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# Gender, affect, and math: a cross-national meta-analysis of Trends in International Mathematics and Science Study 2015 outcomes

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**Abstract**

Understanding why women are consistently underrepresented in STEM fields has been a constant puzzle, with a consistent feature of the puzzle being performance in math. This study uses data from TIMSS exams to investigate cross-national gender differences in math-related affect, more precisely liking mathematics, confidence in mathematics, and valuing mathematics. We compared fourth and eighth graders to track any differences in these gender-related affective characteristics. Our findings suggest that despite the variability and some changes to the magnitude and direction of gender differences in math affect, boys and girls are similar. We also found that cross-national sociocultural, political, and educational equality of adults does not necessarily predict positive affect for both genders. In fact, the researchers found that some countries with a smaller adult gender gaps have students with higher gender differences in mathematics-relevant affect.

## Introduction

The problem of female underrepresentation in mathematics and science related careers has been an ongoing concern despite the societies' efforts to facilitate the process for women to hold "male-dominated" jobs (Ceci and Williams 2011; Frome et al. 2006; Wang et al. 2013). In the United States, for instance, based on NGCP (National Girls Collaborative Project 2018), cited from Science and Engineering Indicators 2016 (National Science Board (US) 2018), women earned 50.3% of science and engineering bachelor's degrees. However, women's percentage in science and engineering at the undergraduate level significantly differs by the fields of study: women receive over half of bachelor's degrees awarded in the biological sciences, they receive 17.9% of bachelor's degrees in computer sciences, 19.3% in engineering, 39% in physical sciences, and 43.1% in mathematics.

Based on the same report by NGCP, however, women are still underrepresented in the STEM labor force. The most imbalance exists in the fields of engineering, computer science, and the physical sciences with only 29% of the science and engineering jobs held by women.

**Literature review**

There is a voluminous literature on possible reasons for the female underrepresentation in STEM fields. What follows is only some of the explanations for the issue. Relatively, some of the older studies relied on evidence related to physical and cognitive differences, such as differences in brain size (Romanes 1887) and assumed evolution-based explanations like male superiority in spatial skills (Levine et al. 1999; Linn and Petersen 1985; Voyer et al. 1995). While there are some physical differences between the brains, the research findings on cognitive distinctions are inconclusive (Hill et al. 2010). For instance, Lynn and Irwing (2004) in their study of gender differences in the Standard and Advanced Progressive Matrices found that there was no difference among children aged 6–14 years on the progressive matrices. They also found that males obtain just slightly higher means from the age of 15 through the old age on the progressive matrices.

Some other researchers found differences in cognitive skills with females outperforming males in certain tasks and vice versa. For example, Hedges and Nowell (1995) found that males, on average, are disadvantaged in reading and writing skills. They found that females slightly outperformed males in tests of reading comprehension, perceptual speed, and associative memory. On the other hand, males slightly, outperformed females in the tests of mathematics and social studies.

Still some other studies found that the existing gender differences, such as differences in spatial and visualization skills in which boys usually outperform girls, could decline and disappear with appropriate training (Baenninger and Newcombe 1989; Sorby and Baartmans 2000; Vasta et al. 1996).

More recent explanations relate these differences to socio-cultural environments and gender stereotypes that support the channeling of young girls away from STEM studies (Beede et al. 2011; Else-Quest et al. 2010; Guiso et al. 2008; Hyde and Mertz 2009). For instance, Nosek et al. (2002a) found that gender stereotypes that mathematics is for males were related to identification with and attitudes towards mathematics, with stronger gender stereotypes corresponding with more negative mathematics attitudes for women but more positive attitudes for men. They suggest that fundamental categorization of 'males' and 'females' produces identification with one's social group which consequently shapes and is shaped by experiences that are expected of that group by the society (p. 57). The gender stereotypes are not necessarily explicit and could be subconscious hypotheses and expectations of men's and women's careers (Nosek et al. 2002b; Valian 1999).

Gender stratification of educational and occupational opportunities (also called gender segregation and gender inequality) has also been recognized as a social factor that could explain women underrepresentation in STEM fields. It has been argued that women and men equality in having access to higher education and job opportunities is positively related to mathematics achievement (Baker and Jones 1993). Guiso et al. (2008) found support for the role of gender stratification in mathematics test performance cross-nationally. This hypothesis has also been supported strongly in reading achievement and partially supported in science achievement (Reilly 2012).

In a similar vein, self-perception of abilities in STEM school subjects, shaped by the children's cultural and social milieu and gender stereotypes, could impact women's interest in STEM careers (Correll 2001, 2004). Correll (2001), analyzing National Educational

Longitudinal Study dataset on high school students, found that males have higher assessment of their own mathematical competence than their female counterparts with the same math grades and test scores. The reverse was observed for verbal skills; female students had higher assessment of their verbal skills than male students. Moreover, she found that the self-assessments of mathematics competence had an impact on both males' and females' decisions to continue the path towards quantitative careers (e.g. enrolling in calculus and choosing quantitative college majores). Ganley and Lubienski (2016) in their analysis of data from the a nationally representative sample of students in the United States over 5 years (3rd–8th grades) found that that girls are less confident and less interested in mathematics than boys across third through eighth grades. Similarly, Cvencek et al. (2011) claim that children as early as second grade demonstrate their understanding of the American cultural stereotype that math is for boys. They also found that elementary school boys identify with math more than girls.

Gender difference in science course selection patterns has also been observed for young children; Farenga and Joyce (1999) found that students perceived physical science and technology-related courses as appropriate subjects for boys and life sciences as appropriate for girls to study. Turner et al. (2008) in their study of gender differences in vocational personality types (Holland 1997) of eighth and ninth grade students found that boys had significantly greater Investigative vocational personality scores than girls associated with enjoying studying and solving mathematics and science problems and valuing science and mathematics.

Finally, some other researchers have focused on the society's negative reactions to women in the workplaces that are perceived as male dominated (Heilman and Okimoto 2007; Heilman et al. 2004). Heilman et al. (2004) found that women who were acknowledged to have been successful in the STEM workplace were less liked than equivalently successful men. Moreover, they found that being disliked can have impacts on the career in terms of overall evaluation and for recommendations for reward allocation. These findings further highlight the impact of social and cultural factors in women decision to choose or stay in 'male gender-typed' jobs.

### Regional differences in TIMSS: outliers or a cluster

In IEA's Trends in International Mathematics and Science Study (TIMSS) 2015 results, a few countries, mainly from the Middle East, are (apparently) outliers in terms of gender difference in achievement (International Association for the Evaluation of Educational Achievement (IEA) 2017). The relationship between socio-economic and educational gender equities and girls' achievement has been negative in this set of nations. In other words, while they are usually ranked low in terms of general gender gaps (e.g. World Economic Forum's Global Gender Gap Report 2019), girls outperform boys in these countries. This observation is in contrast with gender stratification hypothesis which anticipates a positive relationship between general gender equity and scholastic achievement equity (for more information on gender stratification hypothesis see Fiorentine 1993; Kane 1992; Baker and Jones 1993).

The girls' higher achievement in some of the Middle East nations also shows consistency across several waves of TIMSS. For instance, in TIMSS 2015, Saudi Arabi, Oman, Jordan, Bahrain, and Kuwait are among the countries with highest gender difference in mathematics achievement in favor of girls. In TIMSS 2011 (Arora et al. 2012), in addition to the above-mentioned nations, girls in Qatar, Yemen, and Palestinian Nat'l Auth outperformed boys. This trend also exists for the results of TIMSS 2007 (Gonzales et al. 2008) and to a considerably lesser extent for TIMSS 2003 (Mullis et al. 2004).

The literature related to some of these countries reveal that the gender gap for these countries is not limited only to international tests of mathematics and science. The girls have a better performance than boys in other subjects in secondary and tertiary education. There is also a big difference in the proportion of girls and boys at universities in these countries. For instance, 70% of students in tertiary education in the United Arab Emirates are women and at Jordan's largest university, women to men ratio is two to one (Abdulla and Ridge 2011; AlSindi 2013; Ripley 2017; Ridge 2010). Based on Ripley (2017), fewer than one in every five workers in most of these countries is woman which is, as she claims, against the conventional sense in the Western nations: more female graduates must result in more employment for women but it is not what happens in these countries. This highlights the importance of cultural and motivational considerations and a need for some form of classification in cross-national gender studies.

Tables 11, 12 in Appendix 1 represents the mathematics achievement of the 10 countries with the highest gender gap based on Global Gender Gap Report and achievement data availability in TIMSS 2015. Among fourth graders, in eight countries girls outperformed boys in math achievement tests from which four of the differences were statistically significant. For eighth graders, out of the ten high-gap countries, nine countries had girls outperforming boys with two of them significantly different. It is noteworthy to mention that in both grades, all countries except Republic of Korea are in the Middle East.

## Current study

The current study examined gender differences in mathematics-related affect among fourth and eighth grade students cross-nationally using a recent international database. Large and nationally representative data can provide more reliable and generalizable findings to decide on gender similarities and/or differences compared to smaller and selective samples (Reilly 2012). Moreover, the use of secondary national and international data has been a common practice in gender studies (e.g. Guiso et al. 2008; Wiseman 2008). More precisely, we investigated gender difference in confidence in mathematics, liking mathematics, and valuing mathematics. We were interested in investigating the possible affective gender difference related to mathematics in both elementary and middle schools using large and representative samples.

