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Who likes math where? Gender differences in eighth-graders' attitudes around the world

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Some of the most male-dominated science, technology, engineering and mathematics occupations and degree programmes are found in the world's most affluent societies. This article assesses whether gender gaps in *attitudes* follow similarly surprising patterns. Multivariate analysis of eighth-graders' affinity for mathematics and aspirations for mathematically related jobs in 53 countries shows that the attitudinal gender gap is indeed larger in affluent 'postmaterialist' societies. Moreover, both girls and boys view mathematics more negatively in these societies. The authors suggest that cultural ideals of individual self-expression, highly prevalent under conditions of broad-based existential security, operate to reduce girls' and boys' interest in pursuits thought to be economically practical but personally non-expressive. Girls may be particularly susceptible to this negative effect, because taken-for-granted cultural beliefs about core female personality traits (and girls' gendered understandings of their own authentic inner selves) are often at odds with dominant representations of mathematical and technical work.

Keywords: gender; mathematics; education; culture; international

Women's representation in science, technology, engineering and mathematics ('STEM') fields varies a great deal across time and place (Buccheri, Gürber, & Brühwiler, 2011; Charles, 2011a; Tolley, 2003). Recent comparative studies show that this variability follows a surprising pattern: mathematical and technical occupations and degree programmes are considerably more male dominated in affluent, reputably gender-egalitarian societies than in poorer, gender-traditional ones.[1] These patterns are sharply at odds with influential theories of societal development, which depict gender inequality as an artefact of tradition that will wither away steadily under the pressures of economic and cultural modernisation (Baker & LeTendre, 2005; Jackson, 1998; Treiman, 1970). In contrast to these liberal 'degendering' arguments, Maria

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Charles and colleagues have pointed to the resilience of gender-essentialist ideology even in the most modern, egalitarian cultural contexts. The central argument is that seemingly free choices by formally equal men and women may in fact *strengthen* some forms of sex segregation in advanced industrial societies (Charles, 2011a, 2011b; Charles & Bradley, 2009; Charles & Grusky, 2004). This article explores whether attitudes are also more gender-differentiated in these contexts and considers some possible explanations for observed cross-national differences in the attitudinal gender gap.

We assess variability in affinity toward mathematics and aspirations for mathematically related jobs using data on eighth-grade students surveyed in 53 countries and territories between 2003 and 2011. Results indicate that the gender gap in attitudes follows a similar pattern to the gap in representation in STEM fields: it is larger in more economically secure, culturally self-expressive societies. We find, in addition, that both girls *and* boys have more negative attitudes toward mathematics and related careers in these societies.

In considering possible explanations, we pay particular attention to the effects of societal affluence on aspirations – specifically to the role of 'postmaterialist' value systems. According to Ronald Inglehart and colleagues, postmaterialist values become dominant under conditions of broad-based material security, especially in democratic societies with highly diversified, knowledge-based economies (Inglehart & Welzel, 2005). An important dimension of postmaterialism is a strong cultural emphasis on self-expressiveness – including an expectation that people remain true to an authentic inner self in choosing their educational and occupational life courses (Mainiero & Sullivan, 2006). We suggest that ideals of individual self-expression support increased gender-typing of aspirations by increasing the salience of gender stereotypes and gender identities in curricular and career choice. In addition, these ideals may weaken girls' *and* boys' interest in fields (such as mathematics) that are believed to be time consuming, difficult or boring. These arguments are elaborated in the following section.

Who likes math where?

Stereotypes about basic male and female personality traits show considerable consistency across developed and developing societies. Almost everywhere, females are viewed as naturally better at nurturing and interpersonal relations, and males are viewed as physically stronger and more analytical (Lueptow, Garovich-Szabo, & Lueptow, 2001; Williams & Best, 1990). Social psychological studies based on US samples show, moreover, that people are positively inclined toward social roles that they believe are suited to their personality and that the task profiles of male-dominated or high-prestige occupations are generally not considered to be well aligned with stereotypically female personality traits (Cech, in press; Cech, Rubineau, Silbey, & Seron, 2011; Cejka & Eagly, 1999; Cheryan, Plaut, Davies, & Steele, 2009;

Cross & Madson, 1997; Nosek, Banaji, & Greenwald, 2002; Nosek et al., 2009).

One explanation for the strong sex segregation of STEM fields in advanced industrial societies is that women are better able to realise preferences for (generally less lucrative) human-centred work roles in these contexts. By this account, work preferences are similarly gender-typed across countries but societies differ with respect to the economic capacity of the average woman to *indulge* these gendered preferences.[2] A second explanation is that aspirations and dispositions themselves vary across countries. These accounts are not mutually exclusive, and we find evidence that both processes are operating.

Recent theorising on the interaction between gender stereotypes and postmaterialist value systems provides a framework for understanding possible cross-national variability in attitudinal gender gaps. In brief, the argument is that educational and occupational aspirations will be more strongly influenced by cultural gender beliefs in highly affluent societal contexts (Charles, 2011b; Charles & Bradley, 2002, 2009). According to Inglehart and others, diminishing concern about material security leads to the rise and diffusion of highly individualistic cultural value systems focusing on quality of life rather than satisfaction of basic human needs. Educational and occupational choices represent more than practical economic investments in these contexts; they are also acts of self-realisation that help define an individual's sense of self (Bellah, Madsen, Sullivan, Swidler, & Tipton, 2008; Frank & Meyer, 2007; Inglehart & Welzel, 2005; Meyer & Jepperson, 2000; Mullen, 2013).[3]

Where individual fulfilment and self-expression are central cultural concerns, people will more often seek congruence between what they perceive to be their core personality traits and the task content of their social roles. But understandings of core personality traits are highly gendered, as are understandings of occupational task content. Boys and men (girls and women) more often expect to be good at and find fulfilment in activities that are thought to draw upon male-typed (female-typed) personality traits (Charles, 2011b; Correll, 2001, 2004; Ridgeway, 2011). As a result, cultural mandates for individual self-expression may increase the salience of cultural gender frames in the development of aspirations and affinities.[4]

This gender-typing of both personality traits and occupational activities is important to the question at hand because near-universal stereotypes depicting women as predisposed toward interpersonal relations and nurturing map poorly onto cultural representations, prevalent in many advanced industrial societies, that depict engineering and technical work as solitary, non-reflexive and hyper-analytical (Des Jardins, 2010; Faulkner, 2000; Harding, 1991; McIlwee & Robinson, 1992; Sørensen & Berg, 1987). The gender-specific aspirations that arise are not only the result of people wanting to conform to gender stereotypes (although they often do).[5] Rather, they reflect people's assumptions that gender-conforming activities will lead to greater personal fulfilment. In other words, men and women are motivated by a desire to express their authentic (gendered) selves (Charles & Bradley, 2009; Erickson, 1995; Ridgeway, 2011).

Besides producing a larger gender gap, norms of individual self-expression may generate more negative attitudes toward mathematics overall (i.e. among girls *and* boys). In advanced industrial societies at least, self-expressive activities are understood to involve artistic or human-centred pursuits that validate individual subjectivities and allow for creativity or interpersonal collaboration (Astin, 1993; Inglehart & Welzel, 2005; Johnson, 2001; Lee, 1998). While mathematical and technical work often does require collaboration and creativity, it is commonly represented as rigid, abstract, and solitary and as offering few opportunities for injection of individual priorities and personalities into the work process (Des Jardins, 2010; Faulkner, 2007; Osborne, Simon, & Collins, 2003; Thomas, 1990). Moreover, popular depictions of mathematical fields as difficult and labour intensive imply that these activities will take time and energy away from activities perceived to be more enjoyable and self-expressive. Although postmaterialist ideals may encourage some boys to reject fields perceived to be difficult or non-expressive,[6] this effect is likely stronger for girls, whose career trajectories are more often framed as self-expressive life choices (Ahmed, 2010; Messner & Bozada-Deas, 2009). Even in highly affluent postmaterialist contexts, expectations for breadwinning remain gendered, meaning that fewer men than women will sacrifice earnings for self-expression (Gerson, 2010; Mullen, 2013).

The above arguments imply (1) overall more negative attitudes toward mathematics in postmaterialist societies and (2) a larger attitudinal gender gap in more affluent, postmaterialist societies. The first relationship would follow from a general perception that mathematics and mathematics-related fields are intrinsically more effort-intensive and/or less individually satisfying. The second would follow from a general perception that the task content and economic rewards associated with these fields is more aligned with stereotypically masculine personality traits and societal roles.

