Exploring international gender differences in mathematics self-concept

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This study provides an international perspective on mathematics by examining mathematics self-concept, achievement, and the desire to enter a career involving mathematics among eighth graders in 49 countries. Using data from the Trends in International Mathematics and Science Study, this study shows that self-concept in mathematics is more closely related to the desire to enter a career using mathematics than achievement is. Further, while gender differences in mathematics self-concept are smaller in more egalitarian countries, both girls and boys have lower mathematics self-concepts and less interest in mathematics careers in these countries. These findings reveal a policy paradox: policies aimed at training the next generation of STEM professionals often highlight the need to close the gender gap, but countries with smaller gender gaps have fewer boys and girls interested in mathematics-intensive careers. We conclude by highlighting the importance of disentangling instrumental and expressive aspects of gender inequality in STEM fields.

Keywords: gender inequality; mathematics self-concept; international education; mathematics achievement; STEM; eighth graders

Introduction

In spite of the fact that women are excelling in fields such as medicine, law, and literature, women remain under-represented in science, technology, engineering, and mathematics (STEM) fields (Burrelli, 2008; U.S. Department of Labor, Bureau of Labor Statistics, 2005). This is particularly noteworthy given that women are now doing considerably better than men in terms of high school and college graduation (Buchmann, DiPrete, & McDaniel, 2008; Schofer & Meyer, 2005). One factor why women remain under-represented in STEM fields highlighted by previous research is a lack of self-concept in mathematics (Fox, Sonnert, & Nikiforova, 2011).

Self-concept captures a person’s ‘perception of himself’, and these perceptions are thought to influence the ways in which he acts, and his acts in turn influence the ways in which he perceives himself. (Shavelson, Hubner, & Stanton, 1976, p. 411)

Students base their mathematics self-concept largely on their experiences and history of achievement, and this self-concept is a crucial component in pursuing a career in a STEM field, as students with low levels of self-concept do not believe that they will perform well in this area (Bong & Skaalvik, 2003; Louis & Mistele, 2012; Pajares & Miller, 1994; Usher, 2009).

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Although research has highlighted the important role self-concept plays in encouraging women to pursue and excel in mathematics (Hackett, 1985; Luzzo, Hasper, Albert, Bibby, & Martinelli, 1999; Pajares & Miller, 1994), mathematics self-concept is often overlooked in cross-national studies of gender differences, which more often focus on gender differences in achievement (e.g. Baker & Jones, 1993; Felson & Trudeau, 1991; Penner, 2008). Studies of international gender differences in achievement highlight the role that country-level factors play in shaping gender inequality in STEM fields, showing, for example, that gender differences in mathematics and science achievement are smaller in more gender-egalitarian countries (e.g. Guiso, Monte, Sapienza, & Zingales, 2008; Penner & Cadwallader-Olsker, 2012; Riegle-Crumb, 2005). By contrast, research examining the under-representation of women in STEM majors suggests that country-level gender egalitarianism is more closely associated with whether women get degrees than whether they are getting degrees in STEM fields, and suggests that forms of gender egalitarianism that stress self-expression might actually lead women to be more under-represented in STEM fields (Charles & Bradley, 2002, 2009). As such, it is unclear how the overall level of gender egalitarianism in a country might shape gender differences in mathematics self-concept. This study thus draws on data from 49 countries to examine the mathematics self-concepts of eighth-grade girls and boys, comparing not only how gender differences in mathematics self-concept vary across countries and are shaped by the gender egalitarianism of the country, but also how mathematics self-concept and achievement are related to interest in pursuing a career involving mathematics.

We believe that this is important, because while the gender differences in content knowledge represented by gender differences in achievement may play a key role in creating gender inequality in STEM representation, in order to persist in the STEM pipeline, students need to have not just content knowledge, but also mathematics self-concept (cf. Ceci & Williams, 2009). A high aptitude in mathematics is unlikely to translate into a STEM degree without high levels of mathematics self-concept, as self-concept provides the belief that one can succeed in STEM. While previous research has found that mathematics self-concept increases as achievement increases (Hackett, 1985; Louis & Mistele, 2012; Peters, 2013; Usher, 2009; Wang, Osterlind, & Bergin, 2012), given the important role of mathematics self-concept in shaping students’ career interests (Luzzo et al., 1999; Pajares & Miller, 1994), it is important for international research to examine gender differences in mathematics self-concept directly.

In particular, we argue that it is important to examine self-concept directly because of research showing that boys believe that they are more mathematically competent than girls even when they have the same level of mathematics achievement (Correll, 2001). Correll suggests that cultural beliefs and expectations lead men to believe that they are better in mathematics even when they are not, which results in them pursuing mathematical careers at higher rates than women (2001, 2004). While Correll examines only students in the USA, some international research also suggests that mathematics self-concept may be more important for understanding the gender differences in representation in STEM fields (Louis & Mistele, 2012; Peters, 2013).

