The Role of Gender and Attitudes Toward Science in Fourth and Eighth Graders' Science Achievement in South Korea, Turkey, and the United States

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Science, technology, engineering, and mathematics (STEM) education is an international focus in teaching and learning, and factors influencing students' science achievement vary throughout the world. Guided by the Social Role and Expectancy-Value Theories, we investigated the role of fourth and eighth graders' gender and attitudes toward science in science achievement in the Trends in International Mathematics and Science Study (TIMSS) 2015. In this study, we focused on South Korea, Turkey, and the United States, where students' science achievement scores varied substantially in TIMSS 2015. Findings indicated that having a positive attitude toward science positively predicted students' science achievement scores in fourth and eighth grades. Students' science scores varied slightly but significantly between male and female students in South Korea and Turkey, controlling for their attitudes toward science. Longitudinal studies of science achievement may be included in further research.

Keywords: *Science, STEM Education, Self-Efficacy, Student-level Factors, Global Achievement, TIMSS, Social Role Theory, Expectancy-Value Theory*

Science, technology, engineering, and mathematics (STEM) education is a growing field of study throughout the world to promote career and college readiness for all students. The focus on national and international academic achievement and workforce development in STEM fields have cultivated global competition (National Science Foundation, 2018). Science is one of the key components of STEM, and students' science achievement in early grades may predict their achievement in school, as well as career choices in the future. For example, a recent study showed that starting from kindergarten entry, there are gaps in students' general knowledge, which predicts students' general knowledge in the first grade and then science achievement in later school years (from third to eighth grades) (Morgan et al., 2016). To close the achievement gap among students, researchers suggest early intervention programs for students in their early grades (Morgan et al., 2016). If the achievement gap remains among students throughout high school and college years, it may affect their major and career choices in the future (Dou et al., 2019).

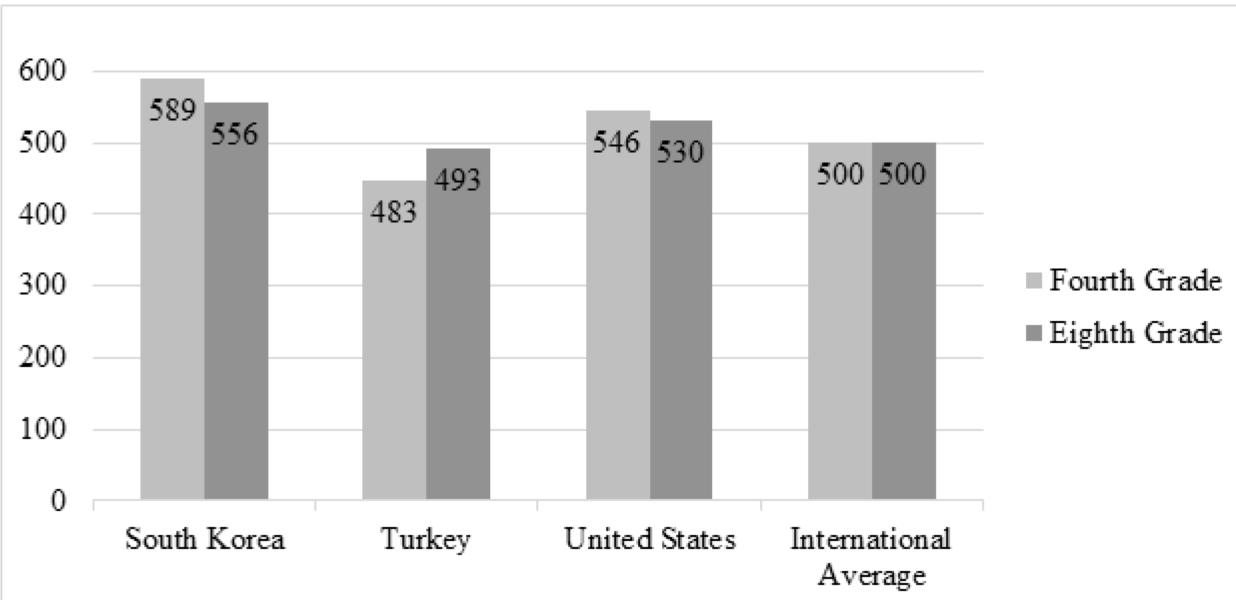
Gender discrepancy also exists in STEM fields. For example, it has been found that female students' intrinsic motivation changes between seventh and eighth grades, and there is a difference between gifted female and male students' science achievement scores in middle school (Edwards, 2019). Relatedly, as of 2017, women are underrepresented in science and engineering jobs in the United States. For example, women represent 52% of the college-educated individuals in the workforce, but 29% of science and engineering jobs are female occupied (National Science Board, National Science Foundation, 2020). Similar to the United States statistics, 55% of women (aged 25 to 54) are in the general workforce throughout the world, and only 28.8% of researchers are female globally (United Nations Equity for Gender Equality and Empowerment of Women, 2019). As a result, educational stakeholders provide various opportunities and activities (e.g., STEM afterschool programs and competitions) to motivate students and encourage their career choices in STEM disciplines in the future (e.g., Kang et al., 2019; Miller et al., 2018).