Previous research provides preliminary evidence that attitudes toward mathematical and technical fields are indeed more gender differentiated in more affluent societies (Charles & Bradley, 2009; Goldman & Penner, 2012; Sikora & Pokropek, 2012). We build upon this work by offering a more precise multilevel estimation of the eighth-grade gender gap in attitudes for a large group of countries, and by investigating the cultural mechanisms that may underlie cross-societal variability in this gap.[7] In particular, we explore the effects of postmaterialism (measured using the Human Development Index, HDI) and self-expressive cultural values (measured using attitudinal indices constructed from the World Values Survey [WVS]). Eighth-graders' attitudes are important, because opting out of high-level mathematics in secondary school can preclude pursuit of STEM careers and degree programmes later in life.[8] Focusing on mathematics, rather than science or STEM, allows us to identify possible causes for growing labour shortages in the most male-typed scientific and technical fields (i.e. computer science and engineering, as opposed to the reputably less mathematics-intensive biology and health fields).

Our models explore variability on two attitudinal dimensions: *affinity toward mathematics* and *aspirations for a mathematically related job*. Results are consistent with the macro-cultural arguments outlined above. Both boys and girls report more negative attitudes toward mathematics in more affluent societies and in societies with more pronounced self-expressive value systems. These negative effects are stronger among girls than boys, and they are not attributable to other factors that distinguish students in rich and poor societies, such as standardised achievement test scores, affinity for school in general, and parental education. We suggest that cultural ideals of individual self-expression are one mechanism by which gender-essentialist stereotypes (i.e. cultural beliefs about innate gender difference) may be translated into gender-differentiated career aspirations and outcomes.

Data and methods

Multilevel logistic regression models are used to assess effects of student- and country-level covariates on boys' and girls' attitudes toward mathematics. Because students in a given country share a common sociopolitical environment, they are likely to be similar in ways that are unmeasured by variables in our models. Using individual-level models for this sort of clustered data would violate a basic assumption of regression analysis (independence of error terms), and standard errors would likely be too small (Luke, 2004; Raudenbush & Bryk, 2002).[9] A multilevel specification allows us to assess more accurately the statistical significance of cross-level interactions between characteristics of individual students (e.g. gender) and characteristics of countries (e.g. HDI scores).[10] To facilitate interpretation, all continuously scaled covariates are grand-mean centred.

Attitudinal and demographic data on more than 300,000 eighth-grade boys and girls in 53 countries and territories are taken from the Trends in International Math and Science Surveys (TIMSS), coordinated by an independent cooperative of national research institutions and government agencies (TIMSS, 2013). Cross-nationally harmonised surveys have been conducted every four years since 1995. We focus here on the three most recent surveys, from 2003, 2007 and 2011. Countries and territories included are shown in the Appendix 1. Although this is by no means a globally representative list (most notably, we are missing data on the very large populations of mainland China and India), our sample of countries is larger and offers more regional and socio-economic diversity than those used for most previous analyses on this topic.

The dependent variables, affinity for mathematics and aspirations for a mathematically related job, are measured using eighth-graders' responses (strongly agree, agree, disagree or strongly disagree) to the statements: 'I enjoy learning math' and 'I would like to work in a field that involves math' (each in their country's dominant language). Data on aspirations are from the 2003 and 2011 surveys (the relevant question was not included on the 2007 survey), and data on affinity are from all three surveys. Our models include an indicator for 2011, the most recent survey year. We create dichotomous variables by distinguishing students who agree or strongly agree (=1) from those who disagree or strongly disagree (=0).[11] General patterns of cross-national difference are unchanged if we use a coding scheme that distinguishes those who strongly agree from all others, or if we treat agreement as a continuous 4-point scale.

A focal independent variable is socio-economic development ('postmaterialism'), which we measure at the country level using the HDI, published by the United Nations Development Programme (following Inglehart & Norris, 2003, Appendix 1). Because it takes into account life expectancy, education and national income, the HDI offers a broader perspective on standard of living than purely economic measures of societal modernisation (UNDP, 2012). The rise and mass-societal diffusion of postmaterialist values systems (e.g. self-expressiveness) requires more than economic affluence; it depends upon existential security and individual autonomy that come to be taken for granted by ensuing birth cohorts (i.e. by those coming of age under conditions of relative societal prosperity). We measure HDI in 1995, which provides a good indicator of the socio-economic environments in which the surveyed students spent their formative childhoods and early adolescence. In supplementary models (available on request), we have replaced HDI with the natural logarithm of 1990 per capita gross domestic product (GDP). Regression results are very similar, which is not surprising given the high correlation between the GDP and HDI variables ($r = .87$). Values of all country-level variables are shown in the Appendix 1.

As a further validity check, we assess more directly the effects of self-expressive value systems on attitudes toward mathematics using aggregate-level self-expressiveness scores. These factor scores, which are available for 41 of our 53 countries, are computed by Inglehart and colleagues based on individual responses to attitudinal items included in the fourth wave of the WVS, conducted in 2000.[12] The component attitudinal items probe respondents' self-described happiness, level of interpersonal trust and relative valuation of quality of life and security, among other things (Inglehart & Welzel, 2005). Larger positive values on the aggregated country-level score indicate more self-expressive value systems; larger negative values indicate greater cultural concern with material security ('survival').

Basic student-level demographic covariates include sex, survey year (represented with a dichotomous indicator for 2011), age and social class. The latter is measured as education level of the most highly educated parent (primary or tertiary, with secondary as the omitted category). We also include individual-level controls for students' mathematics achievement and affinity for school, both of which may be correlated with attitudes toward mathematics. It is possible that female secondary students in less-developed countries are more positively selected (i.e. perform better on average) than their male counterparts because only academically 'exceptional' girls are enroled in secondary school in these contexts. If so, girls' positive attitudes toward mathematics in these countries might be an artefact of their stronger mathematical achievement and their positive attitudes towards academics in general. Mathematical achievement is measured using 'plausible scores' on TIMSS's cross-nationally standardised tests, which range from 0 to 1000 and are standardised to a mean of 500 in 1995. We divide the plausible scores by 100 to simplify tabular presentation of coefficients. Affinity for school is measured as agreement or strong agreement with the statement 'I like school'. We also include an interaction term that allows us to assess gender differences in effects of individual achievement on students' attitudes toward mathematics. To the extent that girls are less confident in their mathematical ability, individual achievement scores may have a weaker effect on girls' than boys' attitudes (Correll, 2001, 2004).

In some models, we include a country-level control for *average* mathematical achievement, measured as the mean of individual student plausible scores (again divided by 100) in each country or territory for the respective survey year. This variable is intended as a rough proxy for *difficulty* of the national mathematics curriculum. Countries with the most intensive mathematics curricula are likely to have higher average achievement scores than countries with less intensive mathematics curricula. Previous research suggests that students are less interested in school subjects perceived to be difficult or time-consuming (Osborne et al., 2003), so it is useful to determine whether effects of postmaterialism hold net of differences between more and less affluent societies in the rigour of their mathematics curricula. It is possible, for example, that students have more negative attitudes toward mathematics in postmaterialist societies simply because the mathematics curricula are more demanding in these contexts.

Results

Cross-national similarities and differences

Table 1 presents girl–boy differences by country in the proportion of students who report enjoying mathematics and aspiring to mathematics-related jobs. Although across country mean scores show that girls' attitudes

Table 1. Girl–boy gender gap in attitudes toward math.