Additionally, this study took a bird's eye view of gender, affect, and math using meta-analysis procedures. Compared to the regular meta-analysis which endorses the use of studies as units of analysis, the present study used nations as the units of analysis (Else-Quest et al. 2010; Reilly 2012). We meta-analyzed data from the International Association for the Evaluation of Educational Achievement's TIMSS 2015 to assess the magnitude and direction of gender differences in mathematics related affect.

The analysis was conducted for both fourth and eighth grade students. Previous research found some evidence of gender difference in mathematics test performance in high school and college but not elementary school (e.g. Hyde et al. 1990). One of our goals was to see if there was a gender difference in mathematics affect between fourth and eighth grade participants.

We were also interested in investigating how countries gender disparity in socio-economic and cultural areas may affect their students' attitude towards math by putting countries in different categories based on the gender gap indices. We used World Economic Forum's Global Gender Gap Report (GGGR) 2017 to achieve this goal. This report includes rankings and indices of 144 countries on four dimensions including economic participation and opportunity, educational attainment, health and survival, and political empowerment (see World Economic Forum 2019).

In sum this study was conducted to answer the following questions:

1. Is there a gender difference in students' interest in mathematics (Liking Mathematics) cross-nationally?
2. Is there a gender difference in students' mathematics self-confidence cross-nationally?
3. Is there a gender difference in how much students value mathematics cross-nationally?
4. How is the general gender gap index (including education, economic participation, political representation, and health) associated with the gender difference in interest in mathematics, mathematics self-confidence, and valuing mathematics?
5. Is there a significant difference between fourth and eighth grade students in terms of mathematics-related affect?

## Method

### Data sources

The data for mathematics affect came from TIMSS 2015. TIMSS is a set of international examinations measuring achievement in mathematics and science. It is sponsored by International Association for the Evaluation of Education Achievement (IEA) and developed by TIMSS & PIRLS International Study Center at Boston College. It is administered every 4 years. At the time of conducting this research, the 2015 wave was the most recent administration. The data were based on students' answers to three sets of items comprising scales in the TIMSS 2015 international database available to the public. The scales were Students Confident in Mathematics scale, Students Like Learning Mathematics scale, and Students Value Mathematics scale. Each of these scales had nine statements which were scored on a four-point scale. The choices for each statement were 'Agree a lot', 'Agree a little', 'Disagree a little', and 'Disagree a lot'. The scale statements across grade levels were not completely identical (see Appendix 2 for the items of each scale at grade 4 and grade 8).

In TIMSS 2015, 57 countries and 7 benchmarking entities (regional jurisdictions of countries such as states or provinces) participated. In total, more than 580,000 students participated in TIMSS 2015. The number of countries and sample sizes for the purpose of the current study are summarized in Table 1.

**Table 1 Sample size and number of countries in each analysis**

| Scale | Grade | No. countries | Number of males | Number of females |
|---|---|---|---|---|
| Liking math | 4 | 48 | 127,581 | 124,176 |
| Liking math | 8 | 40 | 125,403 | 126,677 |
| Math confidence | 4 | 48 | 127,295 | 123,904 |
| Math confidence | 4 | 40 | 124,381 | 126,242 |
| Valuing math | 8 | 40 | 124,206 | 126,057 |

Gender parity measures came from Global Gender Gap Report 2017 (GGGR 2017). It was established by World Economic Forum in 2006 to provide a picture of global gender equality. GGGR 2017 provides a Global Gender Gap Index (GGGI) for each of the major and emerging world economies that was utilized in the current study. GGGR 2017 included 144 countries. GGGR measures gender equality in four areas including economic participation, education (primary, secondary, tertiary), political representation, and health (life expectancy ratio and sex ratio at birth).

One of the relatively new concerns in the use of self-reported Likert-based scales data collected from different cultures is whether they have measurement invariance (e.g. Karakoc Alatli et al. 2016). The measurement invariance refers to a statistical feature of a scale or measurement tool which ensures the same underlying construct is being measured across different groups or times (here across different cultures). In other words, it is possible that a scale scores is affected by some culture-specific features that the researcher did not intend to assess; in that case the scale lacks measurement invariance. Moreover, the aggregation of the scale data from different cultures may result in puzzling patterns and erroneous inferences (He et al. 2017, 2018). In the current study, the measurement invariance was assumed for the scales utilized and the inferences made from the findings.

## Data analysis

This study is based on meta-analysis procedures and techniques proposed Lipsey and Wilson (2001) for the computation of the effect sizes, the overall effect size, and calculation of heterogeneity (i.e. the variation of effect sizes). The mean comparison was utilized as the statistic for the calculation of the effect sizes. Microsoft Excel, IBM SPSS, and IEA's IDB Analyzer were utilized for the purpose of meta-analysis. To calculate the mean effect sizes both Wilson's SPSS macros (Wilson 2017) and hand-written SPSS syntax were utilized.

To check the homogeneity of effect sizes across nations Q and $\tau^2$ (Tau-squared) statistics were calculated. Q values were assessed using the $\chi^2$ distribution with $k-1$ degrees of freedom, where k stood for the number of countries in the analysis. The $\tau^2$ statistic, was assessed from Q random effects analysis. Based upon a rule of thumb, $\tau^2$ values greater than 1 indicated heterogeneity.

To merge and calculate the mean and standard deviation of the mathematics data into a single file IDB analyzer was used. IDB analyzer generates SPSS syntax for both merging and the analysis of the data in the TIMSS 2015 international database. It considers sampling design and standard errors using the jackknife repeated replication (JRR) method. It also makes appropriate use of sampling weights in the analysis.

Meta-analysis is a statistical method for synthesizing the results of multiple mean difference calculations to increase the power of estimates from different studies (Lipsey andWilson 2001). For this analysis, the researchers treated each nation in the TIMSS database as a separate study of gender differences. For each nation, the researchers calculated the effect size (ES) as the mean difference between girls and boys divided by within-country pooled standard deviation. Negative ES values represented the boys' advantage over girls regarding the construct. Effect size refers to the difference of two groups in the standard deviation unit. As a generally accepted guideline, the effect size below 0.2 is considered negligible, effect size of 0.2 is small, 0.5 is moderate, and 0.8 and higher are large (Cohen 1988).

Besides the meta-analysis of all nations together to answer research questions 1–3 (i.e. gender difference in students' interest in mathematics, gender difference in students' mathematics self-confidence, and gender difference in how much students value mathematics), the researchers also decided to select two sets of countries as high-gap and low-gap countries and do separate meta-analysis on each to answer the research question 4. We thought this procedure could provide a better picture of the role of socioeconomic and cultural differences related to mathematics affect. The selected countries, with lowest gender gap, based on the GGGR 2017 report with TIMSS 2015 data available, are as follows: Norway (2), Finland (3), Sweden (5), Slovenia (7), Ireland (8), New Zealand (9), France (11), Germany (12), Denmark (14), and Canada (16). The numbers in the parentheses are the countries global ranking of gender equality. The selected countries with the highest gender gap are: Iran (140), Saudi Arabia (138), Morocco (136), Jordan (135), Turkey (131), Qatar (130), Kuwait (129), Bahrain (126), United Arab Emirates (120), and Republic of Korea (118).

## Results

The meta-analysis of Student Like Mathematics scales revealed that there was almost no gender difference in interest in mathematics between fourth graders (grand random mean ES = −0.073, grand fixed mean ES = −0.065); the effect sizes were heterogeneous [Q(47) = 1596.04, $p < 0.001$] and the $\tau^2$ (between nations true heterogeneity) was 0.024 (see Table 1).

The meta-analysis of gender difference in interest (i.e. Student Like Mathematics scales) for eighth graders showed that there was a slight gender difference favoring male students (Grand Mean ES = −0.106, see Table 2). The effect sizes were heterogeneous [Q (39) = 935.85, $p < 0.001$]. The $\tau^2$ value was .014.

Regarding the unweighted effect sizes, for fourth graders, 15 countries out of 48 countries (31%), and for eighth graders 10 out of 40 countries (25%) had small to medium gender disparity in "liking mathematics" (Tables 3 and 4). In other words, they had *d*s of 0.2 or more but less than 0.5 which were either positive or negative (Cohen 1988).

Regarding mathematics self-confidence both fourth and eighth grade boys were slightly superior than girls and this difference were statistically significant ($p$ <0.001), though very small. The grand mean effect size for gender difference in math

**Table 2 Overall effect size of gender differences in "Liking Mathematics" for fourth and eighth graders**

| | K | ES | SE | $\tau^2$ | Test of Null | | 95% CI | | Test of homogeneity | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Z | *P* | Lower | Upper | Q | *df*(Q) | *P* |
| 4th grade | | | | | | | | | | | |
| Fixed | 48 | −0.065 | 0.004 | | −16.4 | 0.000 | −0.07 | −0.05 | 1596.04 | 47 | 0.000 |
| Random | 48 | −0.073 | 0.023 | 0.024 | −3.2 | 0.001 | −0.11 | −0.02 | | | |
| | K | ES | SE | V | Z | P | Lower | Upper | Q | df(Q) | P |
| 8th grade | | | | | | | | | | | |
| Fixed | 40 | −0.104 | 0.004 | | −26.9 | 0.000 | −0.11 | −0.09 | 935.85 | 39 | 0.000 |
| Random | 40 | −0.106 | 0.019 | 0.014 | −6.0 | 0.000 | −0.15 | −0.07 | | | |

self-confidence for fourth graders was −0.133 and the effect sizes were heterogeneous [Q (47) = 2514.04, $p < 0.001$]. The $\tau^2$ value was 0.03. The grand mean effect size for gender difference in self-confidence among eighth grade students was −0.141. The effect sizes were heterogeneous [Q (39) = 1076.27, $p < 0.001$]. The $\tau^2$ value was 0.01.

