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Gender Differences in Mathematics Self-concept Across the World: an Exploration of Student and Parent Data of TIMSS 2015

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Abstract
Using data from the Trends in International Mathematics and Science Study (TIMSS) 2015 assessment of fourth-grade students in 32 countries, a series of mean comparisons and regression analyses were conducted to determine (1) the gender gap in students' self-concept in mathematics; (2) to what extent student achievement, student gender, and parental characteristics (early numeracy activities, attitudes, expectations, and education) are related to students' self-concept; and (3) to what extent the effect of achievement and parental characteristics on mathematics self-concept differs between male and female students. Results from this study indicate that gender differences in students' self-concept in mathematics are significant in most countries, usually in favour of boys as early as in fourth grade. The differences largely remain the same when the data analysis controls for effects of student achievement and parental involvement.

Keywords Gender differences · Mathematics self-concept · Mathematics achievement · Parental involvement · Primary education

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Introduction

Participation in science, technology, engineering and mathematics (STEM) fields of study and employment is a matter of international concern across several countries (Marginson, Tytler, Freeman & Roberts, 2013). Despite the importance of STEM for scientific discoveries, technological innovations and economic development (Roeser, 2006), there seems to be a decreasing trend in students' aspirations for a job that involves mathematics (Charles, Harr, Cech & Hendley, 2014), a subject which is a core foundation of STEM occupations (Carnevale, Smith & Melton, 2011). Moreover, among the students who do show an interest—and who do pursue a STEM career—the proportion of women is small (Charles et al., 2014; Organization for Economic Cooperation and Development [OECD], 2012). For example, in OECD countries, only 5% of 15-year-old girls expect to pursue a career in engineering and computing compared with 18% of boys (OECD, 2012), and women represent only 31% of the tertiary education graduates in the fields of science and engineering (OECD, 2017).

According to Spearman and Watt (2013), there are three possible explanations for the STEM gender gap: (1) differences in ability between boys and girls, (2) differences in attitudes towards STEM and (3) differences in socialisation. In terms of ability, on average, there are no large differences in the mathematics achievements of boys and girls across countries participating in the latest versions of studies such as the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA) (Mullis, Martin, Foy & Hooper, 2016; OECD, 2016b). However, a consistent finding in these studies, and in secondary analyses using their data, is that the size and the direction of the gender gap in mathematics achievement vary across countries (Alkhateeb, 2001; Badr, Morrissey & Appleton, 2012; Bedard & Cho, 2010; Guiso, Monte, Sapienza & Zingales, 2008; Mullis, Martin, Foy & Arora, 2012; OECD, 2013, 2016b). The reports from several cycles of TIMSS and PISA show that, in general, in most of the countries, there are no significant gender differences and, when they do exist, it tends to be in favour of boys. Only in a few countries (e.g. Qatar, Kuwait, Thailand), the gender differences are in favour of girls (OECD, 2013; Mullis, Martin, & Foy, 2008; Mullis et al., 2012).

The varying gender gaps in mathematics scores across countries together with the fact that students with high mathematics achievement do not necessarily contemplate a STEM career (Charles et al., 2014; OECD, 2012) suggest that the STEM gender gap might be more closely related to differences in attitudes towards STEM, the second explanation, including attitudes such as self-concept (Goldman & Penner, 2016). Although gender differences in mathematics achievement have proven to be small or even non-significant in many countries, there is still a significant gender gap favouring boys in terms of mathematics self-concept (Meelissen & Luyten 2008; Fan & Williams, 2010; Herbert & Stipek, 2005; OECD, 2013; Skaalvik & Skaalvik, 2004; Vandecandelaere, Speybroeck, Vanlaar, De Fraine & Van Damme, 2012; Wilkins, 2004).

The development of students' self-concepts might be closely related to the third explanation, socialisation. Research has suggested that parents, who deeply influence children's values, beliefs and behaviours, are especially important for their child's self-concept and interest in STEM (Dasgupta & Stout, 2014). Understanding gender differences in self-concept could provide insights into girls' participation in STEM and, consequently, help to meet the challenge of increasing their participation in this field. This could foster women's economic empowerment as STEM occupations are among the fastest growing and most lucrative careers (Carnevale et al., 2011; Dasgupta & Stout, 2014; OECD, 2012), and it could lead to greater innovation, creativity and productivity (Corbett & Hill, 2015).

Most of the international research on gender differences in mathematics achievement and attitudes has focused on secondary education students (e.g. Alkhateeb, 2001; Bedard & Cho, 2010; Guiso et al., 2008). However, examining the gender gap at this stage might be too late as previous research shows that gender differences in mathematics attitudes already exist in the elementary grades (Contini, Di Tommaso & Mendolia, 2016; Herbert & Stipek, 2005). Moreover, attitudes towards mathematics might influence important decisions—such as opting to take advanced mathematics courses—that could prevent students from enrolling in a mathematics-intensive STEM degree (Gunderson, Ramirez, Levine & Beilock, 2012; Parsons, Adler & Kaczala, 1982). Therefore, it is important to study differences in attitudes towards mathematics in young students, to understand the origin of the gender gap in mathematics self-concepts, in order to take actions that could prevent the gap from emerging or widening throughout the school years. Another gap in the literature on gender differences in mathematics is that it relates mostly Western countries. Additionally, theory development is largely based on work by authors from Western backgrounds, although the theoretical notions suggest relations that hold under a wide range of contexts. The present study will show to what extent gender differences vary across a wide set of countries. The aim of this study is to examine gender differences in self-concept for mathematics, taking into account student achievement and socialisation (particularly the role of parents), among primary school students with data from the TIMSS 2015 assessment. TIMSS 2015 data give the opportunity not only to study cross-national differences in the gender gap in mathematics self-concept among fourth-grade students but also to examine the association between parental characteristics and students' self-concepts, as for the first time, TIMSS included a questionnaire for parents (Mullis & Martin, 2013). .