	Affinity: 'I enjoy learning math'	Aspirations: 'I would like a math-related job'
Armenia	.01	−.11
Australia	−.06	−.14
Bahrain	−.03	−.08
Belgium	−.04	−.17
Botswana	.02	.02
Bulgaria	.00	−.08
Canada – Ontario	−.06	−.09
Canada – Quebec	−.02	−.14
Chile	−.06	−.11
Colombia	.00	–
Cyprus	.02	−.05
Czech Republic	.04	–
Egypt	−.03	−.07
England	−.09	−.17
Ghana	−.02	−.01
Hong Kong	−.11	−.18
Hungary	−.01	−.12
Indonesia	.02	.00
Iran	−.02	−.11
Israel	−.01	−.08
Italy	−.05	−.18
Japan	−.10	−.11
Jordan	−.03	−.07
Korea	−.04	−.07
Kuwait	−.05	–
Latvia	.02	−.08
Lebanon	−.07	−.10
Lithuania	.00	−.08
Macedonia	.00	−.06
Malaysia	.04	.00
Moldova	.06	−.04
Morocco	−.02	−.07
Netherlands	−.05	−.23
New Zealand	−.09	−.16
Norway	−.03	−.11
Palestine	−.01	−.07
Philippines	.02	−.04
Romania	.03	−.06
Russia	.03	−.09
Saudi Arabia	−.06	−.10
Scotland	−.04	−.11
Serbia	.05	−.02
Singapore	.01	−.07
Slovak Republic	.02	−.11
Slovenia	.00	−.12

(*Continued*)

Table 1. (*Continued*).

	Affinity: 'I enjoy learning math'	Aspirations: 'I would like a math-related job'
South Africa	−.01	−.01
Spain: Basque	−.01	−.09
Sweden	−.03	−.11
Syria	−.02	−.04
Thailand	.01	−.02
Tunisia	−.03	−.11
Turkey	.01	−.07
USA	−.04	−.10
Country Mean	*−.02*	*−.09*
Country Group		
Advanced Industrial	−.05	−.13
Asian Tiger	−.04	−.10
Asian Tiger Cub	.02	−.01
Former Socialist	.02	−.08
Other	−.03	−.06

Note: Values give the girl–boy difference in the proportion agreeing or strongly agreeing in the respective country or territory. Data are from TIMSS of 2003, 2007 and 2011. Aspirations data are available in 2003 and 2011 only. The following countries were not surveyed at all three time points: Belgium, Latvia, Moldavia, Netherlands, Philippines, Scotland, Spain-Basque, Slovak Republic (2003 only); Columbia, Czech Republic, Kuwait (2007 only); Thailand, Turkey (2007 and 2011 only); Bulgaria, Canada-Ontario, Canada-Quebec, Cyprus, Egypt, Serbia (2003 and 2007 only); Chile, England, Macedonia, New Zealand, South Africa (2003 and 2011 only). Country groups are defined in Appendix 1.

are on average less positive than boys' on both affinity and aspirations (−.02 and −.09, respectively), the male advantage on affinity (measured as 'enjoyment') is much smaller. Girls in fact report equal or greater affinity for math, as indicated by a positive or zero value, in 21 of 53 countries, while boys are more likely to report aspirations for mathematically related jobs in all but three countries (Botswana, Indonesia and Malaysia). The greater gender typing of aspirations than affinities is not surprising; adult work roles are understood to be central markers of individual identity, and these pivotal life choices are especially likely to be viewed through a gendered lens (Ridgeway, 2011). As noted above, greater gender parity with respect to enjoyment of mathematical coursework may be attributable to girls' greater affinity for *school* and their roughly equal mathematical achievement in most countries.[13] Our multivariate analyses allow us to assess attitudinal gender gaps net of student-level differences on these other variables.

Although boys are more likely to aspire to a mathematically related job in nearly all countries considered, the size of this gender gap varies widely. The girl–boy gap is 23 percentage points in the Netherlands, but only 1 percentage point in Ghana and South Africa. Girls' aspirations exceed boys' by 2 percentage points in Botswana, and they equal boys' in Indonesia and Malaysia. Cross-national variability is also impressive with respect to affinity. In Moldova, girls are 7 percentage points more likely than boys to report that they enjoy learning math, while the gender gap favours boys by 9 points in England and New Zealand and 10 points in Japan.

Values in Table 1 suggest a general tendency for more gender-differentiated attitudes toward mathematics in more affluent democracies. This bivariate relationship is confirmed by zero-order correlations, which show that girls' attitudes toward mathematics are more negative (relative to boys' attitudes) in high-HDI contexts. The negative correlation is especially strong with respect to aspirations for a mathematics-related job.[14]

The larger gender differences in post-industrial countries are not solely attributable to a tendency for large girl–boy gaps in a small number of very rich countries. In the bottom panel of Table 1, we present these difference scores aggregated to groups commonly used by national governments and international organisations to classify countries regionally, economically, and culturally.[15] Attitudinal gender gaps are very large in both the Advanced Industrial and the Asian Tiger groups, which also have the highest scores on HDI and GDP (see Appendix 1). It is notable that mean gender gap scores differ sharply between the high- and low-income Asian groups, which are similar on many relevant sociocultural dimensions, sharing, for example, strong historical emphases on STEM education as an economic development strategy, cultural tendencies to understand mathematics ability as learned rather than innate (Stevenson & Stigler, 1992), and generally less individualistic cultural values. The latter commonality may account for the very similar self-expressiveness scores for the Tiger and Tiger Cub groups (Appendix 1).[16]

Descriptive results suggest a tight link between socio-economic development and eighth-graders' attitudes toward mathematics. Patterns of variability in the attitudinal gender gap are at odds with conventional modernisation ('degendering') accounts and consistent with the macro-cultural arguments advanced above. We next ascertain whether these patterns persist when we take into account individual-level characteristics of the male and female student populations. Means (uncentred) and standard deviations are displayed in Table 2.

Multivariate analyses

Table 3 shows two sets of multilevel logistic regression models that predict affinity for mathematics (Models A1–A5) and aspirations for a mathematically related job (Models B1–B5). Models A1 and B1 include student-level effects only. The significant gender effects are in line with the aggregate statistics shown in Table 1. On average, girls in our sample have more negative attitudes toward learning mathematics and toward a future job related

Table 2. Descriptive statistics for variables used in regression models.

	Affinity	Aspirations
Enjoy learning math? (1 = agree, strongly agree)	.68 (–)	–
Would like math-related job? (1 = agree, strongly agree)	–	.52 (–)
Female (1 = yes)	.52 (–)	.52 (–)
Age in years	14.34 (.71)	14.35 (.72)
Year 2011 (1 = yes)	.35 (–)	.49 (–)
Parental education: primary school (1 = yes)	.37 (–)	.37 (–)
Parental education: university (1 = yes)	.40 (–)	.40 (–)
Math achievement score	4.86 (1.04)	4.87 (1.04)
Like school? (1 = agree, strongly agree)	.81 (–)	.82 (–)
Mean math achievement score (country level)	4.70 (.69)	4.70 (.70)
Postmaterialism: HDI score (country level)	.72 (.11)	.72 (.11)
Self-expressiveness score (country level)	−.04 (1.18)	−.03 (1.17)
N: Students (Countries)[a]	*352,810* (53)	*247,483* (50)

Note: Values are sample means (standard deviations).
[a]Ns for the self-expressiveness scores are 268,491 students (41 countries) in the affinity models, and 192,764 students (39 countries) in the aspirations models. See Table 1 and Appendix 1 for variable and sample descriptions.

to mathematics than boys. Net of achievement, age, social class and attitudes toward school, boys' odds of 'enjoying math' are about 26% higher than girls' odds [exp(.231) = 1.260], and their odds of aspiring to a mathematically related job are 62% higher [exp(.483) = 1.621].[17]

Not surprisingly, students who are high-achieving in mathematics and who report liking school are also more likely to report enjoying mathematics and aspiring to a mathematically related job. The negative interaction effect in Model B1 indicates, however, that high mathematical achievement has a significantly weaker effect on girls' than boys' aspirations. This may reflect differences in mathematical self-confidence by gender, or negative cultural messages that counteract positive achievement effects (Cech et al., 2011; Correll, 2001, 2004). Older eighth-graders are somewhat more likely to report enjoying math than their younger counterparts.

Affinity for mathematics is significantly higher in 2011 than in the two previous survey years (2003 and 2007), but aspirations for related jobs are weaker. This holds for both boys and girls (results available on request). The generally more positive attitudes toward school-based mathematics may reflect improvements in teaching or increased societal emphasis on the importance of mathematics for academic success. However, concerted international efforts to increase the size and status of the STEM workforce do not appear to have translated into increased interest in mathematically related work among adolescents.

Table 3. Multilevel models predicting eighth-graders' attitudes toward mathematics.