In response to the worldwide competition in STEM disciplines, educational stakeholders and policymakers refer to data from large-scale international studies (e.g., Trends in International Mathematics and Science Study [TIMSS], Programme for International Student Assessment [PISA]) to better understand students' home, school, and cultural relationships to academic success, in addition to their achievement scores (International Association for the Evaluation of Educational Achievement [IEA, 2017]; Organisation for Economic Co-operation and Development [OECD], 2016). TIMSS is a well-known international study administered every four years to students in fourth and eighth grades. TIMSS data provide information regarding trends in mathematics and science at fourth and eighth grades across participating nations (Martin, Mullis, et al., 2016). In addition to mathematics and science achievement, TIMSS data includes information related to students' home environments, backgrounds, and attitudes toward mathematics and science.

The purpose of this study is to explore the relation between gender and attitudes toward science in science achievement for fourth and eighth grade students in three countries: South Korea, Turkey, and the United States. In TIMSS 2015, South Korea is one of the top-achieving countries in science. The United States is slightly above, and Turkey is below the international average score in both fourth and eighth grades (Martin, Mullis, et al., 2016) (see Figure 1). The international average is the scale center point determined by TIMSS organizers. Science content domains vary between grade levels in TIMSS 2015 (see Table 1) with topic areas within each domain. Based on the variance in students' science achievement among these three countries and the countries' focus on STEM education fields, we aim to explore the role of students' gender and the attitudes toward science in fourth and eighth graders' science achievements in South Korea, Turkey, and the United States.

Figure 1

TIMSS 2015 Fourth and Eighth Grade Science Achievement Scores for South Korea, Turkey, and the United States



Note. Information received from Martin, Mullis, et al., 2016

Table 1

TIMSS 2015 Fourth and Eighth Grade Science Content Domains

Science content domains	
Fourth Grade	Eighth Grade
Life science	Biology
Physical science	Chemistry
Earth science	Physics
	Earth science

Note: Items retrieved from Martin, Mullis, et al., 2016.

Research Questions

Given the gender gap in STEM disciplines, and the literature and recent trends in TIMSS 2015, we hypothesized that there would be statistical differences in science achievement scores between male and female students in fourth and eighth grade, respectively; fourth and eighth grade students' attitudes toward science are significantly associated with their science achievement. We examined the following research questions in this study:

1. What are the differences in students' gender and attitudes toward science in South Korea, Turkey, and the United States?

2. What are the unique contributions of gender to fourth and eighth graders' science achievement in South Korea, Turkey, and the United States?

3. What are the unique contributions of attitudes toward science to fourth and eighth graders' science achievement in South Korea, Turkey, and the United States?

Literature Review

As the world becomes more reliant on technology, STEM knowledge and skills have become more critical to students in all areas of the world. Patall et al. (2018) explained that as the global economy continues to grow in the ways of scientific and technological advancements, the need for more students as future workers in STEM fields becomes more demanding. For example, the United States Bureau of Labor Statistics (2020) found that "employment of computer and information research scientists is projected to grow 16 percent from 2018 to 2028, much faster than the average for all occupations" (p.1). This demand in the job market for people who are proficient in computers, data-mining, and programming has brought an equal demand for effective STEM courses to be taught to students starting in early grades to prepare students for success in STEM-related career fields and higher education programs in the future.

The concept of integrating science and mathematics in education has been discussed for many years and tested with positive results at various grade levels. Recently, several experts have called for an interdisciplinary approach that moves beyond mathematics and science, and incorporates engineering and technology (e.g., English, 2016; Havice, 2015; Honey et al., 2014). As a result, the STEM education movement has developed into a mainstream topic in teaching and learning conversations and methods over the past decade. According to Kennedy and Odell (2014),

> STEM education has evolved into a meta-discipline, an integrated effort that removes the traditional barriers between these subjects, and instead focuses on the innovation and the applied process of designing solutions to complex contextual problems using current tools and technologies. (p. 246)

The demand for jobs in STEM-related fields is expected to steadily increase over time, however research indicates that as students enter the middle grades of school, their interest in and attitudes toward STEM disciplines become more negative (Degenhart et al., 2007). Researchers have conducted various studies exploring students' attitudes regarding STEM, and many programs have been developed to increase students' engagement in these disciplines (Chittum et al., 2017; Degenhart et al., 2007; Redmond et al., 2011). For example, Degenhart et al. (2007) investigated middle school students' attitudinal changes toward STEM-related careers after a year-long classroom interaction with a National Science Foundation graduate fellow as a STEM specialist. Analyses of the results indicated that the practical learning experiences provided by the STEM specialist increased students' subject-area confidence, thereby increasing their STEM-related self-efficacy and their attitudes about pursuing a STEM-related career.