Theoretical Background

Self-concept refers to an individual's perception of his or her competence in a given activity (Wigfield & Eccles, 2000) and academic self-concept reflects an individual's perceptions of his or her academic ability (Bong & Skaalvik, 2003; Mullis & Martin, 2013). According to Marsh, Craven, and Martin (2006), academic self-concept is different across domains; an individual's self-concept for mathematics is different from his or her self-concept for science. With that in mind, mathematics self-concept is specifically defined as a student's perceptions about his or her mathematics abilities (OECD, 2016a; Vandecandelaere et al., 2012). Academic self-concept is established in early childhood (Herbert & Stipek, 2005) and there are several factors—such as students' achievement and gender as well as parents' and teachers' influences or behaviours—related to lower or higher levels of self-concept (Stake, 2006).

Achievement Self-concept has been a popular topic of research in recent decades, with most of the research focused on the relationship between self-concept and achievement. This research consistently shows a positive correlation (e.g. Meelissen & Luyten 2008; OECD, 2016b; Wilkins, 2004). However, there is no clear consensus about the type of relationship between these variables. Calsyn and Kenny (1977) described two models for the relationship between self-concept and achievement: the self-enhancement model and the skills development model. In the self-enhancement model, perceptions of evaluations from others cause self-evaluation of ability and this self-evaluation has an impact on achievement. The skills development model posits that achievement has an influence on self-concept. A third model, known as the reciprocal effects model, assumes a reciprocal relationship between self-concept and achievement (Marsh, Trautwein, Lüdtke, Köller & Baumert, 2005).

Parental Characteristics Gender differences in mathematics self-concept may be explained by gender stereotypes that identify mathematics as a typically male domain (Cvencek, Meltzoff & Greenwald, 2011). According to Herbert and Stipek (2005), gender-stereotyped views can be conveyed by significant adults—such as parents and teachers—and result in low self-concepts in this subject among girls. Students' parents and home environments, therefore, play an important role in shaping students' attitudes towards mathematics and science. Parents' involvement in the education of their child refers to different parental behavioural patterns and parental practices, and it can be categorized as direct and indirect involvement (Fan & Chen, 2001; Farr, 2015). In the context of mathematics, direct involvement at home is described as tasks and activities that parents perform with their children to improve their mathematics skills, such as assistance with mathematics homework and mathematics-related games (Farr, 2015). Indirect involvement at home refers to the support given by parents that does not directly relate to helping their children with mathematics. It includes, among others, parents' aspirations or expectations about their children's future education, and parents' attitudes towards mathematics.

Children who frequently played mathematics-related games, or who frequently did mathematics-related activities, might develop familiarity and skills with regard to mathematics and, consequently, feel more confident of their abilities. However, the type and frequency of activities may depend on the children's gender, as some research has suggested that parents tend to engage their sons in more numeracy-oriented activities while engaging their daughters in more literacy-oriented activities (Gustafsson, Hansen & Rosén, 2011). Stereotyped activities may fail to reinforce positive self-concepts in mathematics among girls, as they are less likely than boys to develop familiarity and skill in mathematics-related activities (Skaalvik & Skaalvik, 2004). Parents' beliefs and expectations about their child's future education have also proven to be significant predictors of children's perception of their own skills. When parents have higher educational expectations for their children, children have higher mathematics and English self-concepts (Fan & Williams, 2010).

Regarding parents' attitudes towards mathematics and their influence on students' mathematics self-concepts, research has been inconclusive. Some studies show that negative attitudes—such as mathematics anxiety or low mathematics self-concept—can be transmitted to children (e.g. Gunderson, Ramirez, Levine, & Beilock, 2012; Maloney, Ramirez, Gunderson, Levine & Beilock, 2015) while other studies found no support for this (e.g. Dickens & Cornell, 1993; Phillips, 1987). According to Parsons et al. (1982), parents might convey messages to their children about the importance of mathematics for their lives. If parents think mathematics is useful, they might encourage their children to learn mathematics, do more mathematics-related activities and, consequently, children might feel more confident in their abilities.

However, if they put too much pressure on the importance of mathematics or if parents do not feel confident on their mathematics abilities, there could be a negative impact on the self-concept of their children (Ginsburg & Golbeck, 2004). Finally, parental involvement can be shaped by parents' characteristics, such as the parents' educational background (Farr, 2015). Results by Vandecandelaere et al. (2012) show that students whose parents had a higher educational level reported a higher mathematics self-concept.

As previously mentioned, the theoretical notions regarding gender differences in self-concept originate mainly from research conducted in Western countries. Moreover, they sometimes rely on within-country analyses and use different instruments to measure the key variables studied. It is important to study whether the findings hold across a wide set of countries and using reliable and comparable measures.

Research Questions

Using data from TIMSS 2015, the present study aims to examine gender differences in students' mathematics self-concepts and other factors that are related to students' self-concept (students' mathematics achievement and parental characteristics) and the interaction between these factors and students' gender in 32 countries. The following research questions guided this study:

(a) To what extent is there a gender gap in mathematics self-concept among fourth-grade students and how does the gap vary across countries?
(b) Which student characteristics (i.e. gender, mathematics achievement) and which parental characteristics (i.e. education, attitudes, expectations, and early learning activities) are related to the self-concept of fourth-grade students for mathematics?
(c) To what extent does the effect of achievement and parental characteristics on mathematics self-concept differ for boys and girls?

Method

Data

The data used for this project derive from the TIMSS 2015 assessment of fourth-grade students. TIMSS is an international assessment of mathematics and science at the fourth and eight grades, conducted by the International Association for the Evaluation of Educational Achievement (IEA) every 4 years since 1995 (Mullis & Martin, 2013). In TIMSS 2015, the sixth assessment in the TIMSS series, a total of 50 countries participated in the assessment of fourth-grade students. TIMSS not only measures achievement in the subjects of mathematics and science but also collects data about students' contexts for learning both subjects. There are several sources of context information in TIMSS which include, in the fourth-grade assessment, questionnaires for students, parents, teachers, school principals and national research coordinators (Mullis & Martin, 2013).

To select the participants in TIMSS, a two-stage random sample design is applied. The first stage consists of random sampling of schools in each participating country, and the second stage involves a random sample of intact fourth-grade classes in each sampled school. More information on the methods used in sampling can be found in the TIMSS Methods and Procedures Report (Martin, Mullis & Hooper, 2016).

