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National GDP, Science Interest and Science Achievement: A Person-by-Nation Interaction

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Abstract

Maximizing science achievement is a critical target of educational policy, with important implications for national and international economic and technological competitiveness. Previous research has identified both science interest and socioeconomic status (SES) as robust predictors of science achievement, but little research has examined their joint effects. In a dataset drawn from approximately 400,000 high school students from 57 countries, we document large interest by SES and interest by per capita gross domestic product (GDP) interactions in the prediction of science achievement. Student interest in science is a substantially stronger predictor of science achievement in higher socioeconomic contexts *and* in higher GDP nations. Our results are consistent with the hypothesis that, in higher opportunity contexts, motivational factors play larger roles in learning and achievement. They add to the growing body of evidence indicating that substantial cross national differences in psychological effect sizes are not simply a logical possibility, but in many cases, an empirical reality.

Keywords

Science achievement; science interest; cross national; moderation; PISA

“Whether it’s improving our health or harnessing clean energy, protecting our security or succeeding in the global economy, our future depends on reaffirming America’s role as the world’s engine of scientific discovery and technological innovation. And that leadership tomorrow depends on how we educate our students today, especially in math, science, technology, and engineering. But despite the importance of education in these subjects, we have to admit we are right now being outpaced by our competitors.”

-President Barack Obama, January 6, 2010¹

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Author Contributions

E. M. Tucker Drob initially developed the study concept and led analysis and interpretation. A. K. Cheung and D. A. Briley assisted with analysis and writing of the manuscript. All authors approved the final version of the manuscript before submission.

¹Remarks by the President on the “Educate to Innovate” campaign and science teaching and mentoring awards (2010, January 6). Retrieved on January 17, 2014 from <http://www.whitehouse.gov/the-press-office/remarks-president-educate-innovate-campaign-and-science-teaching-and-mentoring-awar>

Much attention has recently been paid to the status of science achievement among U.S. students, as a key determinant of both domestic prosperity and international economic competitiveness. Understanding the determinants of science achievement at both the individual and national levels has therefore become a major emphasis of basic social science research. Empirical evidence points to strong roles for two classes of factors in science achievement: socioeconomic status (SES; Knudsen, Heckman, Cameron, & Shonkoff, 2006; Sirin, 2005) and science interest (Hulleman & Harackiewicz, 2009). These research emphases are mirrored in science education policy guidelines (National Science Board, 2010).

In spite of thriving research programs that have separately examined the roles of interest and SES on academic achievement, there has until recently been little empirical research on their joint effects. Research on SES and achievement has largely focused on identifying the specific mechanisms that mediate achievement disparities. For example, researchers have examined factors such as such as nutrition, cognitively stimulating materials and experiences, school quality, school peer composition, parent/teacher attitudes, expectations and behaviors, and stressful threatening, and uncontrollable life events (Altonji & Mansfield, 2011; Bradley & Corwyn, 2002; Coleman, 1966). Meanwhile, research on interest and achievement has made use of longitudinal data to disentangle the causal ordering of academic interest and academic achievement (Marsh & Martin, 2011; Marsh & O'Mara, 2008; Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005) and has made use of in depth survey methods to test the mediating roles of task choice and task involvement on the effects of interests and expectations on academic achievement (Eccles & Wigfield, 2002; Fredricks & Eccles, 2002; Jacobs & Eccles, 2000). Results have been consistent with “investment” perspectives of knowledge acquisition (Cattell, 1971; von Stumm & Ackerman, 2013), which posit that individual differences in motivational factors, such as intellectual/academic interest, influence the extent to which individuals choose to invest their time and effort in learning.

Only a small body of recent work, focusing specifically on achievement gaps within the United States, has investigated interest by SES interactions (Tucker Drob & Briley, 2012; Tucker Drob & Harden, 2012a, 2012b). Results have consistently indicated that a constellation of closely related variables representing intellectual interest and achievement motivation on the one hand and family SES on the other hand interact in their prediction of both domain general academic achievement and multiple domain specific aspects of academic achievement, most notably mathematics and science achievement. These results are consistent with the hypothesis that students with the interest and motivation to learn are better able to successfully invest their time and effort in learning when given appropriate opportunities. In other words, rather than facilitating a process by which information is directly transmitted to passive learners, social and educational privilege provides greater opportunity for students to actively engage in the learning process (Tucker Drob, Briley, & Harden, 2013).