Our study builds on this work by examining how students perceive their own mathematical skills through a self-assessment in 49 countries. Studying multiple countries provides a broader perspective on gender differences in mathematics self-concept, and allows us to link gender differences in this domain to the gender egalitarianism of the country more broadly. We begin by examining how mathematics self-concept and achievement are related to gender differences in career interests, showing that mathematics self-concept is more closely linked to career interests than achievement. We then provide
information about gender differences in mathematics self-concept in various countries, and examine the degree to which mathematics self-concept tracks with achievement for girls and boys in the 49 countries we examine. We conclude by examining the importance of broader country-level gender inequality, examining the degree to which Gender Empowerment Measure (GEM) scores track with gender differences in self-concept and interest in a career involving mathematics.

Data and methods

Data

To address these questions, we use data on eighth-grade students from the 2007 Trends in International Mathematics and Study (TIMSS). Eighth grade represents a key stage for understanding the emergence of gender differences in STEM fields, as previous research has highlighted the importance of adolescence in this area (e.g. Riegle-Crumb, Moore, & Ramos-Wada, 2010). TIMSS is a well-established, long-running survey that collects nationally representative survey data on fourth and eighth grade students across a range of countries. Importantly for our purposes, TIMSS not only includes a mathematics test, which examines students’ knowledge, application, and reasoning in four content areas (number, algebra, geometry, and data and probability), but also asks students about their mathematics self-concept and the degree to which they view mathematics as important to their future career (Mullis et al., 2005). While issues of data quality are often a concern in cross-national studies (cf. Bracey, 2000), we believe that they are less problematic here, as our analyses consider how within-country gender differences vary across countries, and focus less on direct comparisons of achievement across countries.

We examine TIMSS data from 49 countries: Armenia, Australia, Bahrain, Bosnia and Herzegovina, Botswana, Bulgaria, Chinese Taipei, Colombia, Cyprus, Czech Republic, Arab Republic of Egypt, El Salvador, Georgia, Ghana, Hong Kong SAR, Hungary, Indonesia, Islamic Republic of Iran, Israel, Italy, Japan, Jordan, Republic of Korea, Kuwait, Lebanon, Lithuania, Malaysia, Malta, Mongolia, Morocco, Norway, Oman, Palestine, Qatar, Romania, Russian Federation, Saudi Arabia, Scotland, Serbia, Singapore, Slovenia, Sweden, Syrian Arab Republic, Thailand, Tunisia, Turkey, Ukraine, UK, and the USA. Table 1 presents information on the number of male and female students in our data for each country.

Although ideally we would follow students from eighth grade through adulthood and directly link the gender differences in mathematics self-concept observed in adolescence to the under-representation of women in STEM fields (cf. Legewie & DiPrete, 2011), there are no large-scale international data sets that permit such longitudinal analyses. Thus, we instead link mathematics self-concept and achievement to students’ assessments of their future work.

While this somewhat limits the conclusions that we are able to draw, given the cumulative nature of the STEM pipeline, we believe that these early differences are important, as cumulative advantage processes suggest that even in the absence of other inequalities, these initial differences will be magnified over time (cf. DiPrete & Eirich, 2006).

Following previous international research interested in overall levels of gender quality in a society (Fuwa, 2004; Penner, 2008), we use the United Nations Development Programme’s Gender Empowerment Measure (Watkins, 2007) to capture the overall level of gender egalitarianism of a country. GEM combines factors such as the percentage of seats in parliament held by women, the percentage of managers who are women, and women’s share of earned income.
Table 1. Number of boys and girls, by country.

| Country name                               | Boys  | Girls | Total  |
|--------------------------------------------|-------|-------|--------|
| Armenia                                   | 2384  | 2305  | 4689   |
| Australia                                 | 2226  | 1843  | 4069   |
| Bahrain                                   | 2256  | 1974  | 4230   |
| Bosnia and Herzegovina                    | 2152  | 2068  | 4220   |
| Botswana                                   | 2015  | 2193  | 4208   |
| Bulgaria                                  | 1974  | 2045  | 4019   |
| Chinese Taipei                             | 2103  | 1943  | 4046   |
| Colombia                                   | 2389  | 2484  | 4873   |
| Cyprus                                     | 2203  | 2196  | 4339   |
| Czech Republic                             | 2510  | 2335  | 4845   |
| Arab Republic of Egypt                     | 3324  | 3258  | 6582   |
| El Salvador                                | 1926  | 2137  | 4063   |
| Georgia                                    | 2059  | 2119  | 4178   |
| Ghana                                      | 2870  | 2424  | 5294   |
| Hong Kong SAR                              | 1722  | 1748  | 3470   |
| Hungary                                    | 2060  | 2051  | 4111   |
| Indonesia                                  | 2025  | 2178  | 4203   |
| Islamic Republic of Iran                   | 2195  | 1786  | 3981   |
| Israel                                     | 1556  | 1737  | 3293   |
| Italy                                      | 2294  | 2114  | 4408   |
| Japan                                      | 2170  | 2142  | 4312   |
| Jordan                                     | 2451  | 2800  | 5251   |
| Republic of Korea                          | 2224  | 2016  | 4240   |
| Kuwait                                     | 1818  | 2273  | 4091   |
| Lebanon                                    | 1735  | 2051  | 3786   |
| Lithuania                                  | 1975  | 2016  | 3991   |
| Malaysia                                   | 2104  | 2362  | 4466   |
| Malta                                      | 2296  | 2374  | 4670   |
| Mongolia                                   | 2191  | 2302  | 4493   |
| Morocco                                    | 1450  | 1607  | 3057   |
| Norway                                     | 2507  | 2245  | 4752   |
| Oman                                       | 2337  | 2290  | 4627   |
| Palestine                                  | 2005  | 2373  | 4378   |
| Qatar                                      | 3545  | 3639  | 7184   |
| Romania                                    | 2104  | 2094  | 4198   |
| Russian Federation                         | 2146  | 2326  | 4472   |
| Saudi Arabia                               | 2017  | 2226  | 4243   |
| Scotland                                   | 2013  | 2057  | 4070   |
| Serbia                                     | 2046  | 1999  | 4045   |
| Singapore                                  | 2353  | 2246  | 4599   |
| Slovenia                                   | 2021  | 2022  | 4043   |
| Sweden                                     | 2721  | 2494  | 5215   |
| Syrian Arab Republic                       | 2311  | 2339  | 4650   |
| Thailand                                   | 2457  | 2955  | 5412   |
| Tunisia                                    | 1959  | 2121  | 4080   |
| Turkey                                     | 2405  | 2093  | 4498   |
| Ukraine                                    | 2130  | 2294  | 4424   |
| UK                                         | 1939  | 2086  | 4025   |
| USA                                        | 3656  | 3721  | 7377   |