For the present study, a purposeful sample of countries that participated in TIMSS 2015 was included in the analyses. Because of our interest in parent characteristics, only those countries for which there was at least an 85% response rate on the home questionnaire were considered. Of the 50 countries that participated in the TIMSS study, 32 countries fulfilled this requirement (see Fig. 1 for selected countries).

Instruments

Data collected by three TIMSS instruments were used in this study: the achievement test for mathematics, the student questionnaire and the home questionnaire. TIMSS 2015 measured achievement in mathematics and science. Each student received a booklet with four blocks of items, two per subject, which included multiple choice items and constructed response items.

After completing the achievement test, students completed a 30-min questionnaire about aspects of their home and school lives. The present study will focus on mathematics self-concept. In the questionnaire, students were asked to indicate their level of agreement on a 4-point Likert scale, ranging from 4 (*agree a lot*) to 1 (*disagree a lot*) to nine statements (e.g. "I usually do well in mathematics"). Using item response theory (IRT) scaling methods, TIMSS combined these nine items into a single scale with the name Students Confident in Mathematics. A score of 10.6 or higher indicated students were very confident in mathematics while a score below 8.5 indicated that students were not confident in mathematics. Students with values between these two points were confident in mathematics (Martin et al., 2016).

TIMSS also included a home questionnaire for students' parents or caregivers. It was designed to collect information about students' home backgrounds and early learning experiences (Martin et al., 2016). As with the student questionnaire, TIMSS combined home questionnaire items into different scales. The following scales were used for this study: (1) early numeracy activities before school, based on parents' answers regarding how frequently (i.e. often, sometimes, never or almost never) they did certain numeracy activities (e.g. "Play with number toys") with their children before they started primary school, and (2) parental attitude toward Mathematics and Science, based on parents' agreement on a 4-point Likert scale, ranging from 4 (*agree a lot*) to 1 (*disagree a lot*), to eight statements about mathematics and science (e.g. "My child needs mathematics to get ahead in the world). Additionally, two individual items from the home questionnaire were used in this study: (1) expectations about child's education: parents were asked to indicate how far in education they expect their child to go; and (2) parent's own level of education. More information regarding the creation, interpretation and reliabilities of the scales derived from the student and the home questionnaires can be found on chapter 15 of the Methods and Procedures in TIMSS 2015 (Martin et al., 2016). The Appendix shows the full set of items and scales used in this study.

Data Analysis and Procedures

Data analysis was conducted using SPSS (IBM Statistics Version 23) and IEA IDB Analyzer (Version 4.0.14), an application developed by the IEA for analysing data from large-scale assessment surveys (IEA, 2017). The software takes into account the test-rotation design (resulting in plausible values as indicators of students' mathematics ability) and the specific sampling design of TIMSS. Data files for the 32 selected countries were downloaded from the TIMSS official website. After deleting invalid or missing cases, the final database contained 146,824 cases. New variables were computed to assess the interaction effects of gender with the other independent variables in the regression analyses (product terms of gender with each of the variables mathematics achievement, parent attitudes, parent expectations, parent education and early numeracy activities). To answer the first research question and to get an overview of the gender gap in mathematics achievement, early numeracy activities and parents' expectations, a mean comparison was conducted, with boys as the reference group and girls as the comparison group. To be able to compare results across variables, correlations between gender and each variable (i.e. mathematics achievement, mathematics self-concept, early numeracy activities and parents' expectations) were calculated. Expressing gender differences as correlations between gender and each of the other variables also facilitates comparability with the outcomes of the subsequent regression analyses. In bivariate regression analyses (i.e. analyses with only one explanatory variable), the standardized regression coefficient equals the correlation between the dependent and independent variable. In the present study, correlations and standardized regression coefficients between − .10 and.10 were considered to denote (very) small effects. Correlations and coefficients in the ranges .10 to .40 (or − .10 to −.40) were considered medium. Effects over .40 (or smaller than − .40) were considered large effects. This is in line with the guidelines suggested by Cohen (1988).

Next, to answer the second research question, a linear regression analysis was conducted with mathematics self-concept as the dependent variable, and student characteristics (i.e. gender, mathematics achievement) and parental characteristics (i.e. early numeracy activities, expectations, attitudes, education) as independent variables, for each of the 32 countries.

For the third research question, additional regression analyses were conducted with the interaction between gender and each parental characteristics variable, as well as the interaction between gender and achievement, to determine if there are differential effects of these variables depending on the gender of the student. For all analyses, all plausible values (i.e. the five proficiency scores calculated by TIMSS 2015 for each student) were used as well as the sampling weight variable 'HOUWGT' (house weight), which sumps up to the national student sample size (Foy, 2017).

Results

This section begins with an overview of the descriptive statistics by gender of mathematics self-concept, mathematics achievement, early numeracy activities before school and parents' educational expectations, together with the correlation between gender and each of these variables. Next, the results of the multiple regression on mathematics self-concept are shown. Finally, the results of the additional regression models that include interactions between gender and parental characteristics, as well as between gender and achievement, are presented.

Gender Differences in Mathematics Self-concept and Achievement

Mathematics Self-concept. In the whole sample, the mathematics self-concept scale ranged from 3.08 to 14.17. The average mathematics self-concept was 9.81 (SD = 1.82) for girls and 10.06 (SD = 1.89) for boys. Girls in Chinese Taipei reported the lowest mathematics self-concepts (M = 8.59, SD = 1.63) while girls in Kazakhstan reported the highest (M = 10.68, SD = 1.98). In the case of boys, also students in Chinese Taipei had the lowest self-concepts (M = 9.20, SD = 1.90) compared to male students in Cyprus who reported the highest levels of mathematics self-concept (M = 10.83, SD = 2.19). The correlation with gender ranged from −.24 to .21. Figure 1 shows the correlation coefficients by country, ranked from lowest to highest. The correlation was negative in most countries (indicating female disadvantage), significantly so in 20 out of the 32 countries. Furthermore, negative correlations were larger than positive ones.

