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Investigating the Interrelationships among Science and Mathematics Achievement, Attitude towards STEM, and Gender

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Abstract

This study aimed to investigate the interrelationships among high school students' science and mathematics achievement, attitude towards STEM and gender. The participants of the study were 446 public high school students (240 females, 206 males) from two cities in Turkey. They were 10th, 11th, and 12th grade level students selected from two different kinds of schools which are Anatolian Religious High School and Anatolian High School. The Structural Equation Modeling (SEM) was used to determine the relationships among the variables of the study. It was found that mathematics achievement and science achievement are significantly and positively associated with students' mathematics attitude, and science attitude, but negatively related to students' attitude towards engineering and technology. On the other hand, 21st-century skills were not found to be significantly associated with both mathematics achievement and science achievement. The results also indicated that female students had higher mathematics and science achievement scores than male students. However, male students had more interest in engineering departments. The results of the study also imply the importance of the indirect effect of attitude towards STEM on the relationship between students' achievement and gender.

Keywords: Gender, mathematics attitude, science attitude, STEM attitude, Structural Equation Modeling

Fen ve Matematik Başarısı, STEM'e Yönelik Tutum ve Cinsiyet Arasındaki İlişkilerin İncelenmesi

Öz

Bu çalışma, lise öğrencilerinin fen ve matematik başarıları, STEM'e yönelik tutumları ve cinsiyetleri arasındaki ilişkileri incelemeyi amaçlamaktadır. Türkiye'nin iki farklı şehrindeki devlet okullarından toplam 446 lise öğrencisi (240 kız, 206 erkek), bu çalışmanın katılımcılarını oluşturmaktadır. Katılımcılar, Anadolu İmam Hatip Lisesi ve Anadolu Lisesi'inde okuyan 10., 11. ve 12. sınıf öğrencilerinden seçilmiştir. Çalışmada ele alınan değişkenler arasındaki ilişkiler Yapısal Eşitlik Modellemesi (YEM) kullanılarak incelenmiştir. Matematik ve fen başarısının öğrencilerin matematik ve fen tutumları ile anlamlı ve pozitif ilişkili olduğu ancak öğrencilerin mühendislik ve teknolojiye yönelik tutumları ile negatif ilişkili olduğu bulunmuştur. Öte yandan, 21. yüzyıl becerileri hem matematik başarısı hem de fen bilimleri başarısı ile anlamlı düzeyde ilişkili bulunmamıştır. Sonuçlar ayrıca kız öğrencilerin erkek öğrencilere göre daha yüksek matematik ve fen başarı puanlarına sahip olduklarını, diğer taraftan erkek öğrencilerin ise kız öğrencilere göre mühendislik bölümlerine daha fazla ilgisi olduğunu göstermiştir. Çalışmanın sonuçları ayrıca öğrencilerin STEM'e yönelik tutumlarının başarı ve cinsiyet ilişkisi üzerindeki dolaylı etkisinin önemini işaret etmektedir.

Anahtar kelimeler: Cinsiyet, fene yönelik tutum, matematiğe yönelik tutum, STEM'e yönelik tutum.

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1 | Introduction

Attitude is defined as "a learned predisposition or tendency on the part of an individual to respond positively or negatively to some object, situation, concept, or another person" (Aiken, 1970, p.551). Attitude towards mathematics or mathematics attitude can be defined as a tendency to involve in or avoid mathematics including feelings and beliefs related to the importance of mathematics performance (Ma & Kishor, 1997). Attitude towards mathematics contains behavior, beliefs, and emotional responses concerning mathematics (Moenikia & Zahed-Babelan, 2010). Similarly, attitude towards science consists of favorable or unfavorable attitude towards science, scientists, and scientific method (Aiken & Aiken, 1969; Gardner, 1975; George, 2000; Schibeci, 1977).

In certain previous studies, there was a significant relationship between the attitude and achievement of students in both mathematics and science (Abosalem, 2014; Akpinar, Yildiz, Tatar & Ergin, 2009; Singh, Granville & Dika, 2002). For instance, Akpinar, Yildiz, Tatar and Ergin (2009) found a strong relationship between attitude towards science and science achievement. Moreover, Singh, Granville and Dika (2002) found a low direct relationship between attitude towards mathematics and mathematics achievement. They also found a medium indirect relationship between attitude towards science and science achievement. On the other hand, researchers had different claims from the studies that investigated the relationships between gender and attitude towards STEM, as well as gender and mathematics and science achievements. Although in some studies, there was no significant difference in achievement and attitude towards STEM of males and females (e.g. Arhin & Offoe, 2015); in some studies, statistically, significant differences were found between the groups (e.g. Brown & Kanyongo, 2010; Mahoney, 2010; Urunibrahimoglu, 2019). Thus, additional research is required to conduct further analysis to understand how attitude towards STEM, and gender are related to the mathematics and science achievement of the students.

In the current study, the interrelations among the students' mathematics and science achievement, attitude towards STEM, and gender were investigated. Thus, the following research questions were examined using structural equation modeling:

Research questions

1. How is gender related to high school students' attitude towards STEM components, and their science and mathematics achievement?