Note: Unweighted number of cases for each country.
Dependent variables

Self-concept. To measure self-concept, we used factor analysis to combine students’ responses to three questions. Students were asked to rate how much they agreed with the statements: ‘I usually do well in math,’ ‘I enjoy learning math,’ and ‘I like math,’ using a four-point Likert scale ranging from ‘Disagree a lot’ to ‘Agree a lot.’ In doing so, we draw on many of the same questions as previous studies using the TIMSS data to examine self-concept, including Wang et al. (2012) and Louis & Mistele (2012). However, we use a more limited set of indicators to more closely mirror the items used by Correll (2001).1

Career involving mathematics. In addition to rating their mathematics self-concept, students were also asked the degree to which they agreed with the statement ‘I need to do well in math to get the job that I want.’ Given the prominence of mathematics in STEM careers (Steele, 2009), and as just over half of the respondents ‘agreed a lot’ with this statement, we recoded this variable into a dummy variable indicating whether respondents agreed a lot with this statement. We use this item to indicate whether students were interested in careers involving mathematics. While we would have preferred to examine a measure directly examining whether students were interested in STEM careers, this measure allows us to examine the degree to which there are differences in attitudes towards mathematics-related jobs more broadly, as well as the degree to which students are not interested in STEM careers.

Independent variables

Gender. To measure gender, we create a dummy variable indicating whether the respondent was female.

GEM. Our key measure of national context is the GEM score of the country. GEM scores range from 0 to 1, and larger values correspond to higher levels of gender equality. The countries in our sample ranged from Saudi Arabia (0.25) to Sweden and Norway (0.91), and the median score was 0.52 (Botswana). In our figures depicting the results from models examining how gender differences in mathematics self-concept and career interest vary by GEM score, we report predicted values for countries with GEM scores at the 10th and 90th percentiles (corresponding to Turkey’s 0.30 and the UK’s 0.78).

Per capita gross national income. In order to ensure that the effects of GEM in our cross-national comparison are not being driven by differences in economic development, all cross-national models include a control for per capita Gross National Income (GNI). We use countries’ 2007 GNI as reported by the World Bank. GNI represents the total value of goods and services within a country, combined with income received from other countries.

Test scores. To examine the importance of mathematics achievement, both in predicting mathematics self-concept and relative to mathematics self-concept in predicting interest in a career involving mathematics, we use data from the TIMSS mathematics assessment. This assessment examines students’ knowledge (35%), application (40%), and reasoning (25%) in the content areas of number (30%), algebra (30%), geometry (20%), and data and probability (20%). Test scores were constructed to range internationally from 0 to 1000, with a mean of 500 and standard deviation of 100.

Methods

We report analyses from Ordinary Least Squares regression models, and take two analytical approaches. In the first, we estimate the same model separately for each of the 49 countries that we examine. Thus, in examining (1) the degree to which mathematics
self-concept and mathematics achievement are linked to interest in a career involving mathematics; (2) international variation in gender differences in mathematics self-concept; and (3) the degree to which mathematics achievement predicts mathematics self-concept differently for girls and boys; we estimate separate models for each of the 49 countries. These models account for survey weights and use cluster robust standard errors to account for clustering on schools. Cluster robust standard errors relax the assumption that students in the same school are independent, and can be thought of intuitively as treating schools, not students, as the unit of analysis for the purposes of calculating standard errors. Our second approach pools students across countries, and estimates one model for all respondents across the 34 countries for which GEM scores were available. Here, we first examine how gender differences in mathematics self-concept are linked to country-level gender equality, and then how gender differences in interest in mathematics careers are linked to country-level gender equality. To insure that the results are not driven by sample size differences between countries, we use both weights that sum to the sample size for that country and weights that sum to 500 for each of the countries (thus providing each country with equal weight in the regression). As we find no substantive differences between these two weighting schemes, we report only the results from the weights summing to the sample size for the country. While our first approach, which estimated models separately for each country, used cluster robust standard errors to account for clustering at the classroom level, models estimated on data pooled across countries use cluster robust standard errors to account for clustering at the country level.