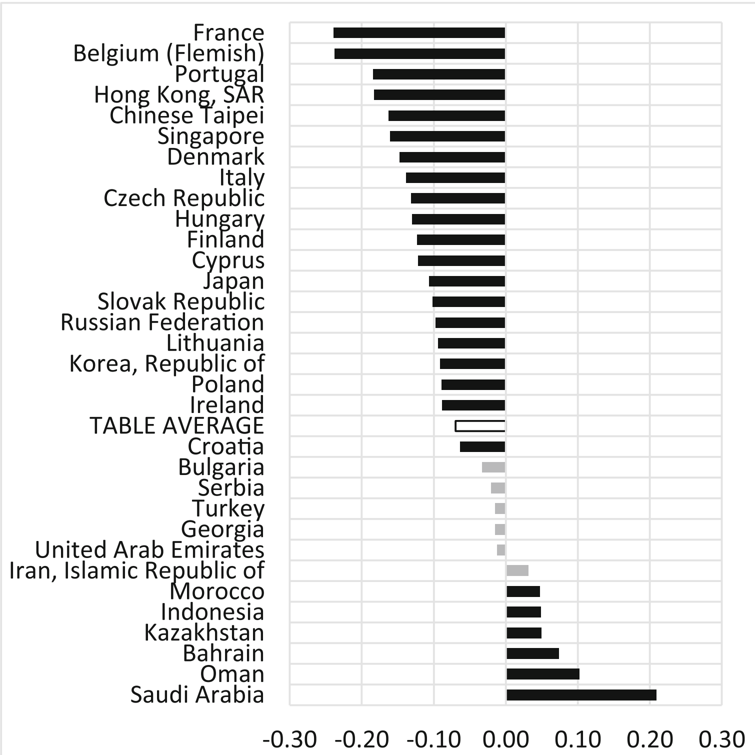

Fig. 1 Correlation between gender and mathematics self-concept by country. Note: Significant correlations (α < .05; two-tailed) printed in black; positive correlations indicate advantages for girls and negative correlations indicate advantages for boys

Mathematics Achievement. Overall, girls and boys had a similar mathematics achievement in TIMSS 2015. However, the gender gap in achievement varied from country to country, either in favour of girls or boys. The average mathematics achievement across 32 countries was 515.63 (SD = 76.03) for girls and 516.24 (SD = 80.77) for boys. The countries with the highest scores, for both girls and boys, were Singapore ($M = 621.87$, SD = 83.21, for girls; $M = 619.07$, SD = 86.4, for boys) and Hong Kong ($M = 611.63$, SD = 62.98, for girls; $M = 619.93$, SD = 67.17, for boys). On the other side of the scale, both female and male students in Morocco achieved the lowest scores ($M = 386.91$, SD = 89.04; $M = 383.68$, SD = 93.36, respectively). The correlation between gender and mathematics achievement ranged from − .16 to .18. The correlation was negative in half of the countries, and significantly so in 13 countries (see Fig. 2). The correlation was positive and statistically significant at the .05 level (two-tailed) only in Saudi Arabia, Oman, Bahrain and Finland.

A comparison of the results presented in Figs. 1 and 2 reveals that in all countries where girls had a significantly lower mathematics achievement than boys, girls also had a significantly lower self-concept. However, in countries where girls and boys performed equally on the mathematics assessment—such as Singapore, Japan and the Russian Federation—girls also showed a significantly lower mathematics self-concept compared to boys. Even in Finland, where girls significantly outperformed boys in

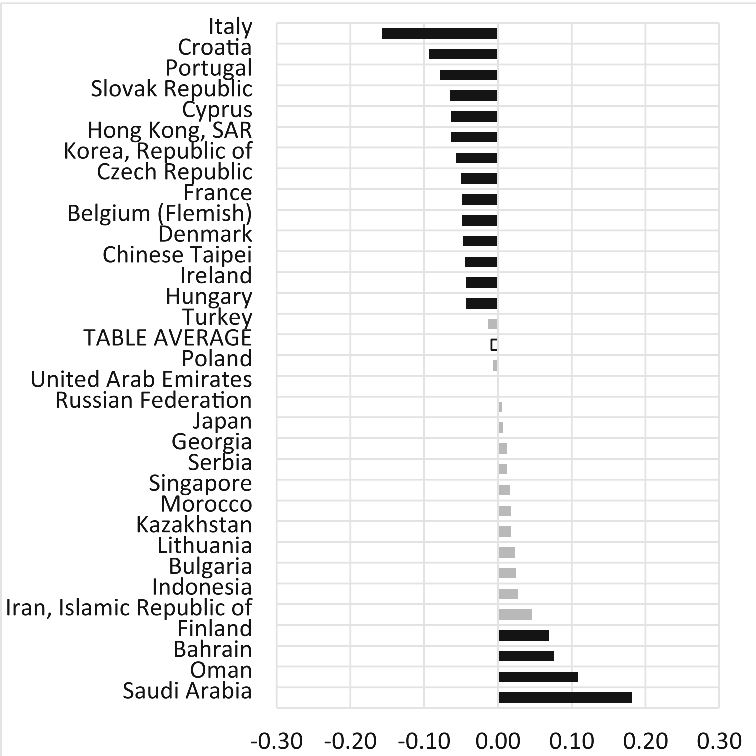

Fig. 2 Correlation between gender and mathematics achievement by country. Note: Significant correlations ($\alpha < .05$; two-tailed) printed in black; positive correlations indicate advantages for girls and negative correlations indicate advantages for boys

mathematics, girls were less confident in their mathematics abilities. This was not the case in the other countries where girls achieved significantly higher achievement results than boys did (i.e. Bahrain, Oman and Saudi Arabia). In these three countries, girls also had an advantage over boys in terms of mathematics self-concept.

Gender Differences in Parental Involvement

Early Numeracy Activities. The score for the frequency of early numeracy activities before school scale ranged from 3.24 to 13.82. The scale average score was 10.09 (SD = 1.89) for girls and 10.08 (SD = 1.87) for boys. Parents in the Russian Federation reported the highest frequency of early numeracy activities, both with girls ($M = 11.22$, SD = 1.91) and boys ($M = 11.13$, SD = 1.85) while the lowest frequency was reported by parents in Morocco ($M = 8.02$, SD = 2.56, for girls; $M = 7.93$, SD = 2.53, for boys). The correlation with gender ranged from − .07 to .08 and was not significant in most of the countries (see Fig. 3).