In other words, the gender difference in mathematics self-confidence among eighth graders was slightly higher than fourth graders, and for both they were in favor of boys (Table 5). In 26 out of 48 (54%) countries for fourth graders and 15 out of 40 (37%) countries for eighth graders the unweighted effect sizes were small to medium when the mean scores of boys and girls were compared (Tables 6 and 7).

In the TIMSS 2015 report the Students Value Mathematics scale data were available just for eighth graders. The meta-analysis of those data showed almost no difference between boys and girls in terms of valuing math (Grand Mean ES = −0.066). The individual effect sizes were heterogeneous [Q (39) = 1295.5, $p < 0.001$, $\tau^2 = 0.02$]. Please see Table 8 for more details. Out of 40 countries, 10 countries (25%) had small effect sizes and none of these 10 effect sizes went over 0.3 when boys and girls were compared (Table 9).

The meta-analysis results of ten high gap and ten low gap countries are summarized in Table 10. For liking mathematics construct, as mentioned previously, the overall effect size was −0.073 for fourth graders. The mean effect size for the low gap countries was −0.127 implying that boys like mathematics more than girls. However, for the high gap countries the effect size was 0.071 representing girls' higher interest in mathematics. For eighth graders, the students in low gap countries revealed higher difference in interest (effect size = −0.141) compared to students in high gap countries (effect size = −0.128), both in favor of boys.

The meta-analysis of the self-confidence in mathematics scale also revealed that boys in both low gap and high gap countries show more confidence, however, in low gap countries the difference between girls and boys were considerably larger. For the low gap countries, the effect sizes were −0.199 and −0.248 for the fourth and eighth grade students respectively. For high gap countries the effect sizes were −0.078 and −0.052 for the fourth and eighth grade students respectively.

The same pattern was observed for valuing mathematics questionnaire as well. While boys revealed valuing mathematics more than girls, the gender difference was

**Table 3 Unweighted effect sizes and descriptive statistics for "Liking Mathematics" for fourth graders**

| Countries | *d* | Mean 1 | Mean 2 | SD1 | SD2 |
|---|---|---|---|---|---|
| Saudi Arabia | 0.43 | 10.71 | 9.95 | 1.79 | 1.76 |
| Oman | 0.27 | 11.21 | 10.79 | 1.5 | 1.61 |
| Bahrain | 0.17 | 10.55 | 10.25 | 1.81 | 1.81 |
| Morocco | 0.16 | 11 | 10.75 | 1.53 | 1.62 |
| Indonesia | 0.12 | 10.83 | 10.65 | 1.41 | 1.47 |
| Kuwait | 0.12 | 10.39 | 10.18 | 1.81 | 1.83 |
| Qatar | 0.11 | 10.27 | 10.07 | 1.87 | 1.81 |
| United Arab Emirates | 0.07 | 10.43 | 10.31 | 1.73 | 1.77 |
| Serbia | 0.06 | 10.13 | 10.01 | 1.93 | 1.98 |
| Kazakhstan | 0.05 | 11.03 | 10.96 | 1.48 | 1.53 |
| Turkey | 0.05 | 11.34 | 11.27 | 1.49 | 1.53 |
| Norway | 0.04 | 10.3 | 10.22 | 1.8 | 1.91 |
| Ireland | 0.03 | 9.62 | 9.56 | 1.77 | 1.88 |
| Iran | 0.03 | 10.79 | 10.74 | 1.63 | 1.65 |
| Chile | 0.02 | 9.99 | 9.96 | 1.92 | 1.92 |
| Cyprus | 0 | 10.26 | 10.27 | 1.95 | 2.1 |
| Bulgaria | − 0.02 | 10.35 | 10.39 | 1.81 | 1.87 |
| Georgia | − 0.03 | 10.48 | 10.52 | 1.51 | 1.53 |
| Denmark | − 0.03 | 9.58 | 9.63 | 1.65 | 1.7 |
| Sweden | − 0.05 | 9.47 | 9.55 | 1.66 | 1.79 |
| United States | − 0.06 | 9.66 | 9.77 | 1.94 | 2.02 |
| Poland | − 0.08 | 9.35 | 9.48 | 1.69 | 1.73 |
| Croatia | − 0.08 | 9.23 | 9.36 | 1.59 | 1.78 |
| Netherlands | − 0.08 | 9.27 | 9.42 | 1.7 | 1.84 |
| Russian Federation | − 0.11 | 10.12 | 10.29 | 1.55 | 1.63 |
| Czech Republic | − 0.11 | 9.38 | 9.57 | 1.7 | 1.85 |
| Slovenia | − 0.11 | 9.32 | 9.52 | 1.74 | 1.96 |
| New Zealand | − 0.11 | 9.71 | 9.92 | 1.84 | 1.97 |
| Slovak Republic | − 0.13 | 9.64 | 9.87 | 1.76 | 1.86 |
| Finland | − 0.14 | 9.05 | 9.29 | 1.61 | 1.78 |
| Singapore | − 0.15 | 9.51 | 9.78 | 1.71 | 1.81 |
| Japan | − 0.15 | 9.12 | 9.37 | 1.52 | 1.71 |
| Northern Ireland | − 0.16 | 9.32 | 9.6 | 1.71 | 1.88 |
| Hungary | − 0.16 | 9.52 | 9.81 | 1.7 | 1.91 |
| Canada | − 0.18 | 9.43 | 9.76 | 1.77 | 1.91 |
| Korea Republic of | − 0.2 | 8.79 | 9.1 | 1.43 | 1.65 |
| Australia | − 0.2 | 9.34 | 9.72 | 1.79 | 1.94 |
| Argentina | − 0.21 | 9.78 | 10.19 | 2.01 | 1.98 |
| Spain | − 0.24 | 9.69 | 10.12 | 1.81 | 1.84 |
| Italy | − 0.24 | 9.83 | 10.27 | 1.84 | 1.84 |
| Belgium | − 0.25 | 9.01 | 9.44 | 1.63 | 1.83 |
| Lithuania | − 0.26 | 9.97 | 10.4 | 1.64 | 1.72 |
| Chinese Taipei | − 0.27 | 8.67 | 9.17 | 1.74 | 2 |
| England | − 0.27 | 9.84 | 10.33 | 1.79 | 1.85 |
| Germany | − 0.27 | 9.27 | 9.79 | 1.82 | 2 |
| Portugal | − 0.29 | 10.34 | 10.85 | 1.72 | 1.76 |
| Hong Kong | − 0.33 | 9.14 | 9.76 | 1.76 | 1.94 |
| France | − 0.38 | 9.77 | 10.4 | 1.63 | 1.71 |

Positive values show the superiority of females and negative values show the superiority of males

**Table 4 Unweighted effect sizes and descriptive statistics for "Liking Mathematics" for eighth graders**

| Countries | *d* | Mean 1 | Mean 2 | SD1 | SD2 |
|---|---|---|---|---|---|
| Oman | 0.21 | 11.13 | 10.78 | 1.71 | 1.69 |
| Malaysia | 0.18 | 10.81 | 10.55 | 1.4 | 1.43 |
| Kazakhstan | 0.1 | 11.07 | 10.87 | 2.09 | 2.04 |
| Botswana | 0.05 | 11.44 | 11.35 | 1.73 | 1.75 |
| Saudi Arabia | 0.04 | 9.8 | 9.72 | 2.11 | 2.08 |
| Turkey | 0.03 | 10.28 | 10.23 | 2 | 1.94 |
| Thailand | − 0.02 | 10.32 | 10.35 | 1.4 | 1.47 |
| Israel | − 0.04 | 9.59 | 9.68 | 2.05 | 2.02 |
| Slovenia | − 0.04 | 8.69 | 8.76 | 1.69 | 1.77 |
| Lithuania | − 0.06 | 9.63 | 9.74 | 1.72 | 1.72 |
| Ireland | − 0.08 | 9.24 | 9.39 | 1.94 | 1.93 |
| South Africa | − 0.08 | 10.82 | 10.97 | 1.79 | 1.78 |
| United States | − 0.08 | 9.43 | 9.59 | 2.1 | 2.03 |
| Egypt | − 0.09 | 10.79 | 10.97 | 2.01 | 1.83 |
| Morocco | − 0.09 | 11.04 | 11.21 | 1.84 | 1.76 |
| Singapore | − 0.09 | 10.06 | 10.23 | 1.8 | 1.94 |
| Georgia | − 0.1 | 10.1 | 10.28 | 1.78 | 1.69 |
| Hungary | − 0.11 | 9.04 | 9.23 | 1.75 | 1.82 |
| Russian Federation | − 0.11 | 9.98 | 10.15 | 1.54 | 1.55 |
| Bahrain | − 0.13 | 9.58 | 9.86 | 2.16 | 2.08 |
| Jordan | − 0.13 | 10.71 | 10.97 | 2.09 | 2.04 |
| Norway | − 0.13 | 9.42 | 9.68 | 1.96 | 1.91 |
| Canada | − 0.15 | 9.7 | 9.98 | 1.88 | 1.94 |
| Chinese Taipei | − 0.15 | 9.07 | 9.35 | 1.7 | 1.97 |
| Korea Republic of | − 0.15 | 8.98 | 9.23 | 1.63 | 1.75 |
| Lebanon | − 0.15 | 10.49 | 10.77 | 1.87 | 1.83 |
| United Arab Emirates | − 0.15 | 10.04 | 10.33 | 1.92 | 1.9 |
| Argentina | − 0.16 | 9.29 | 9.62 | 2.01 | 2.01 |
| Chile | − 0.17 | 9.28 | 9.62 | 2.01 | 1.95 |
| Italy | − 0.17 | 9.25 | 9.58 | 1.9 | 1.98 |
| Iran | − 0.19 | 10.29 | 10.66 | 1.98 | 1.99 |
| Malta | − 0.21 | 9.24 | 9.67 | 2.03 | 2.01 |
| New Zealand | − 0.23 | 9.37 | 9.77 | 1.74 | 1.72 |
| Sweden | − 0.23 | 9.11 | 9.55 | 1.88 | 1.96 |
| Australia | − 0.26 | 9.17 | 9.65 | 1.83 | 1.83 |
| Hong Kong | − 0.26 | 9.22 | 9.73 | 1.83 | 2.03 |
| Japan | − 0.26 | 9 | 9.42 | 1.53 | 1.75 |
| Qatar | − 0.26 | 9.64 | 10.15 | 2.03 | 1.95 |
| England | − 0.27 | 9.27 | 9.74 | 1.76 | 1.77 |
| Kuwait | − 0.4 | 9.65 | 10.46 | 2.13 | 1.96 |