	Affinity: 'enjoy learning math' (2003, 2007, 2011)					Aspirations: 'would like a job involving math' (2003, 2011)				
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5
Student-level covariates										
Female	−.231***	−.231***	−.215***	−.214***	−.217***	−.483***	−.483***	−.480***	−.478***	−.494***
	(.008)	(.008)	(.008)	(.008)	(.009)	(.009)	(.009)	(.009)	(.009)	(.010)
Age	.018*	.018*	.018*	.028***	.025**	.015	.014	.015	.029***	.040***
	(.007)	(.007)	(.007)	(.007)	(.009)	(.008)	(.008)	(.008)	(.008)	(.009)
Year = 2011	.133***	.133***	.133***	.169***	.226***	−.077***	−.078***	−.078***	−.039***	−.046***
	(.009)	(.009)	(.009)	(.009)	(.011)	(.010)	(.010)	(.010)	(.010)	(.012)
Primary school educated parent (1 = yes)	.022*	.022*	.022*	.024*	.039**	.033**	.033**	.033**	.032**	.036**
	(.011)	(.011)	(.011)	(.011)	(.012)	(.012)	(.012)	(.012)	(.012)	(.014)
University – educated parent (1 = yes)	−.036**	−.036**	−.036**	−.037**	−.022	.027*	.027*	.028**	.025*	.022
	(.011)	(.011)	(.011)	(.011)	(.012)	(.012)	(.012)	(.012)	(.012)	(.013)
Math achievement score	.532***	.532***	.515***	.525***	.503***	.387***	.387***	.370***	.382***	.391***
	(.006)	(.006)	(.007)	(.007)	(.008)	(.007)	(.007)	(.007)	(.007)	(.008)
Female × math achievement	−.001	−.001	.033***	−.034***	.008	−.121***	−.121***	−.088***	−.088***	−.121***
	(.008)	(.008)	(.008)	(.008)	(.009)	(.008)	(.008)	(.009)	(.009)	(.010)
Like school (1 = yes)	1.145***	1.145***	1.147***	1.147***	1.169***	.670***	.670***	.673***	.674***	.664***
	(.010)	(.010)	(.010)	(.010)	(.011)	(.012)	(.012)	(.012)	(.012)	(.013)
Country-level covariates										
Postmaterialism (HDI)		−5.825***	−5.354***	−3.502***			−4.873***	−4.447***	−2.480***	
		(.832)	(.834)	(.671)			(.779)	(.780)	(.617)	

Female × postmaterialism			−.894***	−.897***				−.810***	−.816***	
			(.085)	(.085)				(.088)	(.088)	
Mean math achievement				−.466***	−.424***				−.496***	−.527***
				(.035)	(.041)				(.036)	(.042)
Self-expressiveness					−.065					−.039
					(.093)					(.069)
Female × self-expressiveness					−.078***					−.060***
					(.007)					(.008)
Constant	.072	.056	.044	.019	−.083	−.206	−.217*	−.223*	−.238**	−.276**
	(.128)	(.092)	(.093)	(.073)	(.108)	(.118)	(.089)	(.089)	(.069)	(.082)
Std. dev. random effect	.93	.67	.67	.52	.69	.83	.62	.62	.47	.50
Log likelihood	−191,157.91	−191,140.55	−191,084.94	−190,999.91	−147,936.89	−153,039.18	−153,024.71	−152,982.45	−152,888.64	−121,080.37
N students	352,810	352,810	352,810	352,810	268,491	247,483	247,483	247,483	247,483	192,764
N countries	53	53	53	53	41	50	50	50	49	39

Note: Values are coefficients (SEs) from mixed effects logistic regression models predicting agreement or strong agreement with the respective statements.
*$p < .05$.
**$p < .01$.
***$p < .001$.
Models A1/B1: Student-level effects only, A2/B2: HDI effect added, A3/B3: Female × HDI effect added, A4/B4: Mean math achievement added; A5/B5: Self-expressiveness replacing HDI.

Consistent with findings for the United States by Ma (2009) and Harr (2012), results suggest more positive attitudes toward mathematics among students from less privileged social backgrounds. Eighth-graders with primary-educated parents are more likely than those with secondary-educated parents (the reference group) to report enjoying mathematics and aspiring to a mathematically related job. Supplementary models (not shown) indicate that lower parental education is associated with more positive affinity and aspirations *only among girls*. This suggests a possible family-level analogue to the country-level effects discussed above: low socio-economic status may bring about more instrumental (i.e. less self-expressive) value systems within families (Lareau, 2011; Mullen, 2013), which may in turn reduce the likelihood that girls develop gender-typed curricular affinities and aspirations. Effects of *university*-educated parents are overall negative for affinity but positive for aspirations. Models broken down by sex again reveal significant gender differences, with the negative effect on affinity holding only for girls, and the positive effect on aspirations holding only for boys. These gender-specific effects are consistent with the notion that socio-economic privilege is associated with more self-expressive (and/or less economically practical) tastes and aspirations among girls, whereas elite socio-economic origins do not appear to reduce boys' interest in STEM fields.[18]

The standard deviations of the random-effects parameters are sizeable, confirming substantial cross-national variability in students' attitudes toward mathematics, even controlling for individual-level differences.[19] The remaining models explore this cross-national variability through introduction of macro-level covariates.

In Models A2 and B2, we add the postmaterialism measure (HDI). Results suggest that students' attitudes toward mathematics are significantly more negative in high-HDI contexts, even controlling for individual-level and country-level differences in achievement, social background and affinity for school. Specifically, we find that a decrease in the HDI of one-tenth point (approximately the distance between the United States and the Czech Republic) increases by 79% the odds that (male or female) students will report that they enjoy learning math [exp(.583 = 1.791)] and increases by 63% the odds that they will aspire to a math-related job [exp(.487 = 1.627)].

Models A3 and B3 explore gender differences in the relationship between attitudes and HDI. By including interactions between HDI and 'female', we are able to address our argument that girls' attitudes are more negatively influenced by postmaterialism than boys'. In both models, interaction coefficients are negative and significant, meaning that the attitudinal gender gap is larger in higher-HDI countries. It is notable that the main effects of HDI remain negative even after the addition of the interaction term, meaning that boys also have more negative attitudes toward math in higher-HDI contexts (see also Goldman & Penner, 2012).

In Figure 1, we display graphically boy-to-girl odds ratios computed from the coefficients of Models A3 and B3. Values give the ratio of boys'-to-girls' predicted odds of enjoying mathematics and aspiring to a math-related job in three hypothetical countries: a country with a postmaterialism score that is equal to the sample mean of .72 ('medium HDI', e.g. Chile), a country with a postmaterialism score that is .10 points (approximately one standard deviation) below the sample mean ('low HDI', e.g. Jordan), and a country with a postmaterialism score that is .10 points above the sample mean ('high HDI', e.g. England). Controlling for age, year, parental education, mathematical achievement and affinity for school, we find that boys are about 13% more likely than girls to report enjoying mathematics in low-HDI countries, 24% more likely than girls in medium-HDI countries and 36% more likely than girls in high-HDI countries. For job aspirations, the corresponding values are 49, 62 and 75%, respectively.

In a next set of models (A4 and B4), we control for countries' *average* mathematics achievement scores. We know that mathematics achievement is on average higher in more affluent societies (TIMSS, 2012), and it is possible that this is indicative of more demanding mathematics curricula that require more study time and effort. As a proxy for such curricular differences, we use a country-level indicator of average eighth-grade mathematics test scores. Results confirm that students enjoy mathematics significantly

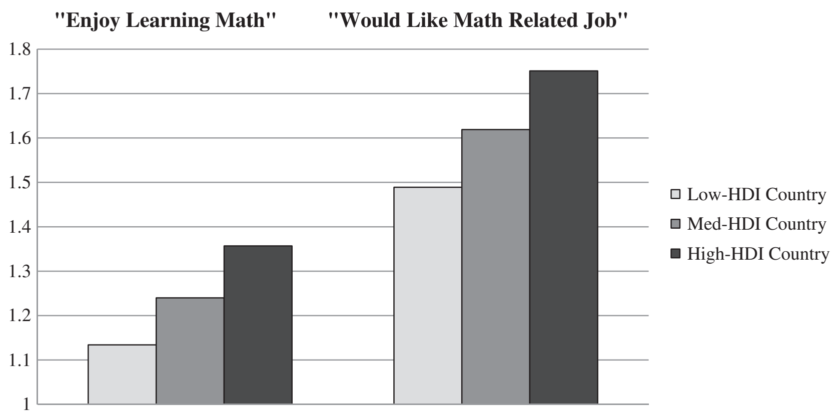

Figure 1. Predicted Boy-to-Girl Odds Ratios, by HDI ('Postmaterialism') Level.
Note: Values are predicted boy-to-girl odds ratios calculated from Models A3 and B3. For example, in a medium-HDI country, the predicted odds that a boy (coded 0 on all other covariates) will enjoy learning mathematics is exp. $(.044) = 1.045$; the odds that a girl (coded 0 on all other covariates) will enjoy learning mathematics is exp. $(.044 - .215) = .843$. The predicted boy-to-girl odds ratio for this HDI level is therefore $1.045/.843 = 1.240$. Medium HDI is defined as the sample mean (.72); high HDI is defined as .10 points (approximately one standard deviation) above the mean; low HDI is defined as .10 points below the mean.