Educational Expectations. The values of this item ranged from 1 (i.e. finish lower secondary education) to 6 (i.e. finish a postgraduate degree). The average score for

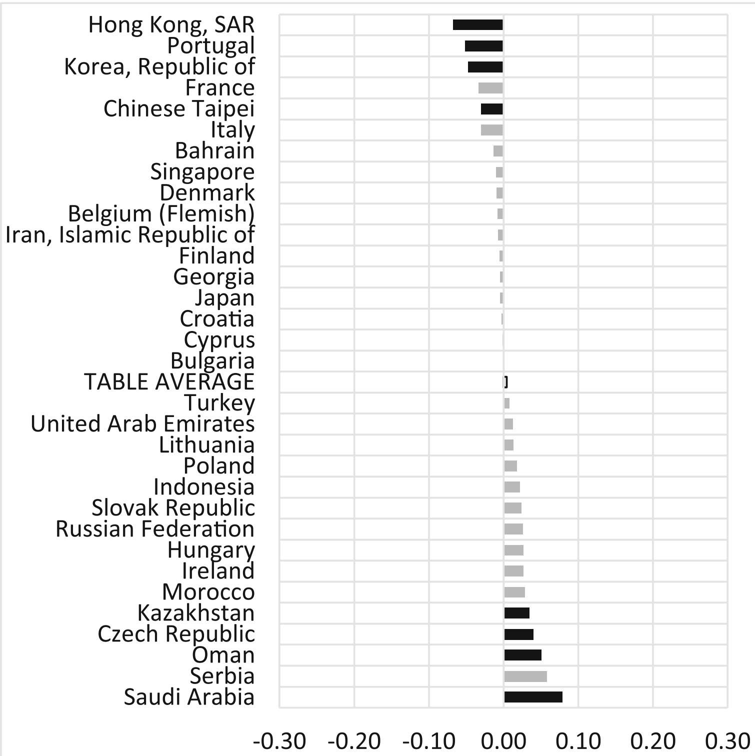

Fig. 3 Correlation between gender and early numeracy activities, by country. Note: Significant correlations ($\alpha < .05$; two-tailed) printed in black; positive correlations indicate advantages for girls and negative correlations indicate advantages for boys.

parents' educational expectations was 4.80 (SD = 1.27) for girls and 4.69 (SD = 1.31) for boys. Parents in Czech Republic reported the lowest expectations for their children (M = 3.72, SD = 1.79, for girls; M = 3.50, SD = 1.80, for boys) while parents in Turkey reported the highest expectations (M = 5.42, SD = 0.99, for girls; M = 5.49, SD = 0.85, for boys). The correlation with gender ranged from − .08 to .12. The correlation was positive in 26 of the 32 countries, and significantly so in 15 countries (see Fig. 4).

Predictors of Students' Self-concept in Mathematics

Multiple regression analyses for each country were conducted to explore the effects (in terms of relations, not causal effects) of student characteristics and parental characteristics on students' self-concept. Two student characteristics (gender and achievement) and four parental characteristics (education, attitudes, expectations and early numeracy activities) were used as the independent variables in the regression models. Figure 5 shows a comparison between the standardized regression coefficients for the gender variable and the coefficients of the bivariate correlations between self-concept and gender (presented in Fig. 2). For most countries, the effect of gender was only slightly less when the effects of achievement and parental involvement were taken into account.

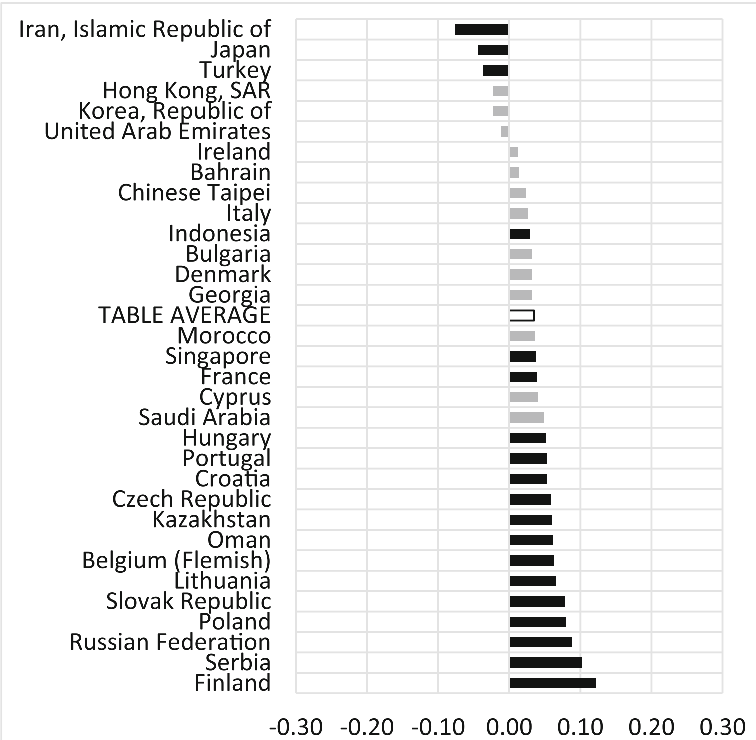

Fig. 4 Correlation between gender and parents' educational expectations by country. Note: Significant correlations ($\alpha < .05$; two-tailed) printed in black; positive correlations indicate advantages for girls and negative correlations indicate advantages for boys