**Results**

We begin by examining the degree to which interest in a career involving mathematics is more closely related to self-concept or achievement. Table 2 presents the results from country-specific regressions predicting whether respondents thought that mathematics would be important in their job using respondents’ mathematics self-concept and achievement. We find that in all countries, self-concept is strongly predictive of interest in a career involving mathematics, such that students with higher levels of mathematics self-concept are more likely to report interest in jobs involving mathematics. Surprisingly, we find that net of mathematics self-concept the relationship between mathematics achievement and interest in a mathematics-related job is statistically significant and negative in the majority of countries we examine, so that among students with the same mathematics self-concept, students with higher levels achievement express lower levels of interest in mathematics-related careers. While the lack of international longitudinal data prevents us from linking mathematics self-concept directly to pursuing a STEM career, these results underscore the importance of mathematics self-concept, and are suggestive that gender differences in STEM representation are driven more by mathematics self-concept than achievement.

Having established the relative importance of mathematics self-concept, we next examine differences in the self-concepts of girls and boys within each of the 49 countries in our data. The first two columns of Table 3 report the boys’ and girls’ levels of mathematics self-concept for each country, providing an indication of how the girls and boys in one country compare to the girls and boys in other countries. We see, for example, that girls and boys in the USA have substantially lower levels of mathematics self-concept than girls and boys in Sweden. While these cross-country comparisons are interesting and potentially very informative, it is difficult to entirely rule out the possibility that there could be driven factors such as differences in translation. By contrast, when we compare
Table 2. Career involving mathematics as a function of mathematics self-concept and achievement, by country.

| Country name                | Self-concept | Achievement |
|-----------------------------|--------------|-------------|
| Armenia                     | 0.094***     | -0.012      |
| Australia                   | 0.100***     | -0.037**    |
| Bahrain                     | 0.068***     | -0.042***   |
| Bosnia and Herzegovina      | 0.055***     | -0.094***   |
| Botswana                    | 0.049***     | 0.070***    |
| Bulgaria                    | 0.088***     | -0.062***   |
| Chinese Taipei              | 0.052***     | -0.011      |
| Colombia                    | 0.066***     | -0.040**    |
| Cyprus                      | 0.099***     | -0.042***   |
| Czech Republic              | 0.080***     | -0.097***   |
| Arab Republic of Egypt      | 0.101***     | 0.016       |
| El Salvador                 | 0.070***     | -0.127***   |
| Georgia                     | 0.091***     | -0.037*     |
| Ghana                       | 0.093***     | 0.034*      |
| Hong Kong SAR               | 0.080***     | 0.005       |
| Hungary                     | 0.086***     | -0.084***   |
| Indonesia                   | 0.109***     | 0.003       |
| Islamic Republic of Iran    | 0.102***     | 0.000       |
| Israel                      | 0.080***     | -0.003      |
| Italy                       | 0.098***     | -0.055***   |
| Japan                       | 0.041***     | 0.001       |
| Jordan                      | 0.078***     | -0.003      |
| Republic of Korea           | 0.060***     | 0.052***    |
| Kuwait                      | 0.093***     | 0.025*      |
| Lebanon                     | 0.097***     | 0.021       |
| Lithuania                   | 0.070***     | -0.030*     |
| Malaysia                    | 0.116***     | -0.031      |
| Malta                       | 0.081***     | -0.066***   |
| Mongolia                    | 0.082***     | -0.048***   |
| Morocco                     | 0.086***     | -0.016      |
| Norway                      | 0.102***     | 0.027*      |
| Oman                        | 0.093***     | -0.089***   |
| Palestine                   | 0.072***     | 0.024*      |
| Qatar                       | 0.113***     | 0.015*      |
| Romania                     | 0.080***     | -0.106***   |
| Russian Federation          | 0.097***     | -0.082***   |
| Saudi Arabia                | 0.101***     | -0.029*     |
| Scotland                    | 0.090***     | -0.029*     |
| Serbia                      | 0.070***     | -0.093***   |
| Singapore                   | 0.100***     | -0.089***   |
| Slovenia                    | 0.066***     | -0.060***   |
| Sweden                      | 0.088***     | -0.062***   |
| Syrian Arab Republic        | 0.084***     | -0.017      |
| Thailand                    | 0.099***     | 0.045***    |
| Tunisia                     | 0.089***     | -0.007      |
| Turkey                      | 0.071***     | 0.014       |
| Ukraine                     | 0.087***     | -0.038***   |
| UK                          | 0.090***     | -0.054***   |
| USA                         | 0.087***     | -0.072***   |

Note: Results from models estimating interest in career involving mathematics by self-concept and achievement, separately for each country. Standard errors account for clustering within school.