less and are less likely to aspire to math-related jobs in countries and territories where average test scores are higher (on effects of curricular difficulty, see Osborne et al., 2003). Negative effects hold for both boys and girls (results available on request). The precise reasons for the negative association warrant further study. If higher average test scores indeed indicate greater curricular difficulty, the negative association with attitudes may be attributable to young people's aversion to pursuits that they expect will require a great expenditure of effort or time. Students may also interpret perceived difficulty as evidence that they lack natural talent and therefore do not 'belong' in a field.

Effects of postmaterialism on attitudes weaken substantially when we control for country-level differences in mathematics achievement scores. But even with this attenuation, Models A4 and B4 still show significant negative effects of HDI on girls' and boys' attitudes toward mathematics.[20]

We have interpreted results thus far as evidence that postmaterialist values, specifically ideals of individual self-expression, operate to reduce girls' interest in mathematics relative to boys' interest. In a final set of models (A5 and B5), we test this cultural interpretation more directly by replacing the HDI variable with Inglehart's measure of self-expressive value systems. These models cover a smaller group of countries because of missing data on self-expressiveness. Results are consistent with a gendering effect of self-expressive cultural values: for the approximately 40 countries considered, we find larger attitudinal differences between boys and girls in countries with a stronger emphasis on self-expressiveness. With a one-point (approximately one standard deviation) increase in scores on the self-expressiveness scale, the ratio of boys' to girls' odds of enjoying mathematics is predicted to increase from 1.24 to 1.34. For aspiring to a mathematics-related job, this ratio increases from 1.64 to 1.74.[21]

In contrast to findings for postmaterialism in previous models, the effects of self-expressiveness are not statistically significant for boys. This is not surprising. Postmaterialism is a multidimensional phenomenon. The negative main effects in Models A4 and B4 reflect operation of both economic and cultural forces on curricular and career aspirations, and these may be mutually opposing for boys. Growing up in a society where economic security is widely taken for granted weakens economic pressures to pursue career paths that are perceived to be economically secure but otherwise unappealing (e.g. difficult or non-creative). At the same time, cultural norms of self-expressiveness may increase the likelihood that boys identify with and aspire to gender-conforming fields and/or feel an aversion to feminine-labelled ones. In other words, replacing the postmaterialism variable with the self-expressiveness variable in Models A5 and B5 likely weakens the negative economic effect, relative to the positive gendering effect, for boys.[22] For girls, by contrast, cultural self-expressiveness is associated with significantly lower levels of affinity toward mathematics and weaker aspirations for mathematically related jobs.

Discussion

It is well established that adolescent girls' negative attitudes toward mathematics and related careers contribute to their poor representation in American STEM occupations and degree programmes. We have explored the macro-social foundations of these attitudes through comparative analysis of eighth-graders in 53 countries and territories. Our cross-national research design was motivated by the surprising fact, documented in previous research, that women's presence in mathematical and technical fields is weaker in affluent, reputably gender-progressive societies than in many poorer, more gender-traditional societies. A central question of the present study was whether the gender gap in *attitudes* follows similarly counterintuitive patterns, or whether it is simply women's economic *capacity to realise* gender-typed curricular and career preferences that varies. Our results provide evidence for both interpretations.

On the one hand, we find considerable cross-national *similarity* in attitudes. For example, girls have weaker aspirations for a mathematically related job than do boys in all but three of 50 countries. This is likely attributable to diverse factors, including perceived incompatibility of mathematically related activities with stereotypically female dispositions, global diffusion of stereotypes associating mathematics with masculinity, and concerted international efforts during the latter half of the twentieth century to increase women's representation in higher education by developing 'female friendly' degree programmes.[23] Whatever the cause, we expect that people will more often act upon any aversion to mathematics in societies where the economic costs of forgoing lucrative STEM careers are more easily borne. Cross-national variability in the economic capacity to 'indulge' gendered preferences is thus a compelling explanation for the surprising patterns of occupational and educational sex segregation revealed in previous studies.

On the other hand, results also point to important cross-national *differences*. We find that the size and even the direction of the attitudinal gender gap varies across countries and that patterns of cross-national variability correspond to previously documented patterns of variability in sex segregation across engineering and technical fields: the attitudinal gender gap is larger in affluent, advanced-industrial societies. This relationship is not attributable to other factors, such as individual mathematics achievement, affinity for school or parental education, which might distinguish male and female students in rich and poor societies.

Although the effects are stronger for girls, our results suggest that societal prosperity also reduces *boys'* affinity for mathematics and aspirations for related jobs. This may be partly attributable to more difficult mathematics curricula (as measured by average test scores) in more economically developed societies. But country-level differences in test scores do not fully account for the negative association between socio-economic development and boys' attitudes toward mathematics. Beliefs that mathematics-related activities are especially effort-intensive or leave less room for creative self-expression may explain the remaining negative effect for boys.[24]

The role of cultural value systems in gendering math

The patterns of cross-national variability that we document are consistent with macro-cultural arguments suggesting more gender-differentiated aspirations and affinities in affluent postmaterialist societies (Charles, 2011a; Charles & Bradley, 2009). We argue that individuals place greater value on aligning their educational and occupational roles with their core self-understandings in contexts characterised by broad-based prosperity and existential security. Because self-understandings are strongly influenced by gender stereotypes, girls in postmaterialist societies will more often feel affinity towards fields reputed to require stereotypically feminine personality traits, and boys will feel greater affinity towards fields reputed to require stereotypically masculine personality traits (or that are *not* reputably feminine, at least). This is important, because the interpersonal and caring skills that are almost universally thought to be core female traits are not among the qualities typically depicted as important to the performance of mathematical and technical tasks (Cejka & Eagly, 1999; Des Jardins, 2010; Faulkner, 2000, 2007; Osborne et al., 2003).

Our cultural interpretation of cross-national differences in the attitudinal gender gap is based partly on work by Inglehart and colleagues, who document an association between widespread societal affluence and what they call 'postmaterialist values'. Inglehart's empirical analyses also show that postmaterialist value systems are associated with *increases* in many forms of gender equality (Inglehart & Norris, 2003; Inglehart & Welzel, 2005). We do not dispute this positive association, but our theoretical frame differs from Inglehart's – and those of traditional modernisation scholars – in that we conceptualise gender equality as a multidimensional phenomenon whose different dimensions respond in different ways to the forces of social and cultural development (Charles & Bradley, 2009; Charles & Grusky, 2004). The forms of gender inequality that prove to be most persistent and culturally legitimate in advanced industrial societies are those that are most readily interpreted as reflecting free choices by formally equal but fundamentally different men and women (Charles, 2011b). The sex segregation that results from adolescent boys' and girls' gender-typed aspirations falls into this category of 'self-expressive' gender inequality (Cech, in press). Such inequality is highly resilient, as it is understood culturally as the product of likes and dislikes that are quintessentially *individual*, rather than gender conforming. Sociocultural modernisation is associated, therefore, not with an across-the-board degendering, but with a relatively peaceful coexistence of liberal egalitarian ideals and gender essentialist stereotypes.

Further studies, including open-ended interviews, are necessary to identify more clearly how and why specific affinities and aspirations develop in different sociocultural contexts and how these influence career outcomes. The causal relationship between attitudes and outcomes is undoubtedly bidirectional, with girls' attitudes also becoming more positive as women's representation in the STEM workforces increases (Cejka & Eagly, 1999; Ridgeway, 2011).

What does the future hold?