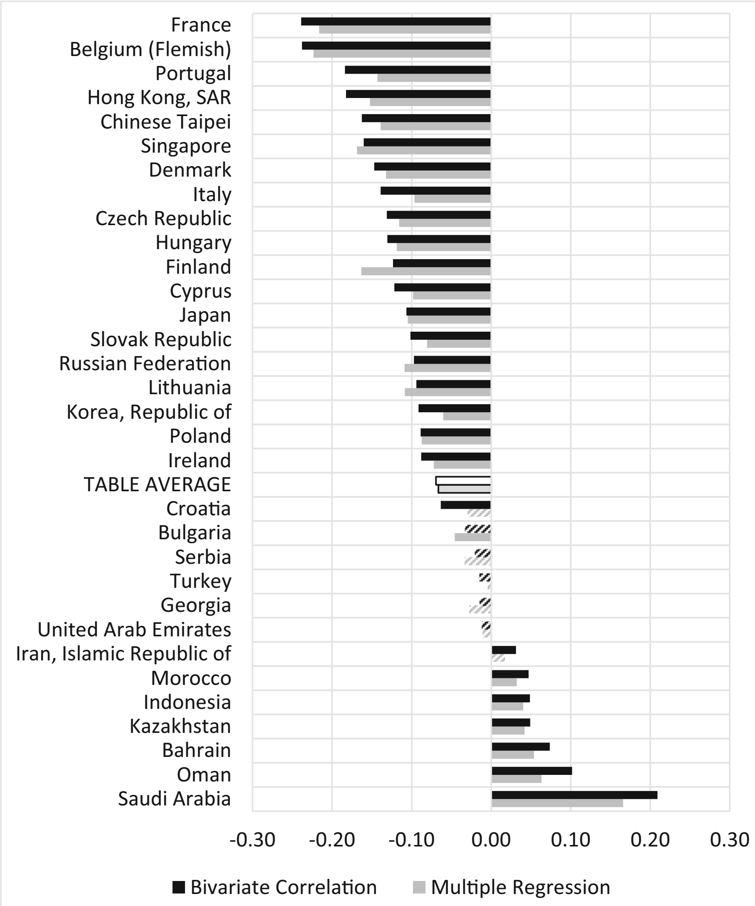

Fig. 5 Gender differences in self-concept in mathematics by country controlling for achievement and parental characteristics (standardized coefficients in multiple regression) and as bivariate correlations. Note: Significant correlations ($\alpha < .05$; two-tailed) printed in solid black and grey; positive correlations indicate advantages for girls and negative correlations indicate advantages for boys

If the effects of the other variables are taken into account, gender had a significant effect in 25 countries, and in 20 of these countries, the effect of gender was negative. In most countries, girls had lower self-concepts, even with achievement included in the model. The largest, negative effects for gender were found in Belgium ($\beta = -0.223$, $p < .001$) and France ($\beta = -0.216$, $p < .001$). In five countries, gender had a significant effect in favour of girls: Indonesia ($\beta = 0.040$, $p = .032$), Kazakhstan ($\beta = 0.042$, $p = .029$), Bahrain ($\beta = 0.054$, $p = .016$), Oman ($\beta = 0.063$, $p < .001$) and Saudi Arabia ($\beta = 0.166$, $p < .001$). The gender effect was not significant in Croatia, Georgia, the Islamic Republic of Iran, Morocco, Serbia, Turkey and the United Arab Emirates.

Student achievement had a significant effect on students' mathematics self-concept in all countries (at the .05 level, two-tailed). The largest effects of mathematics achievement were found in the Republic of Korea ($\beta = 0.520$, $p < .001$) and Turkey ($\beta = 0.492$, $p < .001$).

The parental involvement variables were significant in most countries, some variables more often than others. Parents' expectations were significant in 20 countries, and the effect was always positive. The largest effects of parents' expectations were found in Morocco ($\beta = 0.123$, $p < .001$), Italy ($\beta = 0.124$, $p < .001$) and Bulgaria ($\beta = 0.202$, $p < .001$). Parents' attitudes towards mathematics and science were significant in 19 countries, in which the standardized coefficient for this variable ranged from 0.025, in Singapore, to 0.085, in the Islamic Republic of Iran. The effect of parents' education was significant in 19 countries; however, this effect was mostly negative (we return to this counter-intuitive result in the discussion section). Only in Morocco and Saudi Arabia was a higher level of parents' education related to higher self-concept ($\beta = 0.100$, $p < .001$; $\beta = 0.063$, $p = .007$, respectively). The final variable of the regression model was early numeracy activities and it was significant in half of the countries, always with a positive effect. Early numeracy activities held the largest effects in Italy, Portugal and Bulgaria ($\beta = 0.083$, $p < .001$; $\beta = 0.082$, $p < .001$; $\beta = 0.079$, $p < .001$, respectively).

Gender Interaction with Predictors of Students' Self-concept

To further explore these gender differences in mathematics self-concept, the interaction effects between gender and each of the parental involvement aspects and the interaction between gender and achievement were included in the regression model, which comprises a total of 11 explanatory variables. An overview of the average standardized coefficient of each variable is presented in Fig. 6. Overall, only ten interactions were significant whereas a total of 160 interaction effects were estimated (5 interaction effects per regression analysis and 32 analyses conducted). Merely by chance, one would expect to find 5% of the effects to be significant at the .05 level. The number of significant interaction effects found hardly deviates from the number one would expect to find by chance (eight). The results are too modest to count as convincing evidence of interaction effects between student gender and parental involvement or achievement on self-concept in mathematics.

Limitations of This Study

There are some limitations that should be considered when interpreting the findings from this study. First, although the study was able to find a significant relationship

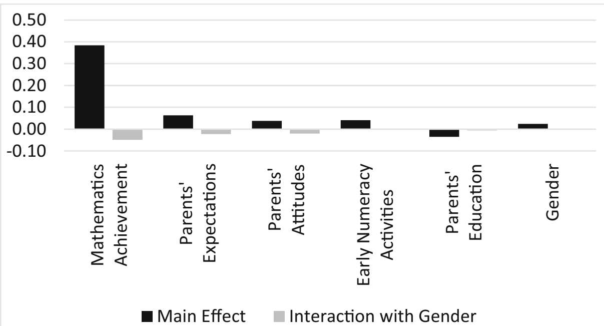

Fig. 6 Summary of regression analyses with gender interaction effects on mathematics self-concept

between some of the variables and students' self-concept in mathematics, it is not possible to determine causality because data were collected at one point in time. A second limitation is that TIMSS questionnaires involve self-report measures which could give incorrect information in two ways. One source of incorrect information comes from answers that require recalling past activities; for example, when parents were asked about early learning activities, it could be that parents did not accurately recall the frequency with which these activities took place. Another way in which self-reports limit the study is because they might allow for social desirability bias to be present. For instance, parents might have reported more involvement than actually occurred. It was expected that the gender gap in self-concept could be explained by differences in the effects of parental characteristics and student achievement between girls and boys. However, the regression analyses with interaction effects showed that few interaction effects were significant, and the results varied a lot between countries. This could have been because of the high number of interaction effects in the regression model.