*p < 0.05; **p < 0.005; ***p < 0.0005.
### Table 3. Comparing boys’ and girls’ self-concept, by country.

| Country                     | Boys’ self-concept | Girls’ self-concept | Difference | GEM value |
|-----------------------------|--------------------|---------------------|------------|-----------|
| Armenia                     | −0.032             | 0.017               | 0.049      |           |
| Australia                   | −0.246             | −0.525              | −0.279***  | 0.85      |
| Bahrain                     | 0.491              | 0.497               | 0.006      |           |
| Bosnia and Herzegovina      | −0.859             | −0.752              | 0.108      |           |
| Botswana                    | 0.636              | 0.602               | −0.034     | 0.52      |
| Bulgaria                    | −0.295             | −0.297              | −0.003     | 0.61      |
| Chinese Taipei              | −0.599             | −1.104              | −0.505***  | 0.53      |
| Colombia                    | 0.643              | 0.511               | −0.132*    | 0.50      |
| Cyprus                      | −0.259             | −0.182              | 0.078      |           |
| Czech Republic              | −0.846             | −0.818              | 0.028      | 0.63      |
| Arab Republic of Egypt      | 1.043              | 0.926               | −0.117*    | 0.26      |
| El Salvador                 | 0.610              | 0.456               | −0.153**   | 0.53      |
| Georgia                     | 0.195              | −0.012              | −0.207*    | 0.41      |
| Ghana                       | 0.896              | 0.695               | −0.200***  |           |
| Hong Kong SAR               | −0.300             | −0.658              | −0.358***  |           |
| Hungary                     | −0.709             | −0.773              | −0.064     | 0.57      |
| Indonesia                   | 0.597              | 0.514               | −0.083*    |           |
| Islamic Republic of Iran    | 0.443              | 0.644               | 0.201      | 0.35      |
| Israel                      | −0.030             | −0.007              | 0.023      | 0.66      |
| Italy                       | −0.583             | −0.715              | −0.132*    | 0.69      |
| Japan                       | −1.062             | −1.354              | −0.292***  | 0.56      |
| Jordan                      | 0.759              | 0.760               | 0.002      |           |
| Republic of Korea           | −0.848             | −1.104              | −0.256***  | 0.51      |
| Kuwait                      | 0.587              | 0.363               | −0.224***  |           |
| Lebanon                     | 0.626              | 0.371               | −0.254***  |           |
| Lithuania                   | −0.519             | −0.514              | 0.005      | 0.67      |
| Malaysia                    | −0.027             | 0.062               | 0.089*     | 0.50      |
| Malta                       | −0.381             | −0.540              | −0.159     | 0.51      |
| Mongolia                    | 0.551              | 0.493               | −0.058     | 0.43      |
| Morocco                     | 1.123              | 1.027               | −0.096*    | 0.33      |
| Norway                      | 0.904              | 1.018               | 0.114*     | 0.91      |
| Oman                        | −0.279             | −0.305              | −0.026     | 0.39      |
| Palestine                   | 0.481              | 0.355               | −0.126     |           |
| Qatar                       | 0.621              | 0.284               | −0.336**   | 0.37      |
| Romania                     | −0.481             | −0.290              | 0.191**    | 0.50      |
| Russian Federation          | −0.366             | −0.109              | 0.258***   | 0.49      |
| Saudi Arabia                | 0.536              | 0.334               | −0.202*    | 0.25      |
| Scotland                    | −0.215             | −0.319              | −0.104*    |           |
| Serbia                      | −1.014             | −0.844              | 0.169      |           |
| Singapore                   | 0.074              | 0.027               | −0.047     | 0.76      |
| Slovenia                    | −0.941             | −0.928              | 0.014      | 0.61      |
| Sweden                      | −0.268             | −0.406              | −0.138***  | 0.91      |
| Syrian Arab Republic        | 0.843              | 0.725               | −0.118*    |           |
| Thailand                    | 0.161              | 0.136               | −0.026     | 0.47      |
| Tunisia                     | 0.766              | 0.737               | −0.029     |           |
| Turkey                      | 0.555              | 0.561               | 0.006      | 0.30      |
| Ukraine                     | −0.345             | −0.128              | 0.218***   | 0.46      |
| UK                          | 0.013              | −0.373              | −0.386***  | 0.78      |
| USA                         | −0.100             | −0.175              | −0.075     | 0.76      |

Note: Results from models estimating self-concept differences between boys and girls, separately for each country and clustered by school. GEM value is listed for given countries.

* $p < 0.05$; **$p < 0.005$; ***$p < 0.0005$. 
the gender differences across countries, these issues are less problematic, as any
differences arising from factors like translation would have to differentially affect girls
and boys. Thus, in the third column, we report the difference between girls’ and boys’
average mathematics self-concept scores for each country. Here we see substantial
variation, and in four countries girls have significantly higher levels of mathematics self-
concept than boys, while in 21 countries boys have higher levels of mathematics self-
concept than girls. These results suggest that while boys have higher average levels of self-
concept in most countries, there is considerable variation in the degree to which this holds.
The final column in Table 3 provides information on GEM scores, to allow for a comparison
of countries’ average gender differences in mathematics concept and GEM scores.