Similarly, Redmond et al. (2011) conducted a study in which middle school teachers partnered with university engineers to implement project-based engineering activities into the existing mathematics and science curriculum. The mixed methods study took place over two years and involved 1287 students in sixth and seventh grade. As a result, the implemented STEM program positively impacted students' effort toward science and mathematics, their awareness of engineering, and interest in a career in a STEM-related field. Chittum and colleagues (2017) also designed an afterschool and summer program, Studio STEM, to engage upper-elementary and middle grade students in STEM concepts and practices. The findings showed that students who participated in Studio STEM program reported significantly higher college plans, science attainment value, science interest value, science utility value, and science competence beliefs than their peers who did not participate in the Studio STEM program.

Given the importance of science achievement for workforce development and global competition, the U. S. Department of Commerce, Economics and Statistics Administration (2011), and National Science Board, National Science Foundation (2020) reported that although women make up half of the workforce, they are greatly underrepresented in STEM fields. This phenomenon is a result of a series of intricate variables that explain the differences between males and females in the workforce, such as temperament, value, and preference for risk and prestige (Baker & Cornelson, 2018; Goldin, 2015). More specifically, differences in attitudes toward STEM are likely to be a crucial contributor to the gender gap in STEM career choices.

While both males' and females' self-efficacy and attitudes toward mathematics and science decline as they enter the middle school grades, researchers indicated an alarming discrepancy with females' confidence and achievement falling at a much more distressing rate (Naizer et al., 2014). However, STEM-related attitudes and skills, as two malleable factors, have demonstrated the potential in shortening the gender gap in STEM fields. Naizer et al. (2014) contended that engaging students, particularly females in STEM subjects, is possible through targeted ongoing exposure and instruction. Through the implementation of a two week STEM summer program and follow up meetings throughout the academic year, researchers found the science and mathematics self-efficacy of participants of the study (66 middle school students) increased, as well as their problem-solving abilities. The study's findings indicated the gender differences found at the commencement of the study had diminished. Naizer et al. (2014) argued that incorporating STEM programs were valuable for all students and might reduce gender inequality in the STEM fields in the future.

Students' achievement in science may drive students' future success in STEM fields, so students must have an interest in science to be motivated to achieve in the field (Cheung, 2018). Female students, compared to their male peers, experience negative stereotypes about their abilities in science, which may contribute to lower performances on tests and lower aspirations for STEM careers in the future (Hill et al., 2010). Hill and colleagues (2010) emphasized the role of environment and culture in STEM fields and programs that influence female students' confidence and skills in STEM disciplines and jobs. Relatedly, Han (2016) examined the associations between national education systems and the gender gap in STEM-related occupational expectations across 49 countries by using data from the PISA. Results indicated that female students are more likely than male students to have a health services occupation. In addition, female students are less likely than male students to have a career in computing and engineering.

In TIMSS 2015, science achievement scores of fourth graders are reported for 47 countries, and eighth graders' science achievement scores are reported for 39 countries (IEA, 2015a, 2015b). According to TIMSS 2015, fourth grade male and female science achievement scores were similar in more than half of the participating countries. Female students had higher achievement scores than male students' scores in only 11 countries (e.g., Bahrain, Finland, Kazakhstan, Saudi Arabia, Sweden) with the average difference of 24 points between the scores of males and females in those 11 countries. In Turkey, female students' science scores were an average of one point higher than the male students' science scores in the fourth grade. On the other hand, male students performed better than female students in 11 countries (e.g., Czech Republic, Hungary, South Korea, United States), with the average difference of 8 points.

When eighth graders' science achievement scores were compared between genders, there was no difference between achievement scores of female and male students in 20 countries (IEA, 2015a, 2015b). Female students performed better in science than their male peers in 14 countries (e.g., Kuwait, Malta, Saudi Arabia, Turkey) with an average difference of 28 points. Male students had higher science achievement scores in five participating countries (e.g., Chile, Hungary, United States, South Korea), with the average difference of 11 points. There was an average of a three-point difference between male and female students in South Korea.

Even though female and male students had similar or the same science achievement scores in half of the participating countries in fourth and eighth grades, the differences between female and male students' science achievement scores still exist and might be a result of students' attitudes toward science or cultural differences. Numerous studies about elementary and secondary school age students' academic achievement in mathematics exist (e.g., Chen, 2014; Geesa, et al. 2019a; Lubinski et al., 2014; Siegler et al., 2012). Similar to mathematics, science is a discipline that affects students' success and future STEM career choices. However, research about students' science achievement, and connections between success in science with their home and individual influences is lacking at this time (Geesa et al., 2019b).