2. How is high school students' attitude towards STEM components related to their science and mathematics achievement?

In the following parts, the studies on the relationships among science attitude and achievement; mathematics attitude and achievement; attitude towards engineering and technology, and achievement; 21st century skills and achievement; and STEM attitude and gender are presented in detail.

2 | Literature Review

Attitude towards science and achievement

In related literature, many studies found that attitude towards science or science attitude was positively correlated with science achievement (e.g. Liu, Horton, Olmanson & Toprac, 2011; Papanastasiou & Zembylas, 2002; Turhan, Aydogdu, Sensoy & Yildirim, 2008). For instance, Papanastasiou and Zembylas (2002) examined senior high school students' science attitude (involving attitude towards physics, chemistry, biology, and earth science) and their relationship with science achievement. They found that attitude towards science significantly predicted science achievement. Moreover, Ozel, Caglak, and Erdogan (2013) examined the relationship of attitude with science achievement of Turkish students who participated in the Programme for International Student Assessment (PISA) 2006 by using linear structural modeling. Aligned with the previous studies, the researchers concluded that attitude significantly (either positively or negatively) affected the science achievement of students. Bidegain and Mujika (2020) examined the relationship between science attitude and science achievement using data from 72 countries participating in PISA 2015. They found that the relationship was negative for all types of attitude (self-efficacy, interest in science, participation in science activities, and enjoyment of science) across countries. Besides, positive non-linear relationships between science attitude and achievement were determined for high science performance values.

Researchers also conducted studies on the middle and primary school level. For instance, Turhan et al. (2008) found a high positive significant relationship between 8th grade students' attitude towards science and their science achievement levels. Similarly, Liu et al. (2011) found a significant positive relationship between sixth grade students' motivation towards science and science learning. Furthermore, Akpinar et al. (2009) supported earlier findings since they found a significant correlation between attitude towards science and science achievement at the primary school level.

Attitude towards mathematics and achievement

Attitude towards mathematics is seen as a key component of mathematics achievement (Moenikia & Zahed-Babelan, 2010). There are many research studies that support a positive relationship between mathematics attitude and mathematics achievement (e.g. Choi & Chang, 2011; Ma & Kishor, 1997; Moenikia & Zahed-Babelan, 2010; Saha, 2007). Ma and Kishor (1997) performed a meta-analysis of 113 studies about the relationship between attitude towards mathematics and mathematics achievement. The researchers also noted that the meta-analysis results implied a strong relationship between attitude towards mathematics and mathematics achievement. Furthermore, Moenikia and Zahed-Babelan (2010) found attitude towards mathematics as a statistically significant predictor of high school students' mathematics achievement.

The relationship between mathematics attitude and achievement was also investigated on international scales such as PISA and the Trends in International Mathematics and Science Study (TIMSS) in some studies. Barut (2020) examined the data from PISA 2012 to investigate the relationship between affective factors concerning mathematics and mathematics literacy levels across Brazil, Norway, Singapore, and Turkey. According to their results, mathematics-related affective variables significantly affected students' mathematics literacy achievement. Besides, Choi and Chang (2011) used the data from TIMSS 2007 to find the effect of attitude towards mathematics on 8th grade students' mathematics achievement. Having a positive attitude towards mathematics and being male were among predictors that were significantly related to participants' mathematics achievement. Similarly, Geesa, Izci, Song, and Chen (2019) used data from TIMSS 2015 to predict fourth grade students' mathematics achievement in South Korea, Turkey, and the United States from the variables of home resources and attitude towards mathematics. According to their results, home resources and attitude towards mathematics were found to be significant predictors of mathematics achievement.

Attitude towards engineering and technology and achievement

There are various studies conducted about engineering and technology attitude of students within STEM (Guzey, Moore, Harwell & Moreno, 2016; Hall, 2018; Mahone, 2010; Tseng, Chang, Lou & Chen, 2011) or engineering attitude separately (Koycu & Vries, 2016; Pearson & Miller, 2012). Koycu and Vries (2016) studied attitude towards engineering and students' concept of engineering (their interest and opinions about the importance, difficulty). They found that upper secondary school children generally have a positive attitude towards engineering. Besides, Tseng et al. (2011) investigated a project-based learning (PBL) design to reveal students learning attitude towards STEM components and their change depending on the project-based learning activity. They found that students' attitude towards engineering and attitude towards technology were both significant and positive. Also, they found that students' attitude towards engineering changed significantly, and positively. Moreover, Pearson and Miller (2012) made an analysis based on the 20-year cumulative record of the Longitudinal Study of American Youth examining the records of 3062 young adults. They found out that mathematics achievement in secondary school affected engineering motivation positively. Hence, they stated mathematics as the gateway to pursue an engineering career.

Attitude towards 21st century skills and achievement

21st century skills include communication, collaboration, creativity/inventive thinking, critical thinking, and technology/innovation (Achzab, Budiyanto & Budianto, 2018; Arevalo & Ignacio, 2018; Shannon, 2015). There are various studies about 21st century skills and their relations with some variables. For instance, the study conducted by Arevalo and Ignacio (2018) examined the relationship between century skills and science achievement in 10th graders. They found out that there was a direct relationship between 21st century skill constructs and science achievement. However, studies about the relationship between attitude towards 21st century skills and achievement are limited. Due to limited studies, there is a need for further studies about the relationship between attitude towards 21st century skills and achievement.