Table 4 builds on the previous columns by examining the degree to which mathematics self-
concept is a function of achievement in different countries (cf. Louis & Mistele, 2012; Peters,
2013). In particular, we are interested in whether the relationship between mathematics self-
concept and mathematics achievement varies by gender. That is, does the mathematics self-
concept of girls and boys increase similarly as they increase in their mathematics
achievement? This is particularly interesting insofar as mathematics self-concept provides
insight into students’ self-assessments of their mathematics ability (cf. Correll, 2001).

As in Tables 2 and 3, we again present the results from models estimated separately for
each country. The first two columns report the main effects of being a girl and mathematics
achievement, and the third column reports the interaction of being a girl and mathematics
achievement. This interaction effect provides information about whether mathematics
achievement translates into bigger, smaller, or similar increases in mathematics self-
concept for girls and boys. For example, if we increased both a girl’s and a boy’s
mathematics score by 100 points, would they have similar increases in mathematics self-
concept, or would one or the other gain more? Negative interaction effects suggest that
girls gain less mathematics self-concept than boys from the same increase in mathematic
achievement, while positive interaction effects suggest girls benefit more than boys.

Overall, we see that only seven of the countries have statistically significant interaction
effects, suggesting that in most countries the relationship between mathematics self-
concept and mathematics achievement is similar for girls and boys. Of the seven countries
where there are statistically significant interaction effects, we find that in six girls’ self-
concept increases more as their achievement increases, suggesting that gender differences
in mathematics self-concept are smaller among high achievers than they are among low
achievers. By contrast, in Chinese Taipei, we find that boys’ mathematics self-concept
increases with achievement more than girls’, suggesting that there are larger gender
differences in self-concept among high achievers.

Taken together, Tables 2–4 suggest that mathematics self-concept plays an important role
in shaping career interests, that girls have lower levels of mathematics self-concept in the
majority of countries examined, and that while in most countries there are no gender differences
in the relationship between mathematics self-concept and achievement, in some contexts girls’
mathematics self-concept is more responsive to mathematics achievement than boys’. We next
turn to examining how gender differences in mathematics self-concept might vary as a function
of the level of gender equality that exists in the larger national context. Figure 1 reports predicted
levels of mathematics self-concept for girls and boys in countries with high and low levels
of gender equality. We see that in countries with low levels of overall gender egalitarianism
(defined here as the GEM score for the 10th percentile country in our sample), girls and boys
have similar levels of mathematics self-concept \((p = 0.13)\). Interestingly, as the gender
egalitarianism of the country rises, the average mathematics self-concept score decreases for
both girls and boys at a similar rate so that there are no gender differences in mathematics self-
Table 4. Self-concept as a function of mathematics score and gender.

| Country                        | Girl | Mathematics score | Girl × mathematics score |
|--------------------------------|------|-------------------|--------------------------|
| Armenia                        | 0.395| 0.329***          | −0.069                   |
| Australia                      | −0.812| 0.569***         | 0.130                    |
| Bahrain                        | −1.174***| 0.318***   | 0.262***                 |
| Bosnia and Herzegovina         | −0.607| 0.555***         | 0.156*                   |
| Botswana                       | 0.150| 0.362***         | −0.063                   |
| Bulgaria                       | −0.424| 0.318***         | 0.082                    |
| Chinese Taipei                 | 0.046| 0.821***         | −0.094*                  |
| Colombia                       | −0.774*| 0.037           | 0.177*                   |
| Cyprus                         | −0.858**| 0.651***    | 0.167**                  |
| Czech Republic                 | 0.188| 0.718***         | −0.035                   |
| Arab Republic of Egypt         | 0.118| 0.174***         | −0.064                   |
| El Salvador                    | 0.166| 0.215***         | −0.083                   |
| Georgia                        | −0.580| 0.395***         | 0.094                    |
| Ghana                          | −0.042| 0.275***         | −0.035                   |
| Hong Kong SAR                  | −0.541| 0.517***         | 0.021                    |
| Hungary                        | 0.163| 0.741***         | −0.039                   |
| Indonesia                      | −0.145| −0.139***        | 0.017                    |
| Islamic Republic of Iran       | −0.464| 0.494***         | 0.113                    |
| Israel                         | −0.068| 0.215***         | 0.021                    |
| Italy                          | −0.193| 0.675***         | 0.023                    |
| Japan                          | −0.070| 0.701***         | −0.034                   |
| Jordan                         | −0.214| 0.329***         | 0.038                    |
| Republic of Korea              | −0.241| 0.821***         | 0.004                    |
| Kuwait                         | −0.402| 0.306***         | 0.031                    |
| Lebanon                        | −0.397| 0.521***         | 0.045                    |
| Lithuania                      | −0.201| 0.722***         | 0.030                    |
| Malaysia                       | −0.098| 0.493***         | 0.029                    |
| Malta                          | −1.187| 0.500***         | 0.211                    |
| Mongolia                       | 0.101| 0.291***         | −0.031                   |
| Morocco                        | −0.725| 0.155**          | 0.170**                  |
| Norway                         | −0.012| 0.256***         | −0.001                   |
| Oman                           | −0.704*| 0.798***        | 0.140*                   |
| Palestine                      | −0.659| 0.378***         | 0.106                    |
| Qatar                          | −0.431| 0.312***         | 0.000                    |
| Romania                        | −0.221| 0.397***         | 0.074                    |
| Russian Federation             | 0.054| 0.571***         | 0.036                    |
| Saudi Arabia                   | −0.554| 0.277***         | 0.079                    |
| Scotland                       | 0.131| 0.401***         | −0.046                   |
| Serbia                         | −0.307| 0.744***         | 0.087                    |
| Singapore                      | −0.254| 0.599***         | 0.018                    |
| Slovenia                       | 0.039| 0.532***         | 0.000                    |
| Sweden                         | −1.045| 0.601***         | 0.177**                  |
| Syrian Arab Republic           | −0.139| 0.342***         | 0.020                    |
| Thailand                       | 0.212| 0.218***         | −0.064                   |
| Tunisia                        | 0.185| 0.608***         | −0.019                   |
| Turkey                         | 0.038| 0.395***         | −0.006                   |
| Ukraine                        | −0.036| 0.436***         | 0.051                    |
| UK                             | −0.840| 0.370***         | 0.092                    |
| USA                            | −0.064| 0.568***         | 0.002                    |