Science Education in South Korea, Turkey and the United States

The emphasis on science education in each country varies throughout the world. Relatedly, the TIMSS science achievement scores differ among South Korea, Turkey, and the United States. For example, South Korea is consistently ranked amongst the top for global education (Martin, Mullis, et al., 2016). According to TIMSS 2015 data, South Korean fourth grade students ranked second in science achievement amongst peers in other countries. Similarly, South Korea was ranked fourth for eighth grade science achievement (Martin, Mullis, et al., 2016). The achievement of South Korean students may be influenced by their science curriculum. All students in elementary and middle schools use a national science curriculum in South Korea (Sang et al., 2016). According to the 2015 science curriculum, students are expected to understand basic science concepts through activities involving inquiry; develop an interest in and curiosity about natural phenomena and objects; and obtain scientific thinking skills and creative problem-solving abilities (Korean Ministry of Education, 2017). In addition, South Korean students' higher achievement scores could be a result of having education fever (Kim et al., 1993; Lee, 2003), as well as the popularity of attending private cram schools after regular school hours (Choi & Cho, 2016; Kim & Park, 2010).

Turkey, on the other hand, is one of the countries where students' achievement scores in science have been rising in recent years at fourth and eighth grades. However, their TIMSS 2015 science achievement scores were below the international average score. Fourth graders' science achievement was ranked 35th among 47 participating countries, and eighth graders' science achievement was ranked 21st among 39 participating countries. In Turkey, students in public elementary and middle schools have free and compulsory education (Özdemir et al., 2016). Fourth grade students take three hours of science courses weekly, while eighth grade students take four hours of science courses each week (Ministry of National Education, 2018). The main objective of the science curriculum in elementary and middle schools is to provide student-centered lessons as well as develop students' competencies, such as problem solving, reasoning, project-based learning, and cooperating with others (Ministry of National Education, 2018).

Since 2016, the Ministry of National Education emphasized STEM education and made promising attempts to expose students and teachers to STEM in elementary and middle school grades (Ministry of National Education, General Directorate of Innovation and Educational Technologies [YEĞİTEK], 2016, 2017, & 2018). Higher education institutions also designed resources and professional development opportunities to support teachers in STEM teaching (Bahçeşehir University, STEM Center [BAUSTEM], 2018).

In comparison to the national curriculum of Turkey and South Korea, each state in the United States is responsible for their education program (Malley et al., 2016). Students in the United States participate in public education beginning in kindergarten through the end of twelfth grade. Since each state governs their education curricula differently, science education differs among states. As an influencer of science education curriculum since 2013, Next Generation Science Standards (NGSS) focus on areas related to engineering, natural science, physical science, and science-related practices for students in all grades (Mullis et al., 2016; Next Generation Science Standards, 2013). Life sciences, earth and space sciences, and physical sciences are usually a part of the science curriculum in the United States (Mullis et al., 2016). College and Career Readiness (CCR) standards and the Every Student Succeeds Act (ESSA) are components of the United States' recent focus on students' knowledge, success, and achievement in STEM fields (Council of Chief State School Officers, 2018; ESSA, 2015; Malin et al., 2017). Local and national organizations support STEM programs, supplies, and professional development in elementary and secondary schools to focus on students' STEM-related careers and higher education options in the future. However, it is critical to better understand students' attitudes toward science and achievement in sciences through an international lens for educators and leaders to better support their success in STEM fields.

Theoretical Framework

In elementary and middle school years, students' attitudes toward science might be influenced by a variety of factors, including cultural and parental expectations, as well as students' own interest areas. Due to those factors, Social Role Theory and Expectancy-Value Theory (EVT) are the frameworks guiding the current study. Social Role Theory asserts that "gender stereotypes form and change in response to observing women and men in differing social roles within a culture" (Miller et al., 2015, p. 631). The gender stereotypes may be developed by messages in mass media, teachers' and parents' opinions, and students' prior experiences in STEM fields. Bidirectional relationships also exist between gender stereotypes and performance (Lindberg et al., 2010; Petersen & Hyde, 2014). That is, STEM fields have traditionally been male-dominated fields and male students tend to outperform females in STEM fields. Meanwhile, female students' excellence in STEM fields can shape and strengthen the gender role. Even though male students are dominating STEM fields, social roles vary throughout the world (Petersen & Hyde, 2014).