Taken in conjunction with a long line of individual-level research on the STEM pipeline, the cross-national patterns revealed by our analyses suggest that increasing the flow of women into mathematical and technical fields in affluent democracies will depend upon the erosion of two kinds of cultural stereotypes that pervade schools, universities, workplaces and society at large: those that depict women as innately ill-suited for scientific and technical work, and those that depict scientific and technical work as uncreative, solitary and fundamentally masculine.

Cultural shifts of this sort occur only gradually, but some glimmers of change can be seen – for example, in conscious efforts by some parents to undermine gender stereotypes in the socialisation of their children and in diverse initiatives by industry, governments and activists around the world to attract more women into scientific and technical fields (Charles 2011a; Grusky & Levanon, 2008). Efforts to reconceptualise STEM as compatible with femininity can also be seen in the rise of 'geek chic' in the United States (Inness, 2007). Even Mattel's Barbie doll has seen a makeover. In sharp contrast to her math-fearing Teen Talk sister of the early 1990s, Computer Engineer Barbie, released in December 2010, comes decked out with a smart phone, pink laptop and a tight t-shirt printed in binary code.[25]

It is too early to tell whether these sorts of rebranding efforts are helping to weaken the male-math-nerd stereotype, but recent experimental research suggests that relatively small changes can make a difference. Cheryan, Plaut, Davies, and Steele (2009) found that making physical spaces less stereotypically masculine (e.g. replacing Star Trek posters in science labs with nature posters) increased interest in STEM careers among women college students. Murphy, Steele, and Gross (2007) found similar effects by altering the portrayal of STEM practitioners in an informational video to include a more balanced representation of women and men. Interventions at the primary school level aimed at increasing girls' exposure to and confidence in mathematically related activities show promise as well (cf. Margolis & Fisher, 2002).

Our analyses suggest that the negative effects of societal affluence on attitudes toward mathematics are not limited to girls, however. Boys too show a significantly weaker orientation toward mathematics and related fields in postmaterialist contexts. This overall negative effect is bad news for those concerned about growing shortages of STEM workers around the world, as is our finding that student interest in mathematically related jobs may have declined between 2003 and 2011.[26] Insuring an adequate supply of scientific and technical labour in the future will depend, therefore, on more than the 'degendering' of STEM fields. It will also require more general changes in the popular perception – and lived experience – of mathematical, scientific and technical work (Ainley & Ainley, 2011; Kjærnsli & Lie, 2011; Osborne et al., 2003; Thomas, 1990). This might be achieved through changes in the climate of STEM work environments, improved teaching of mathematics and science, increased opportunities for collaborative, creative, self-expressive work and less negative stereotyping of scientific and technical workers and work. At the same time, we must work to reverse the myriad processes by which female-dominated *nontechnical* work is devalued socially, culturally and economically (England, Budig, & Folbre, 2002; Ridgeway, 2011).

Conclusion

Results of the present study are consistent with a large body of research showing contextual influences on attitudes. Attitudes are not properties of individuals alone, and they are not distributed evenly across time and space. We suggest that sociocultural modernisation is an overlooked source of variability in attitudes toward STEM fields – specifically that (1) the postmaterialist values of individualism and self-expression that diffuse across advanced industrial democracies are associated with reduced interest in mathematically related pursuits and (2) that girls and women are particularly susceptible to this negative attitudinal effect because self-realisation involves bringing (real or presumed) core personality traits into alignment with the (real or presumed) task content of social roles. Depictions of female nurturance and interpersonal connectedness do not align culturally with common representations of mathematical and technical work.

In highly affluent societies, cultural mandates for individual self-expression interact with gender-essentialist belief systems to encourage development of educational and career aspirations that are simultaneously more self-expressive and more gendered. Sex segregation is so persistent in reputably gender-egalitarian cultural contexts partly because these seemingly free choices legitimate existing patterns of gender inequality and bias expectations of the next generation. An essential component of any 'degendering' strategy, therefore, would be for parents, teachers and other role models to avoid reinforcing stereotypes about what girls and boys like, what they are good at, and what sorts of work they will enjoy doing.

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Notes

1. For example, women earn nearly half of all engineering degrees in Indonesia, while some of the most male-dominated engineering programmes are found in such affluent countries as the United States, Japan and Switzerland. Iran, Romania and Malaysia are among the countries where women earn the largest share of science degrees (Charles, 2011a; Charles & Bradley, 2009; United Nations Educational, Scientific and Cultural Organisation, 2010).
2. This explanation does not require that gender-specific preferences are innate. Beliefs about one's own affinities and about the task content of specific social positions may be biased by gender stereotypes and existing patterns of sex segregation (Charles, 2011a; Ridgeway, 2011). Individuals may also respond to others' expectations that they behave in a gender-normative fashion (West & Fenstermaker, 1995; West & Zimmerman, 1987).
3. Even *within* postmaterialist societies, people differ in their levels of concern about their own existential security. Inglehart's argument suggests, however, that self-expressive value systems will have some (albeit weaker) influence even on economically insecure members of postmaterialist societies.
4. On contextual variability in the salience of gender belief systems, see Deaux & Major, 1987; Ridgeway, 2011.
5. For example, men and boys may wish to avoid the stigma of low earnings or of doing work labelled as 'feminine'.
6. The 'math nerd' is but one version of masculinity in the contemporary West (Connell, 2005).
7. On *structural* processes driving variability in sex segregation, see Charles, 2011b; Charles & Bradley, 2002; Charles & Grusky, 2004.
8. Numerous US-based studies of the STEM pipeline have shown strong effects of early aspirations and affinities on career outcomes (e.g. Cech et al., 2011; Fox & Stephan, 2001; Hackett, 1985; Xie & Shauman, 2003).
9. Three-level models, computed to account for clustering of students within schools, yield nearly identical results (available upon request).
10. Our models assume that effects of other student-level covariates (e.g. age, parental education and achievement) on attitudes are constant across countries.
11. In a null model (i.e. a model with no covariates), the intra-class correlation (ICC) for enjoying mathematics is .14, meaning that 14% of the variability in mathematical affinity occurs across countries. For aspirations, the ICC is .13.
12. Where 2000 scores were missing, we substituted data from the 1995 WVS wave. Scores for neither wave were available for Bahrain, Botswana, Cyprus, Hong Kong, Korea, Kuwait, Lebanon, Malaysia, Syria, Thailand and Tunisia. We measure self-expressiveness at a later time than HDI to simulate a lagged effect of societal affluence on cultural values. The correlation of self-expressiveness with HDI is .74; its correlation with GDP (ln) is .64.
13. Averaged across all countries and years, boys' mean math achievement score is 4.64, compared to 4.66 for girls.

14. Correlations of the boy-girl gap with HDI: −.47 for affinity; −.62 for aspirations.
15. 'Advanced Industrial' societies are high-income countries that have been OECD member states since at least 1974 (see also Charles & Bradley, 2009). 'Formerly Socialist' countries refer to the Eastern- and Central-European members of the former Soviet Union. The 'Asian Tiger' group includes countries and territories that have pursued a successful export-driven development strategy since the 1960s (Hong Kong, South Korea, Singapore in our sample), while the 'Tiger Cubs' are less affluent South-east Asian countries that have come to this development strategy more recently (Indonesia, Malaysia, Philippines and Thailand). The 'Other' category includes high-income oil-producing countries and low- and medium-income countries in Africa, South America and the Middle East.
16. To assess possible pan-Asian effects, we ran a series of supplementary models that included a dummy indicator for Asia. In no case was the Asia effect statistically significant, and in no case did inclusion of this variable significantly affect the HDI coefficient.
17. Among students with secondary-educated parents who report liking school and who have mean scores on age and mathematics achievement, predicted odds of 'enjoying math' (relative to not enjoying math) in 2011 are about four to 1 (3.86) for boys and about three to one (3.06) for girls (Model A1). Predicted odds of aspiring to a mathematically related job (Model B1) are 1.47 and .91 for boys and girls, respectively.
18. In her study of one elite college in the United States, Mullen finds that men are more concerned than women about choosing a major with high financial returns (2013).
19. The standard deviation of .93 in Model A1 indicates that students in a country that is one standard deviation above the mean on the dependent variable have odds of enjoying mathematics that are 153% higher than comparable students in a country with average enjoyment levels, holding constant all individual-level covariates [exp(0.93) = 2.53]. For aspiring to a mathematics job, the corresponding figure is 129% [exp(0.83) = 2.29].
20. Effects of HDI on aspirations are also not artefacts of women's stronger representation in STEM fields in less developed societies. In supplementary models, we added to Models A4 and B4 a country-level indicator of women's share of university engineering students in 1990. The effect of HDI on the attitudinal gender gap remains.
21. See note to Figure 1 on calculation of predicted boy-to-girl odds ratios.
22. Main effects of self-expressiveness become statistically significant if country-level mathematics achievement scores are omitted from Models A5 and B5 (results available on request).
23. Berkovitch and Bradley (1999); Bradley and Charles (2004); Charles and Bradley (2002); Charles and Grusky (2004); Frank and Meyer (2007); Wotipka and Ramirez (2008).
24. Adolescents' more positive attitudes in societies with developing and transitional economies may also reflect a stronger valuation of scientific and technical activities in contexts where building human-capital capacity in STEM fields is deemed crucial for national development and competitiveness in the world economy.
25. Of course, this math-is-feminine strategy risks swapping one set of stereotypes for another.
26. In ongoing work, we are exploring longer-term trends in attitudes toward mathematics and science.