Gender, STEM attitude, and achievement

There is a gender difference in the choices of STEM-related professions as a career path. For instance, Akgunduz (2016) investigated students' interest levels in STEM professions by analyzing the top thousand students' university placement in STEM-related departments between 2000 and 2014. The results suggested that there was a gender difference in the placement rates of students in the STEM fields and male students composed the majority of placement in STEM fields. Engineering departments contained the highest rate of students among STEM fields whereas fundamental sciences and education faculties had relatively lower students. Similarly, Ugras (2019) found a statistically significant difference in middle school students' interest levels towards STEM professions in terms of gender favoring male students. On the other hand, according to Karakaya et al. (2018) females had more interest in STEM.

Mahoney (2010) stated that high school male students had significantly more positive attitude towards STEM especially for the technology and engineering components when compared to the female students. Moreover, Ugras (2019) found a significant difference in the dimensions of engineering and technology favoring male students among middle school students. Besides, Unfried, Faber, and Wiebe (2014) conducted a study on 4th to 12th grades and found out that males had significantly more interest in engineering and technology than females. Their findings also suggested that males' engineering and technology attitude were more positive than females' attitude. On the contrary, Urunibrahimoglu (2019) found that females' attitude levels were higher for the engineering component whereas males developed a more positive attitude for science and mathematics.

The findings from the literature have contradictory results in terms of the relationship between gender and mathematics achievement. Some of the studies indicated that there is no significant difference in mathematics achievement of males and females (e.g. Lindberg, Hyde, Petersen, & Linn, 2010). Arhin and Offoe (2015) examined the performances of females and males in the high school level. The researchers concluded that there was no significant difference between the two genders in the mathematical problem-solving processes. On the contrary, some of the studies showed that females outperformed in mathematics (Brown & Kanyongo, 2010; Bulut, 1994; Robinson & Lubienski, 2011). Erdogan, Baloglu, and Kesici (2011) stated that the performances of males and females might change for particular areas of mathematics. Thus, they conducted research with high school students on both mathematics and geometry. They concluded that in both branches of mathematics, females performed better compared to males. Similarly, Clewell and Campbell (2002) claimed that the gender gap changes with the topic. For instance, females performed better in computation in primary and middle school years. As a result, in the previous studies, the researchers examined the males' and females' performance in different topics of mathematics, and they found inconsistent results. Thus, there is a need for further research to clarify the gender issue of the relationship between gender and mathematics achievement.

Similar to mathematics achievement, for science achievement the findings from previous studies differ. As some of the previous studies related to mathematics achievement, females were also more successful in science. Bezci and Sungur-Vural (2013) conducted a large-scale study with Turkish elementary school students and they found females were more successful than males in science. On the other hand, some of the studies claimed that males' science achievement was higher than females at primary and middle school level (Altınok, 2005; Bacharach, Baumeister & Furr, 2003). Moreover, Bruschi and Anderson (1994) noted that through high school years the males are more successful than females. It is seen that there was no consensus on the results of the relationship between gender and science achievement. Thus, further research might focus on this relationship.

In the literature, it is concluded that gender is related to all components of STEM. Many researchers stated that males developed more positive attitude towards STEM (Akgunduz, 2016; Ugras, 2019). However, in some of the studies, researchers noted there were differences within the STEM components in terms of gender (e.g. Urunibrahimoglu, 2019). On the other hand, males' attitude levels were higher for the engineering component than females. As a result, the gender differences need to be investigated separately for each of the components of STEM and our model was developed accordingly. Moreover, in the previous studies students' science and mathematics achievement were examined with attitude towards different components of STEM. The findings from these studies indicated that attitude towards mathematics and mathematics achievement (Barut, 2020; Choi & Chang, 2011) and also attitude towards science and science achievement were highly correlated (Liu, Horton, Olmanson & Toprac, 2011). Moreover, Aravalo and Ignacio (2018) noted that 21st century skills constructs were directly related to the science achievement of the students. As another component of STEM, engineering attitude was highly correlated with mathematics achievement of the students (Pearson & Miller, 2012). Therefore, attitudes towards STEM components have relationships with science and mathematics achievement as shown in our model. In conclusion, based on the literature review above, a following conceptual model is proposed and tested in the present study (see Figure 1).