Conclusion and Discussion

Despite gender differences in mathematics achievement narrowing over the last decades, gender differences in self-concept in mathematics remain considerable. The aims of the present study were to assess the gender gap in mathematics self-concept among primary school students and to explore whether this gap is related to achievement and parental characteristics using the grade 4 data of TIMSS 2015. The study shows to what extent gender differences vary across countries, but it also reveals important consistencies across countries. In this last section, the main conclusions and their implications are discussed. The main conclusions are (1) in most countries, girls in grade 4 show a lower self-concept in mathematics, even if the effect of mathematics achievement is taken into account; (2) girls perceived their mathematics ability more negatively compared to boys, not only in countries where girls performed less well than boys in mathematics, but also in countries where girls performed equal to or better than boys; and (3) while students' mathematics self-concept was mainly explained by gender and mathematics achievement, parents' expectations, early numeracy activities and parents' attitudes towards mathematics and science had—in general—positive associations with students' self-concept.

The most important finding is that, in most countries, girls show a lower self-concept in mathematics. This finding is in line with previous research results with an international perspective (e.g. Wilkins, 2004) as well as within-country studies (Crombie, Sinclair, Silverthorn, Byrne, DuBois, & Trinneer, 2005; Herbert & Stipek, 2005; King & McInerney, 2014; Meelissen & Luyten, 2008; Skaalvik & Skaalvik, 2004; Vandecandelaere et al., 2012). The reasons for this gap remain unclear. If the effect of students' mathematics achievement is taken into account, girls' perceptions of their mathematics abilities are still less positive than those of boys.

A comparison of gender differences in achievement and self-concept between countries showed that in all countries where girls had significantly lower mathematics achievement than boys, girls also had a significantly lower self-concept. If the relationship between achievement and self-concept is explained by the self-enhancement model proposed by Calsyn and Kenny (1977), girls' lower achievement might be a consequence of their lower self-concept. However, girls also perceived their mathematics ability more negatively compared to boys in countries where girls and boys performed equally in mathematics. Remarkably, this was also the case in Finland, where girls significantly outperformed boys in mathematics. This indicates that even when girls show a better math performance, their self-concept may still lag behind the self-concept of male students. Future research should establish to what extent the differences in self-concept can be attributed to underestimation of one's own capacities by girls, overestimation by boys or both. Useful lines of inquiry might focus on factors that could explain the relatively low levels of self-concept among high-achieving girls or the high levels of self-concept among low-performing boys.

The fact that gender is a significant factor in mathematics self-concept is a matter of concern given its implications for future educational choices such as enrolment in advanced programs or choosing college majors related to STEM. In agreement with Herbert and Stipek (2005), the findings presented here indicate that these differences already exist among grade 4 students and therefore develop before the age of 10, possibly at a very young age. If girls have lower mathematics self-concepts than boys at such a young age, it might be too difficult to encourage their STEM interest in the future, as there is evidence that student attitudes only become less positive throughout the school years (King & McInerney, 2014; Wilkins, 2004). Further research is needed on the origins of self-concept at an early age. When do girls start to lag behind with regard to their self-concept in mathematics? And why do girls believe that they are not very good at mathematics, even when their test scores are similar to those of their male classmates?

Following the suggestions given by Spearman and Watt (2013), it was expected that (aspects of) parent involvement would show a correlation with mathematics self-concept. However, mathematics self-concept was mainly explained by the students' gender and achievement. Across countries, the parental characteristic that showed the largest associations with mathematics self-concept was parents' expectations, which showed a significant positive relation with mathematics self-concept in 20 out of the 32 countries. Similar findings were reported by Fan and Williams (2010) both for mathematics and English. Early numeracy activities also showed positive significant effects for self-concept and this occurred in half of the countries. LeFevre, Skwarchuk, Smith-Chant, Fast, Kamawar and Bisanz (2009) found in their study positive effects of early numeracy activities on student's mathematics achievement in grades 1 and 2. Following the line of reasoning of the skills development model, this suggests that in these countries, early numeracy activities could result in higher achievement in mathematics in the first grades of primary school and that higher achievement might support the development of more positive mathematics self-concepts (Calsyn & Kenny, 1977).

An unexpected finding, and contrary to results by Vandecandelaere et al. (2012), was the negative effect that parents' education had on their child's self-concept (significant in 18 countries). However, it could be that the effect of parents' education was not positive because other aspects of parental involvement were included in the model, which are likely to be highly correlated with parents' education. For example, highly educated parents tend to have higher expectations of their children's education compared to low-educated parents (Tan, 2017). The data used for this study also provides evidence for this pattern; the average correlation between parents' education and parents' expectations was .44, ranging from .21 (in Turkey) to .77 (in Bulgaria). The analyses show that, when statistically controlling for early numeracy activities, educational expectations and parental attitudes, a modestly negative relation remains between parents' education and self-concept. This does not mean that children with highly educated parents have lower self-concepts. Highly educated parents tend to score high on the aforementioned aspects of involvement.

The final aim of this study was to examine if differences in socialisation could explain differences in self-concept. For this, we studied the interaction of students' gender with parental characteristics. Given the prevalence of gender stereotypes that identify mathematics as a typical male domain (Cvencek et al., 2011; Nosek et al., 2009; Smyth & Nosek, 2015), it was expected that parents would differ in the way they interacted with their daughters and sons or that their involvement would affect girls and boys differently. Yet, the overall correlation between gender and early numeracy activities was zero and, in most of the countries, parents reported, on average, the same frequency of numeracy activities with girls and with boys. However, parents did have significantly higher academic expectations for girls than for boys in most of the countries, although in all cases, the correlation between gender and parents' expectations was very low.