Positive values show the superiority of females and negative values show the superiority of males

about three times higher for low gap countries (effect size = − 0.114) than the high gap countries (effect size = − 0.036).

The tau-squared values decreased for all three constructs when two subsets of countries were assigned to high gap and low gap categories (see Table 10). Tau-squared

**Table 5 Overall effect size of gender differences in "Confidence in Mathematics" for fourth and eighth graders**

| | K | ES | SE | $\tau^2$ | Test of Null | | 95% CI | | Test of homogeneity | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Z | *P* | Lower | Upper | Q | *df*(Q) | *P* |
| 4th grade | | | | | | | | | | | |
| Fixed | 48 | −0.0136 | 0.004 | | −33.5 | 0.000 | −0.14 | −0.12 | 2514.04 | 47 | 0.000 |
| Random | 48 | −0.0133 | 0.028 | 0.03 | −4.7 | 0.000 | −0.19 | −0.08 | | | |
| | **K** | **ES** | **SE** | **V** | **Z** | **P** | **Lower** | **Upper** | **Q** | **df(Q)** | **P** |
| 8th grade | | | | | | | | | | | |
| Fixed | 40 | −0.143 | 0.004 | | −36.0 | 0.000 | −0.15 | −0.13 | 1076.27 | 39 | 0.000 |
| Random | 40 | −0.141 | 0.020 | 0.01 | −7.42 | 0.000 | −0.19 | −0.11 | | | |

represents the extent of variation among the effects in different countries here (i.e. between-country variance); it reflects the variance of the true effect sizes (Borenstein et al. 2011). This decrease could be assumed natural since the number of the effect sizes were reduced to ten.

## Discussion

From an international perspective, the magnitude and direction of the mean effect sizes in mathematics affect (i.e. liking mathematics, confidence in mathematics, and valuing mathematics) imply that boys and girls are similar. The mean effect sizes for all three constructs were less than 0.2. However, the variations in the unweighted effect sizes possibly suggest the importance of social and cultural factors in the observed differences. The individual effect sizes of gender difference in mathematics constructs investigated here included both positive and negatives values. The implication is that biological explanations for gender difference in mathematics-related affect are not supported by the current findings. Moreover, the change in the magnitude of the gender differences when fourth and eighth grade students of individual countries were compared is an evidence of the possibility of fostering parity between males and females in mathematics affect. The reduction of gender difference in mathematics confidence among eighth graders compared to fourth graders in the United States is a typical instance. The similar argumentation about the possibility of developing spatial skills in females to match spatial and visual skills of the male counterparts has been made by some researchers (Baenninger and Newcombe 1989; Sorby and Baartmans 2000; Vasta et al. 1996).

The cross-sectional comparison of grand means also reveals that there is an increase in gender difference in mathematics affect (i.e. Liking Math and Confidence in Math) as students make a transition from fourth grade (elementary school) to eighth grade (middle school). The gender difference in interest rose to −0.106 from −0.073 and the gender difference in confidence rose to −0.141 from −0.131. While the magnitude of the differences is small in both grades, its growth from fourth to eighth grade could be a signal implying that losing interest and confidence in mathematics in female students becomes more noticeable as they transition to higher grades. It could be the beginning of the formation of a larger gender gap in mathematics affect as students make transition to colleges and universities.

**Table 6 Unweighted effect sizes and descriptive statistics for "Confidence in Mathematics" for fourth graders**

| Countries | *d* | Mean 1 | Mean 2 | SD1 | SD2 |
|---|---|---|---|---|---|
| Saudi Arabia | 0.45 | 10.54 | 9.69 | 2 | 1.8 |
| Japan | 0.44 | 8.9 | 8.23 | 1.45 | 1.6 |
| Oman | 0.21 | 10.34 | 9.96 | 1.83 | 1.74 |
| Bahrain | 0.17 | 10.34 | 10.02 | 1.97 | 1.89 |
| Kuwait | 0.11 | 10.35 | 10.13 | 1.97 | 1.9 |
| Qatar | 0.11 | 10.21 | 9.99 | 2.02 | 1.93 |
| Indonesia | 0.1 | 9.8 | 9.63 | 1.65 | 1.63 |
| Kazakhstan | 0.08 | 10.66 | 10.5 | 1.97 | 1.96 |
| France | 0.08 | 10.55 | 10.4 | 1.74 | 1.94 |
| Iran | 0.06 | 10.26 | 10.14 | 1.95 | 1.87 |
| Morocco | 0.05 | 10.01 | 9.92 | 1.85 | 1.8 |
| United Arab Emirates | 0.01 | 10.01 | 10 | 1.79 | 1.81 |
| Serbia | − 0.02 | 10.46 | 10.51 | 2.23 | 2.2 |
| Chile | − 0.03 | 9.56 | 9.61 | 1.96 | 1.97 |
| Georgia | − 0.03 | 10.28 | 10.33 | 1.74 | 1.85 |
| Turkey | − 0.03 | 10.37 | 10.44 | 2.05 | 2.08 |
| Bulgaria | − 0.05 | 10.4 | 10.5 | 2.16 | 2.23 |
| Norway | − 0.11 | 10.56 | 10.77 | 1.88 | 1.95 |
| Sweden | − 0.13 | 10.07 | 10.29 | 1.7 | 1.75 |
| Croatia | − 0.14 | 9.93 | 10.2 | 1.79 | 1.93 |
| Ireland | − 0.16 | 10.01 | 10.3 | 1.85 | 1.88 |
| Argentina | − 0.18 | 9.58 | 9.92 | 1.87 | 1.97 |
| Poland | − 0.18 | 9.59 | 9.93 | 1.84 | 1.91 |
| Korea Republic of | − 0.18 | 8.95 | 9.22 | 1.41 | 1.51 |
| Russian Federation | − 0.19 | 9.51 | 9.88 | 1.86 | 1.94 |
| Slovak Republic | − 0.22 | 9.72 | 10.14 | 1.86 | 2 |
| Cyprus | − 0.22 | 10.29 | 10.77 | 2.1 | 2.21 |
| United States | − 0.23 | 9.8 | 10.26 | 2.04 | 2.04 |
| Slovenia | − 0.23 | 9.68 | 10.13 | 1.84 | 2.04 |
| Finland | − 0.24 | 9.58 | 9.98 | 1.62 | 1.73 |
| Hungary | − 0.25 | 9.86 | 10.37 | 1.98 | 2.15 |
| Czech Republic | − 0.26 | 9.32 | 9.79 | 1.7 | 1.85 |
| Italy | − 0.27 | 9.87 | 10.36 | 1.83 | 1.85 |
| New Zealand | − 0.27 | 9.29 | 9.74 | 1.56 | 1.75 |
| Denmark | − 0.27 | 9.84 | 10.32 | 1.69 | 1.81 |
| Canada | − 0.28 | 9.68 | 10.21 | 1.91 | 1.93 |
| Northern Ireland | − 0.3 | 9.61 | 10.17 | 1.83 | 1.94 |
| Singapore | − 0.31 | 8.87 | 9.41 | 1.68 | 1.85 |
| England | − 0.32 | 9.82 | 10.43 | 1.87 | 1.96 |
| Spain | − 0.33 | 9.63 | 10.28 | 1.95 | 2.04 |
| Australia | − 0.34 | 9.35 | 10 | 1.76 | 2.01 |
| Portugal | − 0.35 | 9.21 | 9.88 | 1.74 | 2.02 |
| Lithuania | − 0.37 | 9.47 | 10.1 | 1.66 | 1.73 |
| Netherlands | − 0.38 | 9.9 | 10.68 | 2.02 | 2.11 |
| Germany | − 0.41 | 9.64 | 10.46 | 1.91 | 2.12 |
| Belgium | − 0.46 | 9.32 | 10.16 | 1.76 | 1.89 |
| Chinese Taipei | − 0.33 | 8.58 | 9.16 | 1.61 | 1.9 |
| Hong Kong | − 0.37 | 8.89 | 9.56 | 1.7 | 1.88 |

Positive values show the superiority of females and negative values show the superiority of males