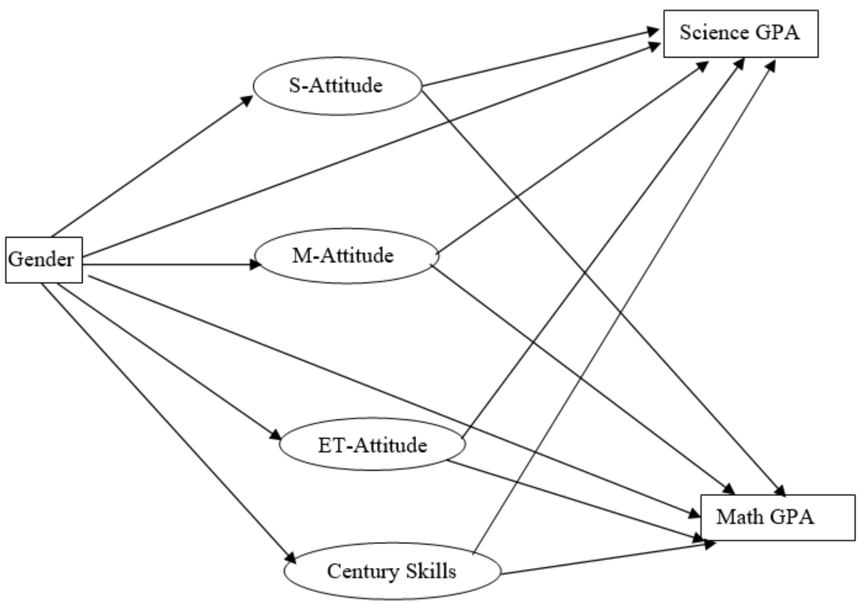

Figure 1. *The Proposed Model of The Study. S-Attitude* attitude towards Science, *M-Attitude* attitude towards Mathematics, *ET-Attitude* attitude towards Engineering, *Century Skills* attitude towards 21st Century Skills, *Science GPA* grade point average of science, and *Math GPA* grade point average of mathematics

3 | METHOD

RESEARCH DESIGN

A correlational research design was used to determine the relationships among the variables. Thus, Structural Equation Modeling (SEM) was conducted to investigate the relationships among the STEM Attitude, mathematics achievement (MGPA), science achievement (SGPA) with gender. The Structural Equation Modeling (SEM) is used for testing a set of dependence relationships among a series of constructs represented with multiple observed variables. (Malhotra, Lopes, & Veiga, 2014). The use of SEM enables researchers to test their theoretical models considering inter-relationships among constructs and observed variables; increases the accuracy of data analysis by taking account into measurement errors of the variables in the model; and examines direct and indirect relations among constructs (Hu & Bentler 1999; Schumacker & Lomax, 2010; Weston & Gore, 2006). In the current study, our model was tested with LISREL 8.8.

PARTICIPANTS

The participants of this study were 446 students from five public high schools in two cities in Turkey. They were selected by a convenient sampling method since these schools were close to researchers' working areas that provided them easy access. The data were collected from an Anatolian Religious High School (54.3%) and Anatolian High Schools (45.5%). Both schools have the same curriculum and science-based courses. However, the former school also has more religious-based elective courses. In the selected sample, 53.5% of the participants were females while 45.9% were males. Students were selected from 10^{th}, 11^{th}, and 12^{th} grade levels. Since students' last year mathematics and science achievement scores (biology, chemistry, and physics) were used, 9^{th} grade students were not included in the sample. The percentages show diversities in terms of grade levels (35.6%, 40.5%, 23.6% of the participants were 10^{th}, 11^{th}, 12^{th} grade level, respectively). Moreover, since students select their study area at the end of the 10^{th} grade, they take more science-based courses according to their study area in their 11^{th} and 12^{th} grade levels.

DATA COLLECTION TOOLS

In this study, Demographic Information Form and Attitude Towards STEM Scale were used. *The demographic information form* was used to get knowledge about participants' school ID, gender, school type, grade level, and last year mathematics and science achievement scores.

Attitude towards STEM scale. This scale was used to get information about participants' attitude towards "Mathematics", "Science", "Engineering and Technology", and "21^{st} Century Skills". Attitude towards STEM Scale is a 5-point Likert scale (from certainly disagree to certainly agree) and consists of 37 items under four sub-themes mentioned above. *"I am sure of myself when I do science."*, *"I am the type of student who does well in mathematics."*, *"I believe I can be successful in a career in engineering."*, and *"I am confident I can set my own learning goals."* are some example items about each theme. The original version of this scale was developed by The Friday Institute for Educational Innovation (2012) for measuring middle school students' STEM attitude. Then, Ozcan and Koca (2019) conducted a study to establish the validity and reliability of the Turkish version of this scale. The Cronbach's alpha coefficient was found to be .91 for the whole scale, .86 for mathematics factor, .87 for science factor, .86 for engineering and technology factor, and .88 for 21^{st} century skills factor. Thus, it can be said that the scale has good reliability considering the threshold value of .70 (Pallant, 2001). Besides, to determine the relationship between the whole scale and its four factors, correlation coefficients were calculated. It was found that those correlation coefficients ranged between .62 and .82 that showed a positive strong correlation. Based on the analyses the researchers made, they claimed that the Turkish version of the scale has a good construct validity and has a factor structure similar to that of the original scale (Ozcan & Koca, 2019).