Note: Results from model estimating the effect of mathematics score, gender, and the interaction of gender and mathematics score on self-concept, separately for each country. Standard errors account for clustering within school.

*p < 0.05; **p < 0.005; ***p < 0.0005.
concept in high GEM countries (defined here as the GEM score for the 90th percentile country in our sample) either \( p = 0.23 \). While the gender differences do not vary as a function of GEM \( p = 0.94 \), we do see that the overall level on mathematics self-concept does vary with GEM, so that both girls and boys in high GEM countries have lower levels of mathematics concept than their counterparts in low GEM countries \( p < 0.00 \).

Figure 2 examines whether a similar pattern emerges when we examine how gender differences in career interests are shaped by the gender egalitarianism of the overall national context. The findings largely parallel the results shown in Figure 1. As with mathematics concept, the slopes for both girls and boys are sharply negative, suggesting that in gender-equalitarian countries both girls and boys are less interested in careers.
involving mathematics. However, while in low GEM countries we again find no gender differences ($p = 0.61$), we do find a statistically significant gender difference in high GEM countries ($p < 0.05$), such that girls in high GEM countries are less interested in mathematics careers than boys. Thus, while for mathematics self-concept (Figure 1) there were no gender differences in either gender-egalitarian or inegalitarian contexts, where careers are involved (Figure 2) we find a gender gap in egalitarian settings that we do not see in inegalitarian contexts. Both Figures 1 and 2 are clear, however, that both girls and boys are less mathematically inclined in gender-egalitarian countries.

**Conclusion**

This study provides an international perspective on gender differences in mathematics self-concept. We begin by presenting findings underscoring the potential importance of mathematics self-concept for understanding the under-representation of women in STEM careers. We show that in all 49 countries examined, students with high levels of mathematics self-concept are more likely to express interest in a career involving mathematics even when mathematics achievement has been controlled for, but that net of mathematics self-concept, mathematics achievement has, if anything, a negative effect on mathematics-related career interests. We then document the gender differences in mathematics self-concept that exist in different countries, highlighting that eighth-grade girls have significantly lower levels of mathematics self-concept than eighth-grade boys in the majority of the countries that we examine. While in a number countries differences in mathematics self-concept vary by achievement, so that there are smaller gender differences in mathematics self-concept among high achievers, in the majority of countries examined the relationship between mathematics achievement and mathematics self-concept does not vary by gender. Finally, we show that both girls and boys are less mathematically inclined in gender-egalitarian countries.

This study is not without limitations. First and foremost, the data we use here are cross-sectional, and do not allow us to follow respondents over time. This means that we are unable to examine long-term behavioural outcomes, such as whether students took advanced mathematics courses, whether they majored in a mathematics-intensive field in tertiary education, and the job that they ended up taking. It is also important to note that while the TIMSS data cover an impressive array of countries, representing a wide range of cultures and levels of development, it is of course possible that with a broader range of countries our findings would be different.

These limitations notwithstanding, in providing an international perspective on these issues, this study provides new insight into not only the importance of gender differences of mathematics self-concept, but also the variety of patterns that gender differences take around the world. These patterns are perhaps not surprising, given the different cultural stereotypes surrounding the image and qualities of a scientist that exist around the world. Western societies, for example, typically present few images of women as scientists, so that when people in these countries think of scientists, they picture a man in a white lab coat (Eccles, 1989; Etzkowitz, Kemelgor, & Uzzi, 2000; Zengin-Arslan, 2001). The construction of gender roles makes it difficult for women to enter STEM fields because it is seen as masculine. By contrast, many formerly Communist countries have historically placed a high degree of emphasis on gender equity, and have higher levels of women in science than in many other countries (Etzkowitz et al., 2000). Differences in broader cultural stereotypes might also help explain why it is that in Turkey women are more under-represented among veterinarians than engineers (Zengin-Arslan, 2001),
while in the USA veterinary medicine is thought of as relatively feminised (Lincoln, 2010).