**Table 7 Unweighted effect sizes and descriptive statistics for "Confidence in Mathematics" for eighth graders**

| Countries | *d* | Mean 1 | Mean 2 | SD1 | SD2 |
|---|---|---|---|---|---|
| Oman | 0.18 | 10.69 | 10.37 | 1.84 | 1.7 |
| Kazakhstan | 0.11 | 10.61 | 10.42 | 1.77 | 1.76 |
| Saudi Arabia | 0.06 | 10.23 | 10.12 | 1.78 | 1.76 |
| Japan | 0.04 | 8.66 | 8.29 | 8.66 | 9.29 |
| Jordan | 0.02 | 10.47 | 10.44 | 1.91 | 1.86 |
| Bahrain | −0.02 | 10.1 | 10.13 | 2.04 | 1.84 |
| Egypt | −0.04 | 10.36 | 10.43 | 1.8 | 1.75 |
| Malaysia | −0.06 | 9.44 | 9.52 | 1.39 | 1.31 |
| Morocco | −0.06 | 9.96 | 10.06 | 1.63 | 1.46 |
| Turkey | −0.06 | 9.68 | 9.82 | 2.4 | 2.15 |
| Iran | −0.07 | 10.09 | 10.24 | 2.22 | 2.01 |
| Lebanon | −0.08 | 10.35 | 10.51 | 1.99 | 1.94 |
| United Arab Emirates | −0.08 | 10.34 | 10.49 | 1.94 | 1.93 |
| Botswana | −0.09 | 9.69 | 9.84 | 1.64 | 1.52 |
| Israel | −0.09 | 10.55 | 10.76 | 2.36 | 2.18 |
| Qatar | −0.1 | 10.16 | 10.36 | 2.03 | 1.81 |
| United States | −0.13 | 10.15 | 10.46 | 2.38 | 2.28 |
| Georgia | −0.14 | 9.88 | 10.14 | 1.88 | 1.76 |
| Lithuania | −0.15 | 10.03 | 10.31 | 2.01 | 1.84 |
| South Africa | −0.15 | 9.67 | 9.93 | 1.83 | 1.74 |
| Russian Federation | −0.16 | 9.69 | 10 | 2.01 | 1.91 |
| Kuwait | −0.17 | 10.05 | 10.38 | 1.96 | 1.86 |
| Hungary | −0.18 | 9.98 | 10.38 | 2.32 | 2.24 |
| Argentina | −0.18 | 9.75 | 10.14 | 2.28 | 2.13 |
| Slovenia | −0.19 | 9.66 | 10.04 | 2.05 | 1.93 |
| Singapore | −0.21 | 9.51 | 9.97 | 2.14 | 2.15 |
| Ireland | −0.22 | 9.79 | 10.26 | 2.18 | 2.08 |
| Korea Republic | −0.22 | 9.24 | 9.64 | 1.77 | 1.9 |
| Thailand | −0.22 | 9 | 9.31 | 1.45 | 1.4 |
| Malta | −0.23 | 9.48 | 9.98 | 2.27 | 2.12 |
| Chile | −0.25 | 9.46 | 9.98 | 2.2 | 1.92 |
| Italy | −0.26 | 9.7 | 10.31 | 2.4 | 2.34 |
| Canada | −0.28 | 10.28 | 10.94 | 2.42 | 2.33 |
| Chinese Taipei | −0.29 | 8.74 | 9.42 | 2.25 | 2.46 |
| New Zealand | −0.31 | 9.65 | 10.22 | 1.78 | 1.92 |
| Norway | −0.33 | 10.03 | 10.81 | 2.47 | 2.29 |
| Hong Kong | −0.34 | 9.04 | 9.78 | 2.17 | 2.23 |
| Australia | −0.36 | 9.63 | 10.37 | 2.12 | 2.03 |
| Sweden | −0.38 | 9.72 | 10.56 | 2.2 | 2.23 |
| England | −0.39 | 9.89 | 10.64 | 1.91 | 1.92 |

Positive values show the superiority of females and negative values show the superiority of males

Despite methodological and procedural differences, current findings are partially consistent with the previous findings. For instance, Ganley and Lubienski (2016) found that math confidence showed smaller gender differences at the eighth grade than at third and fifth grades which is consistent with the current findings. Moreover,

**Table 8 Overall effect size of gender differences in "Valuing Mathematics" for eighth graders**

| | K | ES | SE | $\tau^2$ | Test of null | | 95% CI | | Test of homogeneity | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Z | P | Lower | Upper | Q | df(Q) | P |
| 8th Grade | | | | | | | | | | | |
| Fixed | 40 | − 0.073 | 0.004 | | − 16.87 | 0.000 | − 0.07 | − 0.05 | 1295.5 | 39 | 0.000 |
| Random | 40 | − 0.066 | 0.022 | 0.02 | − 3.54 | 0.000 | − 0.12 | − 0.03 | | | |

like the current findings, they found that gender differences in math confidence are larger than disparities in interest. However, our findings do not seem to be consistent with Turner et al. (2008) findings.

#### Regional differences in international studies

In international studies of gender differences in scholastic achievement, the differential effects of grouping countries based on gender gaps, to the authors' knowledge, has not been sufficiently investigated (e.g. Guiso et al. 2008; Hyde and Mertz 2009). However, some studies have identified the importance of grouping countries in such studies. Reilly (2012), for instance, investigated the gender differences in reading, mathematics and science literacy for nations that participated in Program for International Student Assessment 2009. In some of his analyses, he made a distinction between 34 countries that were members of Organization for Economic Co-operation and Development (OECD) and 31 nations that were non-members or what he called non-OECD countries. He found a larger mean effect size for non-OECD nations in science literacy than when OECD and non-OECD were combined. He claims that "a focus on the combined sample overlooks the pattern of gender differences at a national level where girls show small but meaningful gains over boys in science literacy across large parts of the world" (Reilly 2012, p. 8). The findings of the current study further highlight the need for some form of classification to capture the importance of sociocultural and motivational factors in shaping mathematics-related affect. One of the main implications of this study is that the smaller sociocultural, economic, and educational gender gap does not necessarily mean more parity in boys' and girls' affect related to mathematics. For instance, in terms of "liking mathematics", the maximum gender disparity in favor of boys for fourth graders was observed for France which in World Economic Forum's Global Gender Gap Report (2019) was among top eleven countries in terms of gender equality. Germany and England were two other examples of countries with high ratings for gender equality but among the countries with most gender disparity in liking mathematics in favor of boys. Regarding mathematics self-confidence, Germany, Belgium, and Netherlands were three countries with most gender disparity for fourth graders and England, Sweden, and Australia for eighth graders in favor of boys and again these are countries with high standards in terms of sociocultural, political, and educational gender equality in GGGR (2017). Note that all of these countries are in Europe.

This pattern was observed the other way around as well. For example, in terms of mathematics self-confidence among fourth graders, Saudi Arabia's $d$ was the highest positive value ($d = 0.446$) showing almost a medium effect size in favor of girls. Saudi

**Table 9 Unweighted effect sizes and descriptive statistics for "Valuing Mathematics" for eighth graders**

| Countries | *d* | Mean 1 | Mean 2 | SD1 | SD2 |
|---|---|---|---|---|---|
| Thailand | 0.3 | 10.57 | 10.03 | 1.77 | 1.86 |
| Botswana | 0.22 | 11.45 | 11.03 | 1.77 | 2 |
| Malaysia | 0.22 | 10.04 | 9.65 | 1.72 | 1.79 |
| Oman | 0.18 | 10.86 | 10.5 | 1.83 | 2.09 |
| Turkey | 0.07 | 10.13 | 9.99 | 1.96 | 2.21 |
| Morocco | 0.05 | 11.17 | 11.07 | 1.96 | 2.07 |
| South Africa | 0.04 | 11.19 | 11.11 | 1.82 | 1.88 |
| Israel | 0.03 | 10.55 | 10.49 | 1.87 | 2.21 |
| Saudi Arabia | 0.02 | 9.87 | 9.82 | 1.98 | 2.54 |
| Egypt | 0 | 10.81 | 10.8 | 2.18 | 2.24 |
| Jordan | − 0.02 | 11 | 11.05 | 2.03 | 2.37 |
| Kazakhstan | − 0.04 | 9.98 | 10.06 | 1.87 | 2.07 |
| Bahrain | − 0.05 | 9.71 | 9.82 | 2.07 | 2.44 |
| Lithuania | − 0.06 | 9.67 | 9.78 | 1.62 | 1.94 |
| United States | − 0.07 | 9.91 | 10.04 | 1.88 | 2.1 |
| Chinese Taipei | − 0.07 | 8.08 | 8.2 | 1.55 | 1.95 |
| Lebanon | − 0.09 | 10.6 | 10.79 | 2.18 | 2.29 |
| Argentina | − 0.09 | 9.75 | 9.92 | 1.9 | 2.09 |
| Norway | − 0.1 | 10.09 | 10.28 | 1.78 | 1.93 |
| Canada | − 0.11 | 10.2 | 10.4 | 1.74 | 1.95 |
| Hungary | − 0.11 | 9.16 | 9.36 | 1.7 | 1.91 |
| Singapore | − 0.12 | 9.56 | 9.76 | 1.58 | 1.83 |
| Korea Republic | − 0.12 | 8.5 | 8.7 | 1.45 | 1.8 |
| Chile | − 0.12 | 9.89 | 10.15 | 2.01 | 2.15 |
| Iran | − 0.13 | 10.23 | 10.5 | 1.92 | 2.21 |
| Slovenia | − 0.13 | 8.86 | 9.07 | 1.43 | 1.76 |
| Malta | − 0.14 | 9.82 | 10.09 | 1.83 | 2.1 |
| Georgia | − 0.14 | 9.94 | 10.23 | 1.96 | 2.16 |
| United Arab Emirates | − 0.18 | 9.85 | 10.22 | 1.97 | 2.23 |
| Qatar | − 0.18 | 9.78 | 10.2 | 2.18 | 2.46 |
| Hong Kong | − 0.18 | 8.51 | 8.87 | 1.72 | 2.15 |
| Ireland | − 0.19 | 9.64 | 9.98 | 1.8 | 1.85 |
| Sweden | − 0.19 | 9.19 | 9.53 | 1.58 | 1.92 |
| New Zealand | − 0.21 | 9.71 | 10.1 | 1.77 | 1.95 |
| Kuwait | − 0.22 | 9.83 | 10.27 | 1.94 | 2.12 |
| Russian Federation | − 0.22 | 9.2 | 9.6 | 1.76 | 1.93 |
| Italy | − 0.23 | 8.68 | 9.05 | 1.49 | 1.75 |
| Australia | − 0.27 | 9.62 | 10.15 | 1.93 | 1.99 |
| Japan | − 0.27 | 8.27 | 8.68 | 1.36 | 1.63 |
| England | − 0.3 | 9.81 | 10.33 | 1.66 | 1.86 |