Data analysis

In the data analysis process, male students were coded as "1" and female students were coded as "0". Then, recoding and initial data screening procedures were applied. Missing value analysis was done in IBM SPSS 25.0. Since the percentage of missing values for each variable was greater than 5% (Pituch & Stevens, 2016), 446 cases from 515 remained after the data screening process. Then, the pattern of the remaining missing values was analyzed. Since there was not a statistically significant result (p=1.000 >.05) according to Little's MCAR test (based on EM correlations), the pattern of missing values for the concerned variables was random. Then, LISREL 8.80 was used for testing the proposed model presented in Figure 1. Since the assumption of multivariate normality among the observed variables was met, the maximum likelihood estimation based on the covariance matrix was used in the analysis. Root mean square error of approximation (RMSEA); Chi-square/degrees of freedom (χ^2/df), standard root mean square residual (SRMR), Comparative Fit Index (CFI) and Normed Fit Index (NFI) fit indices were used to evaluate whether the model fitted the data. The threshold values ($2 < \chi^2/df \leq 3$; $.05 < RMSEA \leq .08$; $.05 < SRMR \leq .10$; $.90 \leq NFI < .95$; $.90 \leq CFI < .95$) suggested by Schermelleh-Engel, Moosbrugger, and Müller (2003) were considered to assess whether the model has an acceptable fit. The effect size for explained variances (R^2) on dependent variables was assessed based on threshold values ($R^2 \leq .01$, small effect size; R^2 around .09, medium effect size; $R^2 \geq .25$; large effect size) suggested by Cohen and Cohen (1983). Finally, the magnitude of factor loadings (λ) was evaluated using the threshold value (λ >.32 corresponding to about 10% variance explained of an indicator variable) suggested by Pituch and Stevens (2016).

Research ethics

At the beginning of the study, *Informed Consent Form* were distributed to all of the participants. This form informed the participants about the aim of the study and the procedure of the research. Besides, this form also provided the participants with relevant information about the rights of them such as being able to withdraw from the research at any time. Thus, participation to study was taken voluntarily. For the sake of anonymity, a number was assigned to every participant and the data analysis was done after this procedure.

4 | Findings

Assumptions of the SEM

The required assumptions of SEM were checked to conduct a reliable SEM analysis before carrying out the analysis. These are sample size, normality and linearity, outliers, residuals, and multicollinearity and singularity (Pallant, 2001; Tabachnick & Fidell, 2013). Firstly, SEM requires a large sample size. Kline (2005) provides a guideline regarding the sample size (N) in SEM techniques (N < 100, small; N between 100 and 200; medium; N > 200, large). The sample size of the current study was appropriate for reliable SEM analysis because the participants of the study included 446 cases. Secondly, normality and linearity assumption were checked. As seen in Table 1, the data were normally distributed considering the skewness, kurtosis, and 5% trimmed mean values. Thirdly, there were no influential univariate and multivariate outliers (Tabachnick & Fidell, 2013). Besides, Table 1 indicates the descriptive statistics and reliability coefficients of each variable in the study. It is found that all values were greater than .70 which indicated the scores on the scales were reliable (Pallant, 2001). When we calculated the mean scores of the measured variables considering the five-point Likert scales, they were all greater than the mid-point of the scale. For example, there were eight items for the Mathematics Attitude part of the scale. Thus, the mean score for each item was found 3.36 which is higher than 3.

Table 1. Descriptive Statistics and Cronbach's Alphas of the Measured Variables

Measured variables	Number	Mean	S. D.	5% Trimmed mean	Skewness	Kurtosis	Cronbach's alpha
1. Mathematics	446	26.91	6.013	27.09	- .44	.53	.82
2.Science	446	30.23	7.478	30.47	- .46	.28	.91
3.Engineering	446	32.64	7.741	32.99	- .57	.17	.90
4.Century Skills	446	41.64	7.166	42.05	- .99	2.34	.87
5.Math GPA	446	67.15	18.48	67.81	- .47	- .22	-
6.Science GPA	446	66.30	14.18	66.53	- .34	.21	-
7.Gender	446	1.47	.50	1.46	.14	-1.99	-

Table 2 indicates the inter-correlations among observed variables in the model. It was found that the inter-correlations among the measured variables were less than .90, thus there was no multicollinearity problem (Pallant, 2001). The correlations among the observed variables changed from .002 to .798. The most related variables were Math GPA and Science GPA (.798), while the least related variables were Engineering Attitude and Science GPA (.002).

Table 2. Correlations among the Measured Variables in the Study

Variables	1	2	3	4	5	6	7
1.Mathematics	1						
2.Science	.367	1					
3.Engineering	.303	.345	1				
4.Century Skills	.294	.281	.468	1			
5.Math GPA	.589	.253	.004	.106	1		
6.Science GPA	.528	.341	.002	.118	.798	1	
7.Gender	-.002	-.014	.268	-.068	-.184	-.117	1

MEASUREMENT MODEL OF ATTITUDE TOWARDS STEM

The measurement model of the Attitude Towards STEM involves a four-factor structure measured with 37 items. The CFA was run to test this factor structure on the data of the present study. The fit indices of the CFA analysis were in the acceptable level, according to the recommended cutoff values for goodness of fit indices proposed by Schermelleh-Engel et al. (2003), except for χ^2/df which was bigger than 3 ($\chi^2(623, N = 446) = 1994.21$, $\chi^2/df = 3.2$; *NFI* = .91, *CFI* = .94, RMSEA = .07 (90 % *CI* = .067, .073), SRMR = .07). Therefore, the suggested modifications from the LISREL output were conducted with letting error terms of a few items to be correlated in the same sub-scales. Since those items probe the same component, the association between them was reasonable. After those modifications, the measurement model of STEM-attitude with four components moderately fit the data ($\chi^2(611, N = 446) = 1265.65$, $\chi^2/df = 2.07$, *NFI* = .94, *CFI* = .97, RMSEA = .05 (90 % *CI* = .045, .053), SRMR = .06). All items were significantly loaded to the hypothesized constructs as seen in Table 3. That is, the measurement model of the STEM-attitude was confirmed in the present study, which provided evidence for the construct validity of the scores on the Attitude Towards STEM Scale.