Expectancy-Value Theory (EVT) (Eccles, 2009) is adopted as an additional theoretical framework of the study. The origin of EVT can be traced back to Atkinson's (1957) work, in which Atkinson suggested that one's performance and choice were linked to their task-related expectancy and value beliefs. Building on Atkinson's (1957) theory, Eccles (2009) proposed and empirically validated the EVT model to explain individuals' task persistence, choice, and motivation. There are two essential elements in the EVT: 1) the "expectancy" piece taps into individuals' beliefs about their abilities in accomplishing certain tasks; and 2) the "value" part concerns three dimensions of value that people place on a given task (i.e., importance, interest, and usefulness) (Wigfield & Cambria, 2010). EVT has been widely used by researchers trying to understand the gender gap in STEM-related academic achievement and career choices.

For instance, Ball and colleagues (2016) found that EVT constructs were related to elementary students' STEM-related academic motivation and later course selections. Relatedly, despite similar mathematics performances and attitudes, female adolescents expressed less interest in mathematics- and science-oriented future career choices, as compared to the interests of males (Lubinski & Benbow, 2006). Additional research reported that females lean more toward working with people in careers, and males are more likely to choose to work with objects (Diekman et al., 2011). These findings indicate that females may place less value in choosing careers in STEM, which are usually considered "object-oriented" (Hill et al., 2010). Aligned with our theoretical frameworks, we chose to investigate fourth and eighth grade students' gender (reflecting with the Social Role Theory, [Miller et al., 2015]) and the attitudes toward science (corresponding to the value aspect in EVT [Eccles, 2009]) in relation to their science achievements.

Method

Participants were 21,154 fourth and 21,609 eighth grade students who participated in TIMSS 2015 in South Korea, Turkey, and the United States (see Table 2). TIMSS 2015 participants were students from fourth and eighth grades; therefore, our analysis only included these two available grades. From the TIMSS 2015 International Database, publicly available data were obtained and analyzed for South Korea, Turkey, and the United States from fourth and eighth grade reports. TIMSS 2015 science achievement and student background questionnaire data in these three countries were utilized in this research.

Table 2

TIMSS 2015 Fourth and Eighth Grade Science Participants and Achievement Scores for South Korea, Turkey, and the United States

	Fourth Grade		Eighth Grade	
Country	*N*	TIMSS 2015	*N*	TIMSS 2015
South Korea	4,669	589	5,309	556
Turkey	6,456	483	6,079	493
United States	10,029	546	10,221	530
Total *N*	21,154	-	21,609	-

Note. Information retrieved from IEA, 2017; and Martin, Mullis, et al., 2016.

The International Association for the Evaluation of Educational Achievement (IEA) International Database Analyzer was used to analyze results (The IEA International Database Analyzer, 2013). From the student background questionnaire, we selected 16 items to measure students' attitudes toward science in fourth grade and 26 items in eighth grade. Examples of items included: *I enjoy learning science; I learn many interesting things in science; I learn things quickly in science; My teacher tells me I am good at science; Science is harder for me than for many of my classmates;* and *Science makes me confused.*

In order to measure the internal reliability of the attitudes toward science composite variables, Cronbach's alpha coefficients were calculated by SPSS Statistics software (Neuschmidt, 2007); .91 for 16 items at the fourth grade and .95 for 26 items at the eighth grade. For data analysis, the composite variable of "attitudes toward science," and plausible variables of students' general science achievement were included. The TIMSS 2015 dataset includes five plausible values that measure students' achievements while accounting for unobserved population parameters (OECD, 2016). We used the IEA International Database Analyzer (2013) to assign appropriate sampling weights to the achievement scores, as recommended by IEA (2017). Higher scores in the composite variable mean more positive attitudes toward science. For this study, descriptive and multiple regression analyses were conducted. Additionally, data used in this study were missing at random, and were handled with pairwise deletion methods.

Results and Recommendations

Tables 3 and 4 provide descriptive statistics for gender and attitudes toward science in the fourth and eighth grades in South Korea, Turkey, and the United States. For research question one, "*What are the differences in students' gender and attitudes toward science in South Korea, Turkey, and the United States*?", descriptive data analysis results showed that the total number of participating females and males in both grades across three countries were approximately equal (Table 2). South Korean students scored higher on the science achievement assessment than students in the other two countries scored. This achievement rank remained the same in both fourth and eighth grades.

Among the three countries, South Korean students scored the lowest and Turkish students scored the highest on the attitudes toward science scale at the fourth grade, when compared to the students' attitude of the other two countries (M_{SK} = 49.7, SD_{SK} = 9.28; M_T = 58.03, SD_T = 6.09; M_{US} = 53.80, SD_{US} = 9.92). Similar patterns can be seen at the eighth grade (M_{SK} = 65.92, SD_{SK} = 15.31; M_T = 84.05, SD_T = 14.58; M_{US} = 79.88, SD_{US} = 16.22). Relatedly, the descriptive statistics of female and male students' science achievement at the fourth and eighth grades indicated similar trends across three countries (see Tables 3 & 4).