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References

Ahmed, S. (2010). *The promise of happiness*. Durham, NC: Duke University Press.

Ainley, M., & Ainley, J. (2011). A cultural perspective on the structure of student interest in science. *International Journal of Science Education, 33*, 51–71.

Astin, A. W. (1993). *What matters in college? Four critical years revisited*. San Francisco, CA: Jossey-Bass Publishers.

Baker, D. P., & LeTendre, G. K. (2005). *National differences, global similarities: World culture and the future of schooling*. Stanford, CA: Stanford University Press.

Bellah, R. N., Madsen, R., Sullivan, W. M., Swidler, A., & Tipton, S. M. (2008). *Habits of the heart: Individualism and commitment in American life*. Berkeley, CA: University of California Press.

Berkovitch, N., & Bradley, K. (1999). The globalization of women's status: Consensus/dissensus in the world polity. *Sociological Perspectives, 42*, 481–498.

Bradley, K., & Charles, M. (2004). Uneven inroads: Understanding women's status in higher education. *Research in Sociology of Education, 14*, 247–274.

Buccheri, G., Gürber, N. A., & Brühwiler, C. (2011). The impact of gender on interest in science topics and the choice of scientific and technical vocations. *International Journal of Science Education, 33*, 159–178.

Cech, E. (in press). The self-expressive edge of occupational sex segregation. *American Journal of Sociology*.

Cech, E., Rubineau, B., Silbey, S., & Seron, C. (2011). Professional role confidence and gendered persistence in engineering. *American Sociological Review, 76*, 641–666.

Cejka, M. A., & Eagly, A. H. (1999). Gender-stereotypic images of occupations correspond to the sex segregation of employment. *Personality and Social Psychology Bulletin, 25*, 413–423.
Charles, M. (2011a). What gender is science? *Contexts, 10*, 22–28.
Charles, M. (2011b). A world of difference: International trends in women's economic status. *Annual Review of Sociology, 37*, 355–371.
Charles, M., & Bradley, K. (2002). Equal but separate? A cross-national study of sex segregation in higher education. *American Sociological Review, 67*, 573–599.
Charles, M., & Bradley, K. (2009). Indulging our gendered selves? Sex-segregation by field of study in 44 countries. *American Journal of Sociology, 114*, 924–976.
Charles, M., & Grusky, D. (2004). *Occupational ghettos: The worldwide segregation of women and men*. Stanford, CA: Stanford University Press.
Cheryan, S., Plaut, V. C., Davies, P. G., & Steele, C. M. (2009). Ambient belonging: How stereotypical cues impact gender participation in computer science. *Journal of Personality and Social Psychology, 97*, 1045–1060.
Connell, R. W. (2005). *Masculinities*. Berkeley, CA: University of California Press.
Correll, S. J. (2001). Gender and career choice processes: The role of biased self-assessments. *American Journal of Sociology, 106*, 1691–1730.
Correll, S. J. (2004). Constraints into preferences: Gender, status, and emerging career aspirations. *American Sociological Review, 69*, 93–113.
Cross, S. E., & Madson, L. (1997). Models of the self: Self-construals and gender. *Psychological Bulletin, 122*, 5–37.
Deaux, K., & Major, B. (1987). Putting gender into context: An interactive model of gender-related behavior. *Psychological Review, 94*, 369–389.
Des Jardins, J. (2010). *The Madame Curie complex: The hidden history of women in science*. New York, NY: Feminist Press.
England, P., Budig, M., & Folbre, N. (2002). Wages of virtue: The relative pay of care work. *Social Problems, 49*, 455–473.
Erickson, R. (1995). The importance of authenticity for self and society. *Symbolic Interaction, 18*, 121–144.
Faulkner, W. (2000). Dualisms, hierarchies, and gender in engineering. *Social Studies of Science, 30*, 759–792.
Faulkner, W. (2007). 'Nuts and bolts and people': Gender-troubled engineering identities. *Social Studies of Science, 37*, 331–356.
Fox, M. F., & Stephan, P. E. (2001). Careers of young scientists: Preferences, prospects and realities by gender and field. *Social Studies of Science, 31*, 109–122.
Frank, D. J., & Meyer, J. W. (2007). University expansion and the knowledge society. *Theory and Society, 36*, 287–311.
Gerson, K. (2010). *The unfinished revolution: How a new generation is reshaping family, work, and gender in America*. New York, NY: Oxford University Press.
Goldman, A. D., & Penner, A. M. (2012). *Exploring international gender differences in mathematics self-efficacy*. Irvine: University of California.
Grusky, D. B., and Levanon, A. (2008). Four gloomy futures for sex segregation. In D. B. Grusky, M. C. Ku, & S. Szelényi (Eds.), *Social stratification: Class, race, and gender in sociological perspective* (3rd ed., pp. 812–825). Boulder, CO: Westview Press.
Hackett, G. (1985). Role of mathematics self-efficacy in the choice of math-related majors of college women and men: A path analysis. *Journal of Counseling Psychology, 32*, 47–56.