Table 3. The Completely Standardized Factor Loadings with t-values and the Explained Variances (R^2)

	Completely Standardized Factor Loadings (t values)	*t*-values	R^2
Math 1	.49	9.91	.24
Math2	.38	7.43	.14
Math 3	.55	11.21	.30
Math 4	.64	13.60	.41
Math 5	.52	10.48	.27
Math 6	.51	10.41	.26
Math 7	.67	13.77	.46
Math 8	.78	16.95	.61
Science1	.71	16.68	.50
Science2	.81	20.26	.66
Science3	.78	19.23	.62
Science4	.72	16.97	.52
Science5	.77	18.54	.59
Science6	.71	16.82	.51
Science7	.76	18.42	.58
Science8	.48	10.20	.23
Science9	.62	14.11	.39
Engineering1	.72	16.80	.52
Engineering2	.73	16.93	.53
Engineering3	.64	14.50	.42
Engineering4	.72	16.61	.51
Engineering5	.70	16.05	.49
Engineering6	.71	16.53	.51
Engineering7	.76	18.20	.58
Engineering8	.55	11.93	.30
Enginnering9	.69	15.75	.47
Century Skill1	.52	11.04	.27
Century Skill2	.65	14.45	.42
Century Skill3	.62	13.74	.39
Century Skill4	.65	14.28	.42
Century Skill5	.73	16.98	.54
Century Skill6	.52	11.17	.28
Century Skill7	.69	15.71	.48
Century Skill8	.69	15.57	.47
Century Skill9	.42	8.64	.18
Century Skill10	.55	11.73	.30
Century Skill11	.61	13.51	.38

The results of the model testing

After the justification of the measurement model of STEM-attitude, students' science GPA, mathematics GPA, and gender (being male) were integrated into the measurement model to test the proposed SEM given in Figure 1. The SEM analysis revealed that the structural model fitted the data (χ^2(710, *N* = 446) = 1489.995, χ^2/df = 2.10, *NFI* = .93, *CFI* = .96, RMSEA = .05 (90 % *CI* = .046, .053), SRMR = .06). The tested model with the explained variances (R^2), standardized path coefficients, and insignificant paths with dashed lines was given in Figure 2. In the model, STEM attitude and gender explained 35% of the variance on science achievement and 40% of the variance on math achievement. The effect size for the explained variances of the achievement variables corresponds to a large effect size to the cut off values recommended by (Cohen & Cohen, 1983). That is, the model explained a significant amount of variance in mathematics and science achievement.

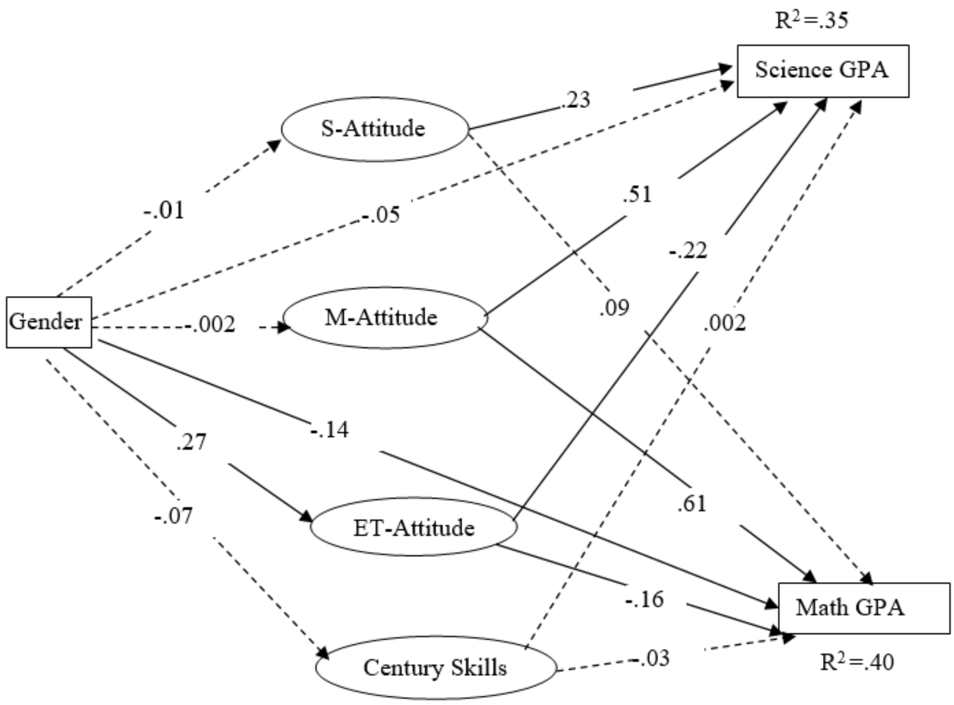

Figure 2. *The Tested Model in the Present Study*. *S-Attitude* attitude towards Science, *M-Attitude* attitude towards Mathematics, *ET-Attitude* attitude towards Engineering, *Century Skills* attitude towards 21st Century Skills, *Science GPA* grade point average of science, and *Math GPA* grade point average of mathematics

The relations of gender to science and mathematics achievement and STEM attitude

In the proposed model, gender was hypothesized to be directly related to all variables. As mentioned before, since, on the gender variable, 1s represent males and 0s represent females, the interpretation of the results related to the gender variable is based on being males. According to model testing results, gender significantly related to mathematics achievement (β = -.14, p < .05). The negative sign of the path coefficient suggests that female students had significantly higher mathematics achievement scores than male students. The indirect relation of gender through STEM attitude was insignificant (β = -.04, p > .05) but this negative indirect effect increased the path coefficient for the total effect of gender on math achievement (β = -.18, p < .05). In other words, STEM attitude led to observing a little bit more gender differences in mathematics achievement.