When planning this study, we did not anticipate a relation between performance in mathematics at the country level and gender differences in self-concept, but the results definitely suggest such a relationship. In top-performing countries—such as Singapore, Chinese Taipei, and the Republic of Korea—on average, boys had a higher score on the mathematics self-concept scale than girls. In countries with low performance—such as Saudi Arabia, Oman, and Bahrain—girls showed a higher self-concept than boys (see Table 1). One possible explanation is that girls' more positive perceptions of their abilities in these Middle East countries come from the separation of sexes in their educational systems, a situation that is reflected in the TIMSS 2015 sample implementation as Saudi Arabia, Bahrain and the Islamic Republic of Iran had an explicit stratification by gender (Martin et al., 2016). Compared to a coeducational setting, girls in single-sex classes tend to have more positive attitudes towards mathematics (Lee & Anderson, 2015; Van Damme, Opdenakker & Van den Broeck, 2004). For boys, the picture is not so clear; Lee and Anderson (2015) report no significant differences in attitudes towards mathematics among boys in single-sex or coeducational settings while results by Van Damme et al. (2004) show that in schools with an equal mix with respect to gender, boys have strong positive attitudes towards mathematics. Using data of international studies, such as TIMSS or PISA, to compare the relationship between self-concept and school and class climate in both types of schools (single-sex and mixed) within countries might provide more insight in why these differences occur. Our findings also suggest that female self-concept in mathematics is relatively low in countries with high average achievement. These findings relate to national contexts. While the present study was an exploration of data in different countries, future research might focus on within-country analyses and more small-scale contexts, comparing student groups (e.g. classes, education tracks) of different proficiency levels.

Despite evidence that the gender gap in mathematics self-concept develops as early as the elementary grades, it might still be interesting to study the effects of parents' direct and indirect involvement on the further development of the self-concept of older students. TIMSS 2015 included home questionnaire only

Table 1 Average mathematics score and correlation between self-concept and gender per country

Country	Score	Correlation between self-concept and gender
Singapore	618	−.16*
Hong Kong SAR	615	−.18*
Korea	608	−.09*
Chinese Taipei	597	−.16*
Japan	593	−.11*
Russian Federation	564	−.10*
Ireland	547	−.09*
Belgium-Flemish	546	−.24*
Kazakhstan	544	.05*
Portugal	541	−.18*
Denmark	539	−.15*
Lithuania	535	−.09*
Finland	535	−.12*
Poland	535	−.09*
Hungary	529	−.13*
Czech Republic	528	−.13*
Bulgaria	524	−.03
Cyprus	523	−.12*
Serbia	518	−.02
Italy	507	−.14*
Croatia	502	−.06*
Slovak Republic	498	−.10*
France	488	−.24*
Turkey	483	−.02
Georgia	463	−.01
United Arab Emirates	452	−.01
Bahrain	451	.07*
Iran	431	.03
Oman	425	.10*
Indonesia	397	.05*
Saudi Arabia	383	.21*
Morocco	377	.05*

Note: $*p < .05$

for fourth-grade students. A home questionnaire for the eighth-grade might provide valuable insights into why girls and boys choose to pursue STEM studies at different rates. It would also be valuable to analyse data from TIMSS Advanced, the third modality of TIMSS, which focusses on students in advanced STEM programs. In this way, the analyses could be aimed at students that actually chose to pursue a STEM course.

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Appendix

Scales from TIMSS 2015 Student and Parent Questionnaire

Source: TIMSS 2015 Student Questionnaire, Grade 4 and TIMSS 2015 Parent Questionnaire, Grade 4. Copyright © 2014 International Association for the Evaluation of Educational Achievement (IEA). Publisher: TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College

Students Confident in Mathematics Scale (ASBGSCM)
How much do you agree with these statements about mathematics?

Variable name	Item wording
ASBM03A	I usually do well in mathematics
ASMB03B[a]	Mathematics is harder for me than for many of my classmates[a]
ASMB03C[a]	I am just not good at mathematics[a]
ASMB03D	I learn quickly in mathematics
ASMB03E[a]	Mathematics makes me nervous[a]
ASMB03F	I am good at working out difficult mathematics problems
ASMB03G	My teacher tells me I am good at mathematics
ASMB03H[a]	Mathematics is harder for me than any other subject[a]
ASMB03BI[a]	Mathematics makes me confused[a]

[a] Items were reverse coded

Early Numeracy Activities Before School Scale (ASBHENA)
Before your child began primary/elementary school, how often did you or someone else in your home do the following activities with him or her?

ASBH02J	Say counting rhymes or sing counting songs
ASBH02K	Play with number toys (e.g. blocks with numbers)
ASBH02L	Count different things
ASBH02M	Play games involving shapes (e.g. shape sorting toys, puzzles)
ASBH02N	Play with building blocks or construction toys
ASBH02O	Play board or card games
ASBH02P	Write numbers

Parental Attitude Toward Mathematics and Science Scale (ASBHAMS)
How much do you agree with these statements about mathematics and science?

ASBH16A	Most occupations need skills in math, science, or technology

ASBH16B	Science and technology can help solve the world’s problems
ASBH16C	Science explains how things in the world work
ASBH16D	My child needs mathematics to get ahead in the world
ASBH16E	Learning science is for everyone
ASBH16F	Technology makes life easier
ASBH16G	Mathematics is applicable to real life
ASBH16H	Engineering is necessary to design things that are safe and useful

Parents Expectations

How far in education do you expect your child to go?

Options
Finish < Lower secondary education – ISCED Level 2>
Finish < Upper secondary education – ISCED Level 3 >
Finish < Post-secondary, non-tertiary education – ISCED Level 4>
Finish < Short-cycle tertiary education – ISCED Level 5>
Finish < Bachelor’s or equivalent level – ISCED Level 6>
Finish < Postgraduate degree: Master’s – ISCED Level 7 or Doctor – ISCED Level 8>

Parents’ Highest Education Level (ASDHEDUP)

What is the highest level of education completed by the child’s father (or stepfather or male guardian) and mother (or stepmother or female guardian)?

Options
Did not go to school
Some <Primary education – ISCED Level 1 or Lower secondary education – ISCED Level 2>
< Lower secondary education – ISCED Level 2>
< Upper secondary education – ISCED Level 3 >
< Post-secondary, non-tertiary education – ISCED Level 4>
< Short-cycle tertiary education – ISCED Level 5>
<Bachelor’s or equivalent level – ISCED Level 6>
<Postgraduate degree: Master’s – ISCED Level 7 or Doctor – ISCED Level 8>
Not applicable

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