Table 3

Descriptive Statistics of Fourth Graders in South Korea, Turkey, and the United States

	South Korea (*N*=4412)		Turkey (*N*=5936)		United States (*N*=8661)	
Fourth Graders (Minimum: 16, maximum: 64 points)	*M*	*SD*	*M*	*SD*	*M*	*SD*
Attitudes Toward Science (female)	48.90	9.00	58.74	6.41	53.40	10.04
Attitudes Toward Science (male)	50.68	9.34	57.33	7.47	54.16	9.82

Note. Original data collected from Martin, Mullis, et al., 2016.

Table 4

Descriptive Statistics of Eighth Graders in South Korea, Turkey, and the United States

	South Korea (N=5190)		Turkey (N=5478)		United States (N=9235)	
Eight Graders (Minimum: 26, maximum: 104 points)	*M*	*SD*	*M*	*SD*	*M*	*SD*
Attitudes Toward Science (female)	63.93	14.37	85.18	14.55	78.66	16.48
Attitudes Toward Science (male)	67.53	15.79	82.70	14.48	81.03	15.91

Note. Original data collected from Martin, Mullis, et al., 2016.

To answer the second and third research questions, the roles of gender and attitudes toward science in fourth and eighth grade students' science achievement were investigated. Multiple regressions were conducted using the IEA International Database Analyzer for each of the three countries (see Tables 5 and 6). For the second research question, "*What are the unique contributions of gender to fourth and eighth graders' science achievement in South Korea, Turkey, and the United States?,"* the results showed that gender weakly, but significantly predicted fourth grade students' science achievement in South Korea and Turkey (β_{SKG} = .06, p = .003 β_{TG} = .04, p = .005; β_{USG} = .02, p = .25) but not in the United States, holding attitudes toward science constant. Females were treated as the reference group in the data.

Very limited variance was explained by the fourth-grade regression models (R^2_{SK} = .11; R^2_T= .19; R^2_{US} = .05). The results suggested that fourth grade males were more likely to score higher in science than females in South Korea and Turkey. Similar to fourth grade students, gender weakly, but significantly predicted eighth grade students' science achievement in South Korea and Turkey (β_{SKG} = -.04, p = .005; β_{TG} = -.08, p <.001; β_{USG} = .01, p = .21) but not in the United States, holding attitudes toward science constant. Different than the gender effect in the fourth grade, eighth grade females in the United States were associated with higher science achievement scores than males had in South Korea and Turkey. However, the eighth grade regression models demonstrated limited explanatory power (R^2_{SK} = .23; R^2_T = .07; R^2_{US} = .09).

Table 5

Multiple Regression Results with Gender and Attitudes Toward Science as Predictors by South Korea, Turkey, and the United States of Fourth Grade Students

		β Coefficient	Standardized β Coefficient	*t*
South Korea (*N*=4669)	Gender	6.09	.06	2.79**
	Attitudes Toward Science	2.16	.32	17.00***
Turkey (*N*=6456)	Gender	6.82	.04	2.55**
	Attitudes Toward Science	5.89	.44	20.41***
United States (*N*=10029)	Gender	2.82	.02	1.36
	Attitudes Toward Science	1.77	.22	16.72***

Note. Original data collected from Martin, Mullis, et al., 2016.

*ρ <.05, ** ρ <.01, *** ρ <.001

Table 6

Multiple Regression Results with Gender and Attitudes Toward Science as Predictors by South Korea, Turkey, and the United States of Eighth Grade Students

		β Coefficient	Standardized β Coefficient	*t*
South Korea (*N*=5309)	Gender	-5.69	-.04	-2.57**
	Attitudes Toward Science	2.55	.50	37.37***
Turkey (*N*=6079)	Gender	-14.69	-.08	-4.73***
	Attitudes Toward Science	1.70	.26	14.64***
United States (*N*=10221)	Gender	1.39	.01	.72
	Attitudes Toward Science	1.58	.32	22.53***

Note. Original data collected from Martin, Mullis, et al., 2016.

*ρ <.05, ** ρ <.01, *** ρ <.001

For research question 3, "*What are the unique contributions of attitudes toward science to fourth and eighth graders' science achievement in South Korea, Turkey, and the United States*?," attitudes toward science significantly predicted fourth graders' science achievement ($\beta_{SKAT} = .32$, $p < .001$; $\beta_{TAT} = .44$, $p < .001$; $\beta_{USAT} = .22$, $p < .001$), when holding gender constant. The same analysis in eighth grade showed comparable patterns ($\beta_{SKAT} = .50$, $p < .001$; $\beta_{TAT} = .26$,

$p < .001$; $\beta_{USAT} = .32$, $p < .001$). Overall, the results indicated an increasingly important role of attitudes toward science as students enter more advanced grades. Limited variance was explained by our models, as mentioned above.