The direct relations of gender to science achievement were not significant (*β* = -.05, *p* > .05). The indirect effect of gender through STEM attitude was not significant (*β* = -.07, *p* > .05) but it caused the total effect of gender on science achievement to be significant (*β* = -.12, *p* < .05). That is, gender differences in STEM attitude led to significant gender differences in science achievement as well.

THE RELATION OF GENDER TO STEM ATTITUDE

As seen in Table 4 and Figure 2, gender was directly associated with attitude towards engineering and technology (*β* = .27, *p* < .05). The male students demonstrated higher attitude towards engineering and technology than female students. On the other hand, the direct relations of gender to attitude towards science (*β* = -.01, *p* > .05), attitude towards mathematics (*β* = -.002, *p* > .05), and century skills (*β* = -.07, *p* > .05) were not significant. That is, male and female students demonstrated similar attitude towards mathematics, science, and century skills in the current study.

Table 4. Direct, Indirect, and Total Relations of Gender to Achievement and Attitude towards STEM

Variables		MGPA			SGPA			Mat	Sat	Eat	Cat
		Direct	Indirect	Total	Direct	Indirect	Total	Direct	Direct	Direct	Direct
Gender	*β*	-.14	-.04	-.18	-.05	-.07	-.12	-.002	-.01	.27	-.07
	t	-3.3	-1.17	-3.95	-1.24	-1.78	-2.49	-.046	-.28	5.32	-1.32

THE RELATIONS OF THE COMPONENTS OF STEM ATTITUDE TO SCIENCE AND MATHEMATICS ACHIEVEMENT

Mathematics attitude was significantly related to both mathematics achievement (*β* = .61, *p* < .05) and science achievement (*β* = .51, *p* < .05). Similarly, science attitude was significantly related to science achievement (*β* = .24, *p* < .05) while it was not significantly associated with mathematics achievement (*β* = .09, *p* > .05). Engineering and technology attitude were significantly and negatively related to both mathematics achievement (*β* = -.16, *p* < .05) and science achievement (*β* = -.22, *p* < .05). Finally, the non-significant relations were observed between attitude towards century skills and mathematics achievements and science achievement.

Table 5. The Relations of the Components of STEM-attitude to Science and Mathematics Achievement

Variables		MGPA	SGPA
Mat	*β*	.61	.51
	t	8.32	7.48
Sat	*β*	.09	.23
	t	1.87	4.54
Eat	*β*	-.16	-.22
	t	-2.81	-3.73
Cat	*β*	-.03	.002
	t	-.67	.03

5 | DISCUSSION & CONCLUSION

In the current study, the researchers focused on different factors which are attitude towards Science, Mathematics, Engineering, 21st Century skills, students' gender, and their science and mathematics achievements by the use of SEM. It was found that the proposed model explained a significant amount of variance in mathematics and science achievement. These results are in parallel with the literature examining relations between science attitude and science achievement (e.g. Liu et al., 2011; Papanastasiou

& Zembylas, 2002; Turhan et al., 2008), mathematics attitude and mathematics achievement (e.g. Choi & Chang, 2011; Ma & Kishor, 1997; Saha, 2007), and also gender and science and mathematics achievement (e.g. Brown & Kanyongo, 2010), and gender and STEM attitude (e.g. Unfried et al., 2014).

In our testing model, it was found that gender had a significant direct relationship with mathematics achievement in the favor of females. Although the findings in the literature have contradictory results in terms of the relationship between gender and mathematics achievement, some studies showed that females outperformed in mathematics (Brown & Kanyongo, 2010; Bulut, 1994; Robinson & Lubienski, 2011). For example, Clewell and Campbell (2002) in their study concluded that the gender gap changes with the topic since females performed better in computation in primary and middle school years. Besides, Erdogan et al. (2011) in their study worked with high school students on both mathematics and geometry and they noted that in both branches of mathematics, females performed better compared to males.

On the other hand, the direct relation between gender and science achievement was not significant in this study. However, the indirect effect via STEM attitude caused the total effect of gender on science achievement to be significant. In the literature, it was seen that even in some studies females are more successful than males in science (Bezci & Sungur-Vural, 2013), some studies indicated that males' science achievement was higher than females (e.g. Altınok, 2005; Bacharach et al., 2003) in primary and middle school level. Thus, the results of the study are consistent with the results of the previous studies.