Positive values show the superiority of females and negative values show the superiority of males

Arabia is among 7 countries with the lowest gender parity in GGGR 2017. Another example of girls' superiority in confidence over boys in countries with lower gender equality is Oman. Oman also had the maximum female superiority in our meta-analysis in liking mathematics. This apparently unexpected trend was observed for all three constructs in both grades with some exceptions (See Figs. 1, 2 and 3). As mentioned above (in "Regional differences in TIMSS: outliers or a cluster"), these countries are are known

**Table 10 Grand mean effect sizes (ES) for all countries together as well as classified based on their GGGR Index of gender parity**

| | K | Mean ES | $\tau^2$ |
|---|---|---|---|
| Liking math | | | |
| Fourth graders | | | |
| All countries | 48 | −0.073 | 0.024 |
| Countries with the lowest gap (GGGI) | 10 | −0.127 | 0.018 |
| Countries with the highest gap (GGGI) | 10 | 0.071 | 0.022 |
| Eighth graders | | | |
| All countries | 40 | −0.106 | 0.014 |
| Countries with the lowest gap (GGGI) | 10 | −0.141 | 0.005 |
| Countries with the highest gap (GGGI) | 10 | −0.128 | 0.012 |
| Confidence in math | | | |
| Fourth graders | | | |
| All countries | 48 | −0.133 | 0.033 |
| Countries with the lowest gap (GGGI) | 10 | −0.199 | 0.017 |
| Countries with the highest gap (GGGI) | 10 | −0.078 | 0.032 |
| Eighth graders | | | |
| All countries | 40 | −0.141 | 0.01 |
| Countries with the lowest gap (GGGI) | 10 | −0.248 | 0.008 |
| Countries with the highest gap (GGGI) | 10 | −0.052 | 0.003 |
| Valuing math | | | |
| Eighth grader | | | |
| All countries | 40 | −0.066 | 0.02 |
| Countries with the lowest gap (GGGI) | 10 | −0.114 | 0.01 |
| Countries with the highest gap (GGGI) | 10 | −0.036 | 0.008 |

for boys that do worse than girls at school in general, not only in mathematics. Therefore, the trend observed here should not be surprising: higher interest, higher confidence, and putting higher value on mathematics resulted in better mathematics achievement for the girls in this set of countries. It is worth mentioning that the girls' better performance is relative to their nations' boys. Compared to countries that did well in TIMSS, the Middle East nations are behind. Some numbers would help in getting a vision of where these nations stand globally; in TIMSS 2015 the top achievers are East Asian countries including Singapore, Hong Kong SAR, Korea, Chinese Taipei, and Japan with relatively large performance gap between them and the next high performing country. In the eighth grade, for instance, Singapore achievement is 621. The closest neighbor to East Asian countries is Russian Federation with the achievement of 538. The highest achievement for the Middle East countries belongs to the United Arab Emirates (465) and the lowest belongs to Saudi Arabia (368).

Some previous studies found that gender inequality and gaps could be a factor that negatively influences mathematics performance; these studies suggest that variation in the gender stratification of educational, and occupational opportunities is a factor that leads to variation in the mathematics performance in favor of men (Baker and Jones 1993; Guiso et al. 2008). Regarding mathematics-relevant interest and self-confidence, and valuing mathematics this hypothesis is not fortified. The socio-cultural features, especially in male dominated countries, could have contributed to this seemingly controversial correlation of gender gap and math affect.

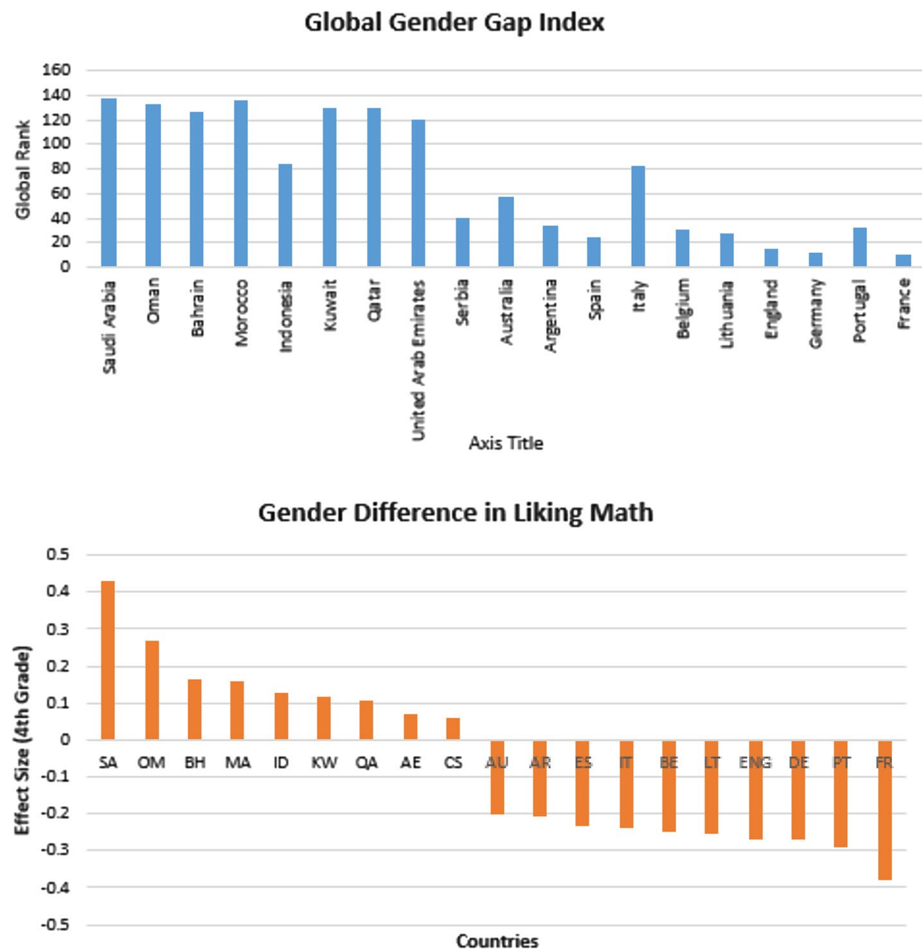


**Fig. 1** Positive values of the effect size represent difference in "liking mathematics" in favor of girls and negative values represent difference in favor of boys. Countries with higher gender gaps mostly represent females' superiority in mathematics interest

In case of Middle Eastern nations, the gap between boys and girls in schools has been identified and studied relatively well. Ripley (2017) in her article entitled "Boys are not defective" describes motivation as the dark matter of education in these nations. She mentions several factors that resulted in this gap. In some of these countries, boys unlike girls are guaranteed a government job no matter how they perform at schools which gives them low incentives to study hard. Moreover, there are distinct parental expectations from boys and girls: while girls are kept closer to home with more observation over what they do, boys enjoy more freedom and consequently are subject to more distractions in their education. Girls also have fewer job options than boys: many service jobs (e.g. jobs at restaurants and hotels) are not considered socially appropriate for women. There are other explanations such as girls having better teachers and better schools than boys, and male teachers have less job satisfaction than female teachers which result in boys' poor performance in the single-sex education systems of these countries (see Ripley 2017) (Fig. 3).