In this study, we explored roles of gender and attitudes toward science in fourth and eighth grade science achievement in South Korea, Turkey, and the United States with TIMSS 2015 data. The underrepresentation of girls and women in STEM fields is a continual concern for social scientists and policymakers (Akgunduz, 2016; Piatek-Jimenez et al., 2018; Stoet & Geary, 2018). Our findings indicated that gender played a small, but significant role in science achievement in lower grades when taking student attitudes toward science into consideration. Male students tended to have higher science scores in fourth grade, and female students tended to have higher science scores in eighth grade, only in South Korea and Turkey.

A noteworthy gender difference between students in higher grades is present. Regardless of the small significant gender differences found in fourth and eighth graders' science achievement scores, male students tend to dominate STEM related college majors and career fields (Lindberg et al., 2010). This could be partially explained by the Social Role Theory, which states that male and female's development trajectories may subject them to preconceived gender-specific roles embedded in their society (Petersen & Hyde, 2014). As compared to genders, students' attitudes toward science played a vital role in the students' science achievement in both grades. The importance of students' positive attitudes toward science is even more prevalent in higher grades (Mattern & Schau, 2002). The results in this study suggest that cultivating positive attitudes and fostering efficacy toward science could be one way to bridge the gender achievement and career choices gap in certain STEM areas.

A consistent pattern across grades is present in the findings. Despite achieving the highest score among the three countries, South Korean students had fewer positive attitudes toward science than students in the other two countries. It is a prevalent belief among South Korean parents that children's success in school will lead to success in life (Kim & Bang, 2016). The collective culture of South Korea emphasizes the value of education and is referred to as "education fever" (Lee, 2003). The EVT framework (Eccles, 2009) suggests that "value" is a determining factor for one's task persistence and performance, which could potentially explain South Korean students' higher achievement despite lower attitudes.

Furthermore, it is well established that South Korean students have a tendency to memorize content knowledge and repeat the problem-solving strategies continuously to be successful in competitive exams (Park et al., 2016). This could also be a reason behind their achievement and attitudes toward science in TIMSS 2015. Recently, the arts (e.g., music, fine arts) have become a part of the focus of STEM education to promote more creative and innovative thinking in schools. As a result, the South Korean government has made attempts to include STEAM (science, technology, engineering, arts, and mathematics) education into kindergarten through twelfth grade classrooms in recent years (Martin, Im, et al., 2016; Park et al., 2016).

On the contrary, Turkish students had the highest attitudes score, but achieved the lowest in science achievement among the three countries in both fourth and eighth grades. When examining Turkish students' TIMSS achievement scores from 2011 to 2015, the recent reports suggest that despite the increasing average scores, Turkish students' ranking actually decreased in 2015 (Martin, Mullis, et al., 2016; Geesa et al. 2019a, 2019b). This could be attributed to other nations' continuous efforts in STEM education (Akgunduz, 2016). In addition, Turkish students' increasing scores in TIMSS from 2011 to 2015 could be attributed to the efforts of the Ministry of National Education to increase STEM activities in schools, which coincides with EVT (Eccles, 2009). In response to the escalating competition in STEM education and careers across nations, the Turkish government began to focus on improving STEM education in the last few years (e.g., releasing STEM education reports and manuals, offering STEM curriculum trainings) (Ministry of National Education, General Directorate of Innovation and Educational Technologies [YEĞİTEK], 2016, 2017, & 2018).

Similar to South Korea and Turkey, the United States has a growing focus on STEM education and workforce development. While the United States may strive to keep a leading role in technological innovations, the country should consider how other countries address education in STEM fields. Based on the 2015 TIMSS data, fourth and eighth grade science scores are not ranked highly in the United States. Given that lower-elementary science scores are linked to students' later science achievements (Morgan et al., 2016), the United States should direct education efforts to enhance science learning among young students. Based on our study, we argue that the United States may learn from South Korea's focus on developing STEM career awareness in early grades, strengthening curriculum and providing extra-curricular STEM learning opportunities (Park et al., 2016). Additionally, the United States may gain insights from Turkey's focus on national STEM policies and the attempts of creating a STEM learning culture (Eccles, 2009). Coinciding with our theoretical frameworks, there is a national interest to cultivate students who are competent and genuinely interested in STEM subjects.

Future Actions and Research Directions

When considering opportunities for future research, the limitations of this study should be reviewed. First, fourth and eighth grades' student background questionnaires included a different number of questions to measure students' attitudes toward science. Our selection included 16 items to measure students' attitudes toward science in the fourth grade, and 26 items in the eighth grade. Second, a few questions examining students' perspectives regarding science teachers' effectiveness in science courses were excluded in both grade levels. Third, we only conducted data analyses using student background questionnaires and focused on students' gender and attitudes toward science. It would be worthwhile for future research to examine the effect of school and teacher related variables on students' science achievement.