When the relationship between gender and STEM-attitude was examined, it was found that gender was directly associated with attitude towards engineering and technology. The male students demonstrated higher positive attitude towards engineering and technology than female students. Mahoney (2010) found that male students have a significantly more positive attitude towards STEM, particularly for the technology and engineering components, when compared to female students. The results were also parallel with Akgunduz's study (2016) that gender affects students' choices of STEM-related professions in which male students compose the majority of placement in STEM fields. Besides, in our model, we found that male and female students demonstrated similar attitude towards mathematics, science, and century skills in the current study. These findings support the results of other studies. For example, Unfried et al. (2014) in their study found that attitude towards mathematics did not change according to gender. However, males had significantly more interest in science fields, engineering, and technology than females. Their findings also suggested that males' engineering and technology attitude were more positive than females' attitude.

In the current study, it is found that mathematics attitude was significantly related to both mathematics achievement and science achievement. According to the meta-analysis study of Ma and Kishor (1997) in which they examined 113 studies, there was a strong relationship between attitude towards mathematics and mathematics achievement. The study of Moenikia and Zahed-Babelan (2010) showed that mathematics' attitude was a statistically significant predictor of high school students' mathematics achievement. The research of Barut (2020) in which he analyzed the data from PISA across Brazil, Norway, Singapore, and Turkey, indicated that mathematics-related affective variables significantly affected students' mathematics literacy. Moreover, according to the results of the studies conducted by Choi and Chang (2011) and Geesa et al. (2019) in which they used the data from TIMSS 2007 and TIMMS 2015 respectively, the positive attitude towards mathematics was found one of the strong predictors that were significantly related to participants' mathematics achievement. Also, the results of the previous studies show that there is a strong and statistically significant relationship between attitude towards mathematics and mathematics achievement (Babelan, 2010; Barut, 2020; Geesa et al. 1997; Moneikia et al. 2011; Song & Chen, 2019). Therefore, the results of the study correspond with the results of the previous studies. However, in the literature, there is not encountered with results showing the relationship between mathematics attitude and science achievement.

Moreover, in the current study, it is found that science attitude was significantly related to science achievement. However, it was not significantly associated with mathematics achievement. In the literature, researchers found that science attitude predict students' science achievement (Papanastasiou & Zembylas, 2002; Ozel, Caglak & Erdogan, 2013). Also, the previous results show that there is a significant and positive relationship between attitude towards science and science achievement (Akpinar et al., 2009; Bidegain & Mujika, 2020; Liu et al. 2011; Turhan et al. 2008). Therefore, the findings from this study aligned with the literature.

Furthermore, in this study, it was found that engineering and technology attitude significantly and negatively affected both mathematics achievement and science achievement. According to the research conducted by Pearson and Miller (2012), in which they made an analysis based on the 20 – year cumulative record of the Longitudinal Study of American Youth, examining the records of 3062 young adults, mathematics achievement in secondary school affected engineering motivation positively. In other words, success in mathematics is the starting point of an engineering career. However, to our knowledge, there is no study directly investigating the effect of engineering and technology attitude on mathematics and science achievement. Hence, there is a need for further studies examining these relationships and our study might contribute to the literature in terms of indicating how engineering and technology attitude related to mathematics and science achievement.

Finally, in the study, non-significant relations were observed between attitude towards century skills and mathematics achievement and science achievement. However, according to the results of the study conducted by Aravalo and Ignacio (2018) in which they examined constructs (digital age literacy, inventive thinking, effective communication, and high productivity) and overall, of 21st century skills' relation to science achievement in 10th grade students, they found out that there is a direct and positive relationship between century skills and science achievement. Since there has been a limited number of studies addressing the relationships between century skills and science and mathematics achievement, there is a need for more research to investigate how century skills are associated with mathematics and science achievement.

This study points out the importance of the indirect effect of STEM attitude on the relationship between gender and achievement. The difference in engineering and technology attitude between males and females increased the gender difference in science and mathematics achievement. The possible explanation of this result might be that the negative tendency of female students towards technology and engineering areas led them to study science and mathematics more compared to male students or vice versa. Therefore, addressing gender differences in engineering and technology attitude can also contribute to gender equality in science and mathematics achievement.

In our study, our model explained the factors that affect students' mathematics and science achievement. Since each component of STEM attitude related to both science and mathematics achievement, the teachers might benefit from the findings of the study to increase students' achievement. When students have difficulties in science and mathematics, the tasks that might develop positive STEM attitude can be used in the classroom to support students' achievement. Furthermore, since there is a very limited number of research studies investigating the relationship between engineering and technology attitude and mathematics and science achievement, and the relationship between 21st century skills and mathematics and science achievement, further comparison studies are needed to test whether similar relations to those observed in the current study will be found by other researchers.

Finally, as one limitation of this study, it should be noted that the schools participating in the current study were selected conveniently; thus, they might not represent the population in all related characteristics. Therefore, the replication studies in other settings are recommended to ensure generalizability of the results observed in this study. Another limitation is that two types of schools namely, Anatolian Religious High School and Anatolian High Schools were included in the study, which also decreases the external validity of the study. Future studies can also consider other school types such as science and vocational high schools.

Statements of publication ethics

The research has no unethical problem, and no research and publication ethics have been observed.

Researchers' contribution rate

There is an equal contribution to the study.

Conflict of interest

There is no conflict of interest.

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