The contrastive affect pattern of some of the Middle East nations and Western nations, the negative correlation of general gender gap and gender difference in mathematics affect in the some of the European countries, and the achievement gap between East

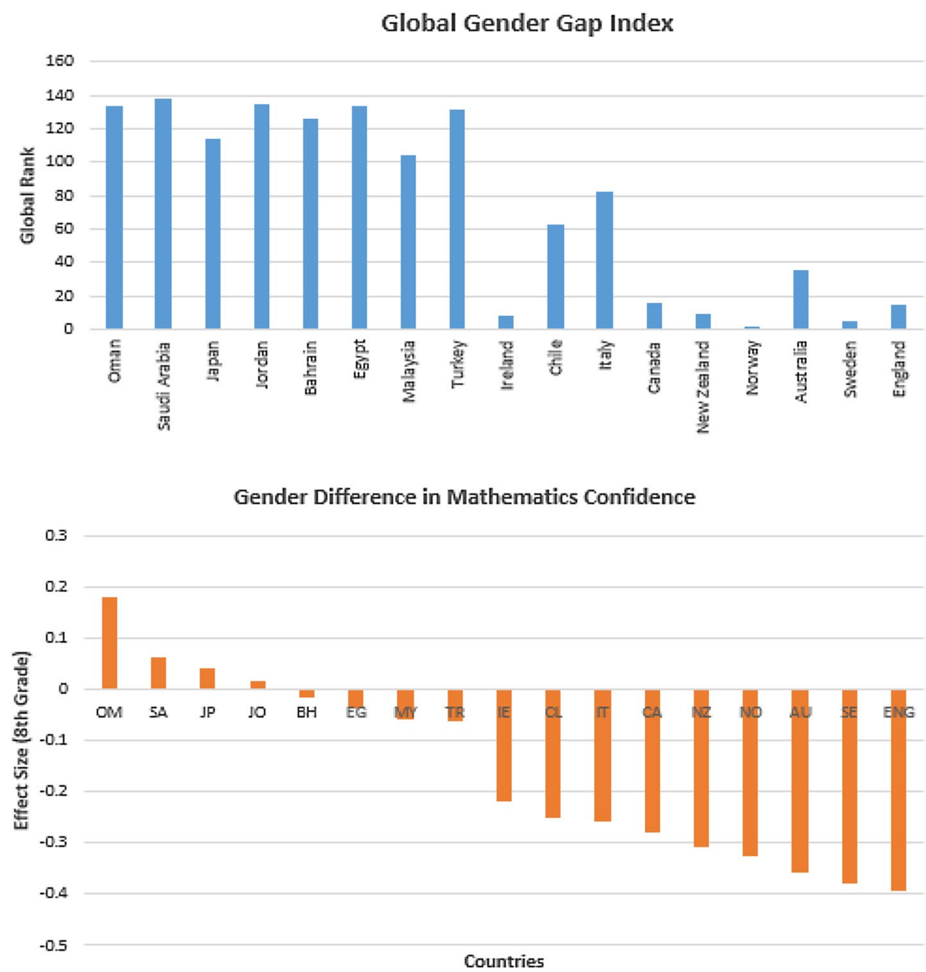


**Fig. 2** Positive values of effect size represent difference in "mathematics confidence" in favor of girls and negative values represent difference in math confidence in favor of boys. In countries with higher gender gap, girls showed a little more confidence in mathematics and in countries with lower gender gap, math confidence favored boys

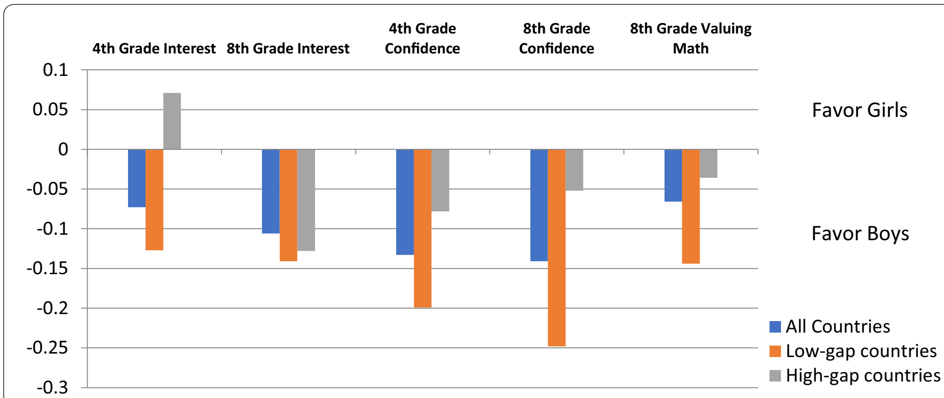


**Fig. 3** Gender differences in math affect as represented by the mean effect sizes. Three different bars for each construct are for all countries, low gender gap countries and high gender gap countries

Asian nations and other nations imply the importance of regional differences in the interpretations made from cross-national studies. Moreover, in the calculation of the mean effect size for all nations together, the positive and negative effect sizes cancel out each other and obscure the significance of cultural and motivational patterns that are mainly regional.

### Limitations of the study

There are some limitations for this study that should be considered in the interpretation of the findings. First, the idea of comparing fourth and eighth grade students' affect based on two very similar scales for each construct at a single point in time overlooks the differences in mathematics perceptions of the two grades; the two groups are so different regarding the materials they have been taught and tested on and in terms of psychological characteristics. Future studies may get a better estimation of the change in affect by comparing boys and girls in two waves of TIMSS instead of one. For instance, they could compare the fourth graders in TIMSS 2011 with eighth graders in TIMSS 2015, assuming they are the same students after 4 years of education. However, this approach is not flawless either.

The second limitation is the assumption of measurement invariance made for the scales used in the study. Next studies could check the measurement invariance first before proceeding to deeper analyses. As previously mentioned, the lack of invariance could result in misleading interpretation in cross-cultural studies (He et al. 2017, 2018).

Finally, some generalizations were made for specific regions in this study such as Middle East nations, East Asian nations, European nations, and high and low gap countries. These generalizations are limited by the number countries that participated in TIMSS 2015 and is by no means all-inclusive.

## Conclusion

The findings of the current study show that the gender difference in liking mathematics, confidence in mathematics, and valuing mathematics are very small and negligible in general. However, variations were observed in the magnitude of the differences across different nations. This provides further evidence for the malleable nature of the existing gender differences in mathematics. In addition, the comparison of the mean effect sizes of the gender difference in interest and mathematics-related confidence, revealed an increase in the gender gap from fourth grade to the eighth grade. Although the increase was relatively small, and the differences were still negligible, it could be a representation of an ascending trend in gender differences as students grow and get closer to the final years of compulsory education.

In contrary to some previous research findings, the current study did not support the idea that students develop 'math is for boys' gender stereotypes as early as elementary school. However, the scales used here touched on students' explicit perceptions and attitudes and not the implicit ones. Finally, the social-cultural gender gaps could not consistently account for the direction and the magnitude of the effect size of gender difference in the investigated constructs. More precisely, the findings imply that more gender parities in social, educational, economic, and health standards did not lead to less gender distinctions in attitudes towards mathematics (in a number of European countries) and less gender parities in those standards did not lead to more gender differences, as in the case of Middle Eastern nations. Moreover, this implication further illustrates the significance of regional differences and motivational patterns in cross-cultural studies.

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**Authors' contributions**
Both authors had equal dedications and contributions in compiling this manuscript. Both authors read and approved the final manuscript.

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**Availability of data and materials**
Data sets used in this study come from TIMSS international database which is publicly available for use in research. Therefore, this study did not need IRB approval.

**Competing interests**
The author declares that they have no competing interests.

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## Appendices

### Appendix 1

See Tables 11, 12.

**Table 11 Mathematics achievement of ten high GGGR 2017 gap countries adopted from TIMSS 2015 report for the 4th grade students**

| | Country | Avg. girls | Avg. boys | Girls higher | Boys higher | Sig. |
|---|---|---|---|---|---|---|
| 4th grade | Saudi Arabia | 405 | 363 | −43 | | ● |
| | Jordan | 384 | 368 | −15 | | ● |
| | Bahrain | 359 | 347 | −12 | | ● |
| | Kuwait | 437 | 426 | −10 | | ● |
| | Iran | 403 | 393 | −10 | | |
| | UAE | 465 | 461 | −3 | | |
| | Qatar | 537 | 534 | −2 | | |
| | Morocco | 519 | 518 | −1 | | |
| | Turkey | 569 | 571 | | 2 | |
| | Korea, Rep. | 526 | 534 | | 7 | ● |

**Table 12 Mathematics achievement of ten high GGGR 2017 gap countries adopted from TIMSS 2015 report for the 8th grade students**

| | Country | Girls avg. | Boys avg. | Girls higher | Boys higher | Sig. |
|---|---|---|---|---|---|---|
| 8th grade | Jordan | 395 | 376 | −19 | | ● |
| | Bahrain | 462 | 446 | −16 | | ● |
| | Saudi Arabia | 375 | 360 | −14 | | |
| | UAE | 471 | 459 | −12 | | |
| | Kuwait | 396 | 389 | −7 | | |
| | Qatar | 440 | 434 | −7 | | |
| | Turkey | 461 | 455 | −6 | | |
| | Iran | 438 | 435 | −3 | | |
| | Morocco | 385 | 384 | −2 | | |
| | Korea, Rep. of | 605 | 606 | | 1 | |

## Appendix 2

***Students confident in mathematics scale (4th grade)***

**How much do you agree with these statements about mathematics?**

| | Agree a lot | Agree a little | Disagree a little | Disagree a lot |
|---|---|---|---|---|
| 1) I usually do well in mathematics | ○ | ○ | ○ | ○ |
| 2) Mathematics is harder for me than for many of my classmates* | ○ | ○ | ○ | ○ |
| 3) I am just not good at mathematics* | ○ | ○ | ○ | ○ |
| 4) I learn things quickly in mathematics | ○ | ○ | ○ | ○ |
| 5) Mathematics makes me nervous* | ○ | ○ | ○ | ○ |
| 6) I am good at working out difficult mathematics problems | ○ | ○ | ○ | ○ |
| 7) My teacher tells me I am good at mathematics | ○ | ○ | ○ | ○ |
| 8) Mathematics is harder for me than any other subject* | ○ | ○ | ○ | ○ |
| 9) Mathematics makes me confused* | ○ | ○ | ○ | ○ |