In order to encourage female students' interest in science and other STEM disciplines, further actions need to be taken in the future, such as providing all students equitable access to teachers and resources as well as creating assignments that focus on the applicability of science in daily lives (Blickenstaff, 2005). Prior research suggested that curricular changes to include STEM in classrooms could be beneficial to students' self-efficacy in the area of mathematics and science, as well as increase students' interest in the aforementioned subject areas (Redmond et al., 2011). In addition, in reference to our theoretical frameworks, Social Role Theory and EVT, it is conceivable that fostering a positive STEM culture could be one way to cultivate students', particularly female students', attitudes toward STEM that may subsequently benefit the future STEM workforce. For instance, exposing students to female role models in STEM disciplines may help eliminate possible biases toward the subject of science and encourage them to be interested in science and other STEM disciplines, which may affect their career choices in the future (Cheryan et al., 2017).

In addition, eliminating the presence of women with stereotypical roles on media (Bond, 2016), fighting against societal stereotypes toward girls and women, and social identities (Piatek-Jimenez et al., 2018) may contribute to future generations' career choices in STEM disciplines. Providing students age-appropriate media content and portraying characters in STEM disciplines may increase their interest in science, starting from early elementary grades. Researchers also recommend that engaging STEM programs should be grade-appropriate and encompass hands-on, collaborative approaches to learning (Kennedy & Odell, 2014).

While teachers play a critical role in educating students in STEM subjects, school and district leaders and policymakers are responsible for decision-making practices, which guide the focus on STEM education and other subjects in schools. To allow for all PreK-12 students to have access to learning in STEM disciplines, Rose et al. (2019) identified critical characteristics integrative STEM leaders should have to provide equitable STEM opportunities for all students in schools. These characteristics that support students, teachers, and stakeholders are included in the following school-focused leadership domains: Mission & Culture, Equity & Social Responsibility, Infrastructure & Programming, Curriculum & Instruction, Extended Learning, Professional Growth, and Evaluation & Assessment. While additional STEM training, support, and resources may be needed for educators in South Korea, Turkey, and the United States, stakeholders and policymakers should discuss ways to make STEM learning inclusive of *all* learners' needs and to offer a variety of learning strategies (e.g., problem-based, project-based, and inquiry-based) for students to explore and gain interest in STEM disciplines.

From an international education perspective, three countries that are included in this study have implications for their education systems. Even though South Korea is a high achieving country in science, students' attitudes toward science is the lowest among the three countries. Policymakers and educational leaders in South Korea need to learn from Turkey and other TIMSS participating nations on how to maintain students' positive attitudes toward science. On the other hand, Turkish educational stakeholders should benefit from various STEM initiatives of South Korea and the United States to provide applicable and relevant science content to science curriculum. Furthermore, offering afterschool programs, as well as print and digital media with science content and activities may contribute to Turkish students' science knowledge and skills in the future. Educational stakeholders in the United States could also learn from South Korea and Turkey how to promote students' content knowledge and self-efficacy in science.

Conclusion

Gender and attitudes toward science related to science achievement of fourth and eighth grade students in South Korea, Turkey, and the United States were compared in this study. This TIMSS 2015 data analyses further advances the understanding of relations across these three academically and culturally different countries. Although science education and student achievement vary between countries, analyses of students' attitudes toward science and gender across South Korea, Turkey, and the United States can further conversations and opportunities for all students to feel competent and thrive in science.

Educational stakeholders benefit from the results of international large-scale assessments or surveys (e.g., TIMSS, PISA) to better examine possible reasons for outcomes as well as cross-national comparisons in students' achievement in STEM disciplines (McKnight & Schmidt, 1998). Our findings pointed to the potential benefit of cultivating a positive STEM culture at early grades, especially for girls, to remediate gender-related social stereotypes associated with STEM fields. A positive STEM culture needs systemic educational efforts in order to sustain students' interests in STEM and create future workforce for STEM fields. A proactive approach can ensure that students are on track through middle and high school to complete the needed coursework for adequate preparation to enter STEM degree programs at institutions of higher learning or STEM-related career fields (DeJarnette, 2012). Future researchers should consider exploring other personal level (e.g., home resources) and contextual level (e.g., schools' STEM education attitude) predictors associated with students' science achievement. Longitudinal studies that examine students' science achievement from elementary grades to college are also worth pursuing to understand various trends and patterns of student achievement. Results from these potential types of future research could also inform STEM leadership training to enhance learning outcomes in STEM fields for all students (Rose et al., 2019).

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