-spatial working memory during mental rotation is influenced by sex, menstrual cycle, and sex steroid hormones. *Neuropsychologia*, *45*(14), 3203-3214. 10.1016/j.neuropsychologia.2007.06.011

Shayer, M., & Adey, P. S. (1992). Accelerating the development of formal thinking in middle and high school students III: Testing the permanency of effects. *Journal of Research in Science Teaching*, *29*(10), 1101-1115. https://doi.org/10.1002/tea.3660291007

Sorby S. (1999). Developing 3-D Spatial visualization skills. *Engineering Desing Graphics Journal*, *63*(2), 21-32. http://diggingdeeper.pbworks.com/.

Stamovlasis, D. (2010). Methodological and epistemological issues on linear regression applied to psychometric variables in problem solving: Rethinking variance. *Chemistry Education Research and Practice*, *11*(1), 59-68. https://doi.org/10.1039/C001048K

Stender, A., Schwichow, M., Zimmerman, C., & Härtig, H. (2018). Making inquiry-based science learning visible: The influence of CVS and cognitive skills on content knowledge learning in guided inquiry. *International Journal of Science Education*, *40*(15), 1812-1831. https://doi.org/10.1080/09500693.2018.1504346

Sundberg, S. E. (1994). *Effect of spatial training on spatial ability and mathematical achievement as compared to traditional geometry instruction* [Doctoral dissertation, University of Missouri]. University of Missouri ProQuest Dissertations Publishing. https://www.proquest.com/openview/e180e40a661b32cf3d509c8003755af3/1?pq-origsite=gscholar&cbl=18750&diss=y

Talib, C.A., Rajan, S.T., Hakim, N.W.A., Malik, A.M.A., Siang, K.H., & Ali, M. (2018, November 8-9). *Gender difference as a factor in fostering scientific reasoning skills among students*. [Paper presentation]. IEEE 10th International Conference on Engineering Education, Kuala Lumpur, Malaysia.

Taş, U. E., Arıcı, Ö., Ozarkan, H. B., & Özgürlük, B. (2016*). Pısa 2015 Ulusal Raporu*. MEB.

Terrell S. T., (2002), *The use of cognitive style as a predictor of membership in middle and High School Programs for the academically gifted.* [Paper presentation]. The Annual Meeting of the American Educational Research Association, New Orleans, Louisiana.

Tinajero, C., Lemos, S. M., Araujo, M., Ferraces, M. J., & Paramo, M. F. (2012). Cognitive style and learning strategies as factors which affect academic achievement of Brazilian University Students. *Psicologia-Reflexao E Critica*, *25*(1), 105–113. https://doi.org/10.1590/S0102-79722012000100013

Titze, C., Jansen, P. & Heil, M. (2010). Mental rotation performance in fourth graders: No effects of gender beliefs (yet?). *Learning and Individual Differences*, *20*, 459-463. https://doi.org/10.1016/j.lindif.2010.04.003.

Turkish Ministry of Education. (2016). *Uluslararası öğrenci değerlendirme programı PISA 2015 ulusal raporu,* MEB.

Turkish Ministry of Education. (2017). *Science lesson curriculum (primary and secondary school 3, 4, 5, 6, 7 and 8th grades.* Talim ve Terbiye Kurulu Başkanlığı.

Tobin, K. G., & Capie, W. (1981). The development and validation of a group test of logical thinking. *Educational and Psychological Measurement*, *41*(2), 413-423. https://doi.org/10.1177/001316448104100220

Tsaparlis, G. (1998). Dimensional analysis and predictive models in problem solving. *International Journal of Science Education, 20*, 335–50. http://dx.doi.org/10.1080/0950069980200306.

Tsaparlis, G. (2005). Non-algorithmic quantitative problem solving in university physical chemistry: a correlation study of the role of selective cognitive factors. *Research in Science & Technological Education*, *23*(2), 125-148. http://dx.doi.org/10.1080/02635140500266369.

Tsaparlis, G., M. Kousathana, and M. Niaz. (1998). Molecular-equilibrium problems: Manipulation of logical structure and of M-demand, and their effect on student performance. *Science Education, 82*, 437–54.

Uttal, D. H., Meadow, N. G., Tipton, E., Hand, L. L., Alden, A. R., Warren, C., & Newcombe, N. S. (2013). The malleability of spatial skills: A meta-analysis of training studies. *Psychological Bulletin*, *139* (2), 352–402. https://doi.org/10.1037/a0028446

Üstün, U., Özdemir, E., Cansız, M., & Cansız, N. (2020). What are the factors affecting Turkish students' science literacy? A hierarchical linear modelling study using PISA 2015 data.

Hacettepe University Journal of Education, 35(3), 720-732. https://doi.org/10.16986/HUJE.2019050786

Valanides, N.C. (1996). Formal reasoning and science teaching. *School Science and Mathematics*, *96*(2), 99-107. https://doi.org/10.1111/j.1949-8594.1996.tb15818.x

Witkin, H. A., Moore, C. A., Goodenough, D. R., & Cox, P. W. (1977). Field-dependent and field-independent cognitive styles and their educational implications. R*eview* of *Educational Research, 7*(1), 1-64. https://doi.org/10.2307/1169967

Witkin, H. A., Oltman, P. K., Raskin, E., & Karp, S. A. (1971). *A manual for the embedded figures test*. Consulting Psychologist.

Yenilmez, A., Sungur, S., & Tekkaya, C. (2005). Investigating students' logical thinking abilities: The effects of gender and grade level. *Hacettepe University Journal of Education*, *28*(28), 219-225. https://eric.ed.gov/?id=EJ808059

Yıldız, B., & Tüzün, H. (2011). Üç-boyutlu sanal ortam ve somut materyal kullanımının uzamsal yeteneğe etkileri. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, *41*, 498-508. http://dergipark.ulakbim.gov.tr.

Zimmerman, C. (2000). The development of scientific reasoning skills. *Developmental Review, 20*(1), 99–149. https://doi.org/10.1006/drev.1999.0497