Harding, S. (1991). *Whose science? Whose knowledge?* Ithaca, NY: Cornell University Press.
Harr, B. (2012). *Inculcating instrumentality: How socioeconomic status and school context impact eighth graders' attitudes toward math and science*. Santa Barbara: University of California.
Inglehart, R., & Norris, P. (2003). *Rising tide: Gender equality and cultural change around the world*. Cambridge: Cambridge University Press.
Inglehart, R., & Welzel, C. (2005). *Modernization, cultural change, and democracy: The human development sequence*. New York, NY: Cambridge University Press.
Inness, S. A. (Ed.). (2007). *Geek chic: Smart women in popular culture*. New York, NY: Palgrave MacMillan.
Jackson, R. M. (1998). *Destined for equality: The inevitable rise of women's status*. Cambridge, MA: Harvard University Press.
Johnson, M. K. (2001). Change in job values during the transition to adulthood. *Work and Occupations, 28*, 315–345.
Kjærnsli, M., & Lie, S. (2011). Students' preference for science careers: International comparisons based on PISA 2006. *International Journal of Science Education, 33*, 121–144.
Lareau, A. (2011). *Unequal childhoods: Class, race, and family life* (2nd ed.). Berkeley, CA: University of California Press.
Lee, J. D. (1998). Which kids can "become" scientists? Effects of gender, self-concepts, and perceptions of scientists. *Social Psychology Quarterly, 61*, 199–219.
Lueptow, L. B., Garovich-Szabo, L., & Lueptow, M. B. (2001). Social change and the persistence of sex typing: 1974–1997. *Social Forces, 80*, 1–36.
Luke, D. A. (2004). *Multilevel modeling*. Thousand Oaks, CA: Sage.
Ma, Y. (2009). Family SES, parental involvement and college major choices. *Sociological Perspectives, 52*, 211–234.
Mainiero, L. A., & Sullivan, S. E. (2006). *The opt-out revolt: Why people are leaving companies to create kaleidoscope careers*. Mountain View, CA: Davies-Black.
Margolis, J., & Fisher, A. (2002). *Unlocking the clubhouse: Women in computing*. Cambridge, MA: MIT Press.
McIlwee, J. S., & Gregg Robinson, J. (1992). *Women in engineering: Gender, power, and workplace culture*. Albany, NY: State University of New York Press.
Messner, M. A., & Bozada-Deas, S. (2009). Separating the men from the moms: The making of adult gender segregation in youth sports. *Gender & Society, 23*, 49–71.
Meyer, J. W., & Jepperson, R. L. (2000). The 'actors' of modern society: The cultural construction of social agency. *Sociological Theory, 18*, 100–120.
Mullen, A. L. (2013). Gender, social background, and the choice of college major in a liberal arts context. *Gender & Society*, Online First, January 2014.
Murphy, M. C., Steele, C. M., & Gross, J. J. (2007). Signaling threat: How situational cues affect women in math, science, and engineering settings. *Psychological Science, 18*, 879–885.
Nosek, B. A., Banaji, M. R., & Greenwald, A. G. (2002). Math = male, me = female, therefore math ≠ me. *Journal of Personality and Social Psychology, 83*, 44–59.
Nosek, B. A., Smyth, F. L., Sriram, N., Lindner, N. M., Devos, T., Ayala, A., … Greenwald, A. (2009). National differences in gender-science stereotypes predict national sex differences in science and math achievement. *Proceedings of the National Academy of Sciences, 106*, 10593–10597.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*, 1049–1079.
Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods*. Newbury Park, CA: Sage.
Ridgeway, C. (2011). *Framed by gender: How gender inequality persists in the modern world*. Oxford: Oxford University Press.
Sikora, J., & Pokropek, A. (2012). Gender segregation of adolescent science career plans in 50 countries. *Science Education, 96*, 234–264.
Sørensen, K. H., & Berg, A.-J. (1987). Genderization of technology among Norwegian engineering students. *Acta Sociologica, 30*, 151–171.
Stevenson, H. W., & Stigler, J. W. (1992). *The learning gap: Why our schools are failing and what we can learn from Japanese and Chinese education*. New York, NY: Simon & Schuster.
Thomas, K. (1990). *Gender and subject in higher education*. Bristol, PA: Open University Press.
Tolley, K. (2003). *The science education of American girls: A historical perspective*. New York, NY: Routledge.
Trends in International Mathematics and Science Study at the Eighth Grade. (2012). *TIMSS 2011 international results in mathematics*. Chestnut Hill, MA: Boston College.
Trends in International Mathematics and Science Study at the Eighth Grade. (2013). *TIMSS 2011 user guide for the international data base*. Chestnut Hill, MA: Boston College.
Treiman, D. (1970). Industrialization and social stratification. In E. O. Laumann (Ed.), *Social stratification: Research and theory for the 1970s* (pp. 207–234). Indianapolis, IN: Bobbs-Merrill.
United Nations Development Programme. (2012). *Human development report statistics*. Retrieved from http://hdrstats.undp.org/indicators/
United Nations Educational, Scientific, and Cultural Organization. (2010). Retrieved from http://stats.uis.unesco.org/unesco/TableViewer/document.aspx?ReportId=143&IF
West, C., & Fenstermaker, S. (1995). Doing difference. *Gender & Society, 9*, 8–37.
West, C., & Zimmerman, D. H. (1987). Doing gender. *Gender & Society, 1*, 125–151.
Williams, J. E., & Best, D. L. (1990). *Measuring sex stereotypes: A multi-nation study*. Newbury Park, CA: Sage.
Wotipka, C. M., & Ramirez, F. O. (2008). Women's studies as a global innovation. *International Perspectives on Education and Society, 9*, 89–110.
Xie, Y., & Shauman, K. A. (2003). *Women in science: Career processes and outcomes*. Cambridge, MA: Harvard University Press.

Appendix 1. Scores on country-level covariates.

	Human development index, HDI (1995)	Gross domestic product per capita, GDP (1990)	Mean mathematics achievement	Self-expressiveness score (2000)
Armenia	.60	7581	5.00	−1.31
Australia	.89	26,541	4.95	1.96
Bahrain	.75	19,389	4.04	–
Belgium	.85	26,412	5.45	1.13
Botswana	.60	7581	3.64	–
Bulgaria	.70	7893	4.82	−1.52
Canada – Ontario	.87	29,177	5.15	1.72
Canada – Quebec	.87	29,177	5.27	1.72
Chile	.72	7128	4.03	.12
Colombia	.63	6511	3.80	.68
Cyprus	.79	18,543	4.65	–
Czech Republic	.79	17,318	5.05	.38
Egypt	.54	3448	4.10	−.54
England	.82	24,617	5.15	1.31
Ghana	.55	971	3.17	−.29
Hong Kong	.81	25,657	5.76	–
Hungary	.74	13,596	5.22	−1.22
Indonesia	.53	2260	4.02	−.50
Iran	.60	6772	4.14	−.45
Israel	.82	19,512	4.64	.36
Italy	.80	26,307	4.79	.85
Japan	.85	28,152	5.71	.54
Jordan	.62	3576	4.22	−1.05
Korea	.79	12,347	5.96	–
Kuwait	.74	40,079	3.53	–
Latvia	.67	8951	5.17	−1.27
Lebanon	.71	9268	4.61	–
Lithuania	.70	9674	5.11	−1.00
Macedonia	.70	8829	4.37	−.72
Malaysia	.67	7195	4.74	–
Moldova	.58	1794	4.62	−1.69
Morocco	.47	2906	3.80	−1.09
Netherlands	.87	28,287	5.41	1.94
New Zealand	.86	20,188	4.88	1.78
Norway	.88	38,161	4.70	1.33
Palestine	.66	1153	3.89	−.29
Philippines	.59	2582	3.78	−.11
Romania	.69	8962	4.73	−1.60
Russia	.68	13,674	5.18	−1.88
Saudi Arabia	.71	20,747	3.33	.15
Scotland	.82	24,617	4.90	1.31

(*Continued*)

Appendix 1. (*Continued*).

	Human development index, HDI (1995)	Gross domestic product per capita, GDP (1990)	Mean mathematics achievement	Self-expressiveness score (2000)
Serbia	.72	13,308	4.91	−1.03
Singapore	.80	25,828	5.88	−.28
Slovak Republic	.75	13,426	5.22	−.43
Slovenia	.76	16,814	5.03	.38
South Africa	.64	8471	2.68	−.46
Spain-Basque	.80	22,039	–	.51
Sweden	.86	26,978	4.94	2.09
Syria	.57	3189	3.96	–
Thailand	.60	4289	4.47	–
Tunisia	.59	4351	4.23	–
Turkey	.59	8778	4.38	−.34
USA	.88	34,594	5.06	1.59
Country Mean	*.72*	*15,087*	*4.62*	*.07*
*Country Groups**				
Advanced Industrial	.86	28,641	5.07	1.45
Asian Tiger	.80	21,235	5.95	−.58
Tiger Cub	.60	4315	4.32	−.38
Former Socialist	.69	11,103	4.94	−1.07
Other	.63	8361	3.97	−.37

Note: HDI and GDP scores are taken from the United Nations Development Programme (UNDP) Human Development reports. On both GDP and HDI, Canada's values are used for Ontario and Quebec, and Spain's values are used for Basque. Great Britain's GDP was used for both England and Scotland. Palestine's HDI score is for 2010, Kuwait's GDP was calculated by averaging 1980 and 2000 values, and Moldova's GDP was measured in 2000. Self-expressiveness scores are computed by Inglehart and Welzel from the 2000 wave of the WVS (1995 wave for Australia, Armenia, Ghana, New Zealand, Norway, and South Africa). Data on mathematics achievement are 'plausible scores' (/100) from TIMSS of 2003, 2007, 2011.

**Advanced Industrial*: Australia, Belgium, Canada, England, Italy, Japan, Netherlands, New Zealand, Norway, Scotland, Spain, Sweden, and USA. *Asian Tiger*: Hong Kong, Korea, Singapore. *Tiger Cub*: Indonesia, Malaysia, Philippines, Thailand. *Former Socialist*: Armenia, Bulgaria, Czech Republic, Hungary, Latvia, Lithuania, Macedonia, Moldova, Romania, Russia, Serbia, Slovak Republic, Slovenia. *Other*: Bahrain, Botswana, Chile, Colombia, Cyprus, Egypt, Ghana, Hong Kong, Iran, Israel, Jordan, Kuwait, Lebanon, Morocco, Palestine, Saudi Arabia, South Africa, Syria, Tunisia, Turkey.