To systematically examine how variation in the national context might affect gender differences in mathematics, we conducted analyses linking the broader country-level egalitarianism and gender differences in mathematics and career interests (Figures 1 and 2). A priori, one might expect gender differences in mathematics self-concept to be smaller in countries with higher overall levels of gender egalitarianism. International research on gender differences suggests that gender differences in mathematics achievement are shaped in important ways by larger systems of gender inequality, a line of research that Else-Quest, Hyde, and Linn (2010) refer to as the gender stratification hypothesis. Riegle-Crumb (2005), for example, argues that girls are aware of the gender-specific opportunities available to them and that this awareness influences their performance by affecting the amount of effort they invest in their education. Research shows that gender differences in mathematics and science achievement vary systematically according to larger societal gender inequalities (Else-Quest et al., 2010; Penner, 2008; Penner & Cadwallader-Olsker, 2012; Riegle-Crumb, 2005), with stratification in the labour force, research sector, and politics being particularly important. Given research linking mathematics achievement and self-concept (e.g. Pajares & Miller, 1994), we would expect gender differences in mathematics self-concept and career interest to function similarly, especially as given research by Harnisch, Steinkamp, Tsai, and Walberg (1986) showing that girls in countries with a larger percentage of women in the labour force not only score higher on mathematics tests, but also have more positive attitudes towards mathematics (but see Ayalon & Livneh, 2012; Else-Quest et al., 2010).

Surprisingly, however, we find no evidence for this. In fact, if anything, our results suggest that gender differences in interest in a career involving mathematics only emerge in gender-egalitarian countries. Perhaps more importantly, Figures 1 and 2 show that both mathematics self-concept and interest in a mathematics career are lower for both girls and boys in egalitarian contexts. These results hold regardless of whether we control for per capita GNI (as in Figures 1 and 2) or not, suggesting that the results are not being driven by differences in countries’ levels of development.

While this finding is perhaps unexpected, we suggest that it is in line with arguments about how national contexts shape gender differences in STEM that focus on the role that self-expression plays in recreating gender inequality (Charles & Bradley, 2009). This research suggests that gender-egalitarian contexts can encourage girls and boys to express societally approved gender ideals as part of their gender performance. Education in these contexts thus serves not only an instrumental function, but also an expressive function, so that students’ educational choices are thought to reflect important aspects of who they are. From this perspective, educational aspirations can be seen as not simply reflecting the world of possibilities that girls believe are open to them, but also become an arena in which girls perform the gendered identities that they have internalised. Thus, while girls in gender-egalitarian contexts may have more opportunities to pursue STEM fields, they may also decide that it is more feminine to be interested in other fields of study, and choose these other fields that they believe more closely match the image that they are seeking to realise. That is, while egalitarian contexts may remove many of the constraints facing women in STEM fields, to the degree that constraints become internalised as preferences (cf. Correll, 2004), these egalitarian contexts may serve to magnify these differences.

To the degree that gender-egalitarian contexts encourage both girls and boys to express themselves freely, and provide more opportunities for them to do so, gender-egalitarian
contexts can actually lead to higher levels of gender inequality. Perhaps even more importantly from a policy perspective, gender egalitarianism that encourages self-expression can lead to lower levels of mathematics self-concept and career interest for both girls and boys. Thus, contexts valuing self-expression may actually provide a rationale to pursue non-STEM fields not just for girls, but also for boys. While higher levels of overall gender egalitarianism are obviously desirable for many reasons, this study suggests that simply creating gender-egalitarian contexts is unlikely to sufficiently address gender inequality in STEM representation, and may actually have iatrogenic consequences. This is particularly problematic for policies aimed at increasing interest in STEM, as we see that interest in STEM drops for both girls and boys in egalitarian contexts. Future research should examine whether local contexts operate similarly, to see how gender egalitarianism, norms around self-expression, and STEM participation play out at the school and classroom level.

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Notes
1. Correll used three items: mathematics is one of my best subjects, I have always done well in mathematics, and I get good marks in mathematics. Wang et al. (2012) used four items: I usually do well in mathematics, mathematics is more difficult for me than for many of my classmates (reverse coded), mathematics is not one of my strengths (reverse coded), and I learn things quickly in mathematics. Louis & Mistele (2012) used eight items, including the items used by Wang et al. (2012) as well as the additional items: I would like to take more mathematics in school, I enjoy learning mathematics, mathematics is boring, and I like mathematics.
2. GEM scores were not available for Algeria, Armenia, Bahrain, Bosnia and Herzegovina, Cyprus, Ghana, Hong Kong SAR, Indonesia, Jordan, Kuwait, Lebanon, Palestine, Scotland, Serbia, Syrian Arab Republic, and Tunisia.
3. Coefficients for mathematics achievement were negative and significant in 26 of the 49 countries we examine, while only 8 of the countries had significant positive coefficients. Note that in models that do not control for mathematics self-concept, but just examine the bivariate relationship between mathematics achievement and mathematics-related career interest, we see that mathematics achievement and mathematics-related career interest are positively correlated.

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