* Reverse coded

Very Confident in Mathematics | 10.6 | Confident in Mathematics | 8.5 | Not Confident in Mathematics

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***Students confident in mathematics scale (8th grade)***

**How much do you agree with these statements about mathematics?**

| | Agree a lot | Agree a little | Disagree a little | Disagree a lot |
|---|---|---|---|---|
| 1) I usually do well in mathematics | ○ | ○ | ○ | ○ |
| 2) Mathematics is more difficult for me than for many of my classmates* | ○ | ○ | ○ | ○ |
| 3) Mathematics is not one of my strengths* | ○ | ○ | ○ | ○ |
| 4) I learn things quickly in mathematics | ○ | ○ | ○ | ○ |
| 5) Mathematics makes me nervous* | ○ | ○ | ○ | ○ |
| 6) I am good at working out difficult mathematics problems | ○ | ○ | ○ | ○ |
| 7) My teacher tells me I am good at mathematics | ○ | ○ | ○ | ○ |
| 8) Mathematics is harder for me than any other subject* | ○ | ○ | ○ | ○ |
| 9) Mathematics makes me confused* | ○ | ○ | ○ | ○ |

* Reverse coded

Very Confident in Mathematics | 12.1 | Confident in Mathematics | 9.5 | Not Confident in Mathematics

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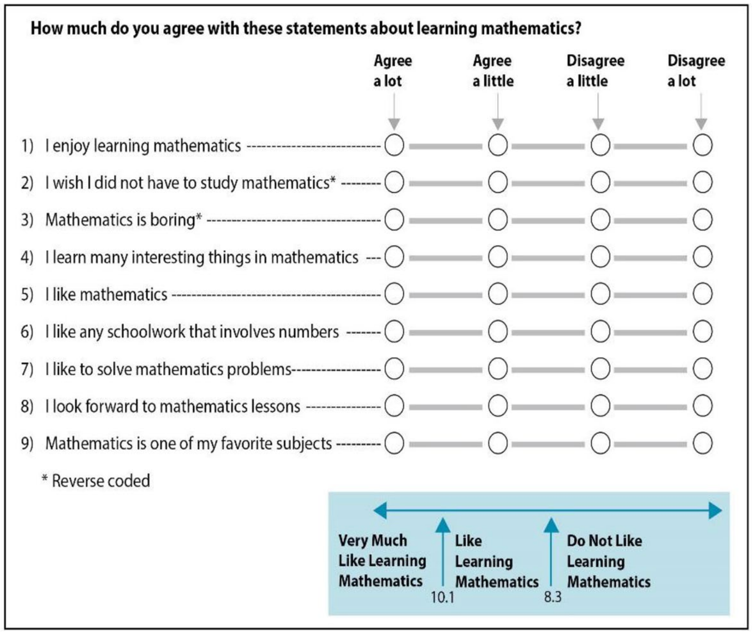
***Students like learning mathematics scale (4th grade)***



How much do you agree with these statements about learning mathematics?

| | Agree a lot | Agree a little | Disagree a little | Disagree a lot |
|---|---|---|---|---|
| 1) I enjoy learning mathematics | ○ | ○ | ○ | ○ |
| 2) I wish I did not have to study mathematics* | ○ | ○ | ○ | ○ |
| 3) Mathematics is boring* | ○ | ○ | ○ | ○ |
| 4) I learn many interesting things in mathematics | ○ | ○ | ○ | ○ |
| 5) I like mathematics | ○ | ○ | ○ | ○ |
| 6) I like any schoolwork that involves numbers | ○ | ○ | ○ | ○ |
| 7) I like to solve mathematics problems | ○ | ○ | ○ | ○ |
| 8) I look forward to mathematics lessons | ○ | ○ | ○ | ○ |
| 9) Mathematics is one of my favorite subjects | ○ | ○ | ○ | ○ |

* Reverse coded



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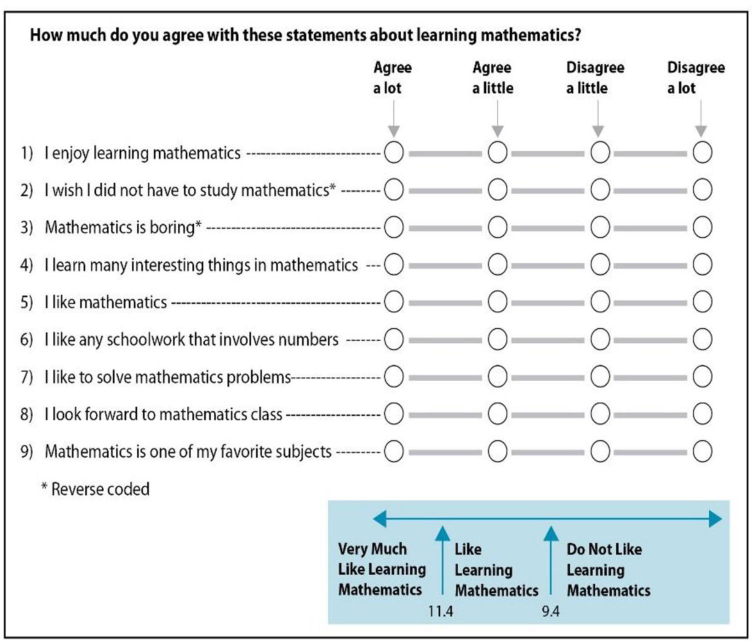
***Students like learning mathematics scale (8th grade)***



How much do you agree with these statements about learning mathematics?

| | Agree a lot | Agree a little | Disagree a little | Disagree a lot |
|---|---|---|---|---|
| 1) I enjoy learning mathematics | ○ | ○ | ○ | ○ |
| 2) I wish I did not have to study mathematics* | ○ | ○ | ○ | ○ |
| 3) Mathematics is boring* | ○ | ○ | ○ | ○ |
| 4) I learn many interesting things in mathematics | ○ | ○ | ○ | ○ |
| 5) I like mathematics | ○ | ○ | ○ | ○ |
| 6) I like any schoolwork that involves numbers | ○ | ○ | ○ | ○ |
| 7) I like to solve mathematics problems | ○ | ○ | ○ | ○ |
| 8) I look forward to mathematics class | ○ | ○ | ○ | ○ |
| 9) Mathematics is one of my favorite subjects | ○ | ○ | ○ | ○ |

* Reverse coded



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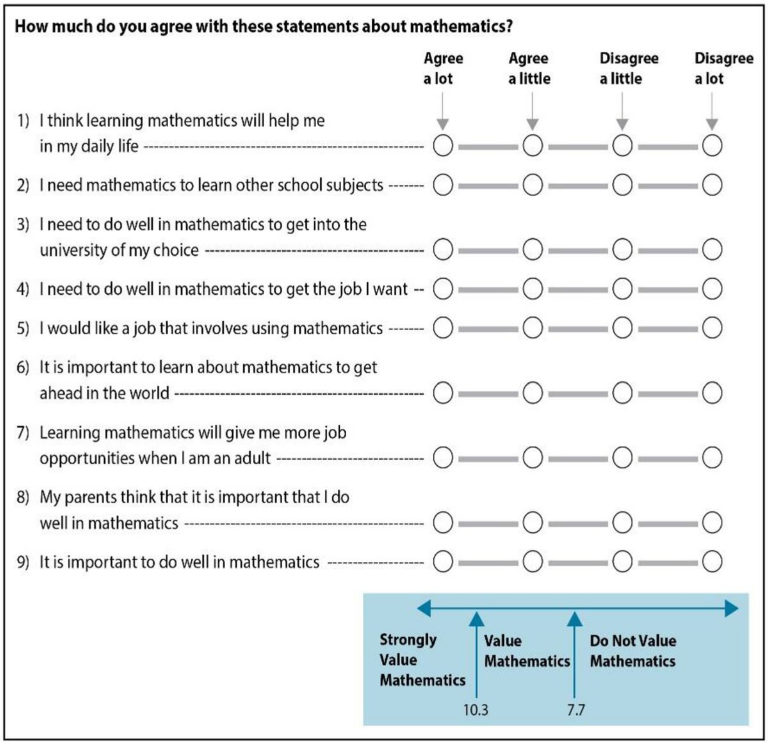
***Students value mathematics scale (8th grade) copied directly from TIMSS 2015 website***


**How much do you agree with these statements about mathematics?**

| | Agree a lot | Agree a little | Disagree a little | Disagree a lot |
|---|---|---|---|---|
| 1) I think learning mathematics will help me in my daily life | ○ | ○ | ○ | ○ |
| 2) I need mathematics to learn other school subjects | ○ | ○ | ○ | ○ |
| 3) I need to do well in mathematics to get into the university of my choice | ○ | ○ | ○ | ○ |
| 4) I need to do well in mathematics to get the job I want | ○ | ○ | ○ | ○ |
| 5) I would like a job that involves using mathematics | ○ | ○ | ○ | ○ |
| 6) It is important to learn about mathematics to get ahead in the world | ○ | ○ | ○ | ○ |
| 7) Learning mathematics will give me more job opportunities when I am an adult | ○ | ○ | ○ | ○ |
| 8) My parents think that it is important that I do well in mathematics | ○ | ○ | ○ | ○ |
| 9) It is important to do well in mathematics | ○ | ○ | ○ | ○ |



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## Publisher's Note