The current project extends this nascent body of work on interest by family SES interactions in a number of important ways. First, we seek to determine whether such interactions apply to nations outside of the United States. Second, we seek to determine whether the interaction

with family SES is accounted for by School SES. Third, we seek to examine whether national socioeconomic context (as indexed by per capita Gross Domestic Product) also interacts with individual science interest in the prediction of science achievement. Finally, we seek to establish that interest by SES interactions are independent of other established effects, specifically nonlinear effects and interest by self concept interactions.

We hypothesize that, because adolescent learning opportunities for science are primarily concentrated in schools and because family SES is often stratified across schools (i.e. children from poorer families tend to attend poorer schools with poorer student bodies), interest by family SES interactions will be substantially mediated by interest by school SES interactions. Additionally, based both on previous theoretical work (Tucker Drob et al., 2013) and empirical work on SES by interest interactions in the United States (Tucker Drob & Briley, 2012; Tucker Drob & Harden, 2012a, 2012b), we hypothesize that socioeconomic context and individual science interest will interact to predict individual science achievement, and that this interaction will be evident at both the intra national and international levels. We propose that in wealthy nations, students interested in science may select, evoke, and attend to science relevant learning experiences, whereas in poorer nations, students will be far more limited in their options to invest their interests in this way. We therefore predict that *national* socioeconomic prosperity will interact with science interest to predict science achievement. The current project represents the first test of such a person by nation interaction in the prediction of achievement. Finally, we predict that these interactions will be robust to controls for nonlinear effects and interest by self concept interactions that have previously been reported in the literature (Nagengast & Marsh, 2012; Nagengast et al., 2011). We use science interest and test score data from a large sample of 15 year olds from 57 nations which we combine with per capita Gross Domestic Product data.

Method

Participants

Data were drawn from the Organization for Economic Co operation and Development (OECD) Programme for International Student Assessment (PISA), an ongoing international project begun in 2003 to assess the academic competency of 15 year olds around the world. Every three years, a new international sample of 15 year olds is assessed on reading, mathematics, and science skills, and surveyed on a selection of items focused on a particular subject (reading, mathematics, or science), with the subject rotating across waves. The most recent wave that focused on science was the 2006 wave (reading was the focus in 2009, and mathematics was the focus in 2012). We specifically selected the 2006 dataset for this reason. This dataset contains 398,750 individual student participants, carefully selected to be representative of the general population of 15 year old students from 57 nations. Full details of the recruitment, procedures, and assessment methods can be found in technical reports (OECD, 2006, 2007, 2009). Briefly, a two hour paper and pencil test was given that primarily assessed scientific literacy. Literacy refers to the ability to apply scientific thinking to real world problems, rather than specific curricular items. The test items were extensively piloted and analyzed using item response theory techniques. Additionally, the participants

completed a 30 minute questionnaire about their demographic background and individual characteristics. All test material was back translated from two source languages by two independent translators. A third independent linguist adjudicated any discrepancies. This procedure is far more stringent than standard back translation in that it uses two source languages and three independent translators. Standard methods typically use only one source language and translator. This was done to ensure that the content was appropriate in all countries and languages. Numerous quality control measures were in place to guarantee that accurate data were obtained from the students and entered into the dataset.

Measures

For the current paper, we analyzed the variables described below. We did not analyze any of the many other variables provided in the PISA 2006 dataset. For instance, PISA 2006 also includes measures of math achievement and reading achievement. We did not analyze these measures as (1) we were specifically interested in science achievement, (2) PISA 2006 focused its survey questions (e.g. interest) specifically on science (which is specifically why we chose the dataset), and does not include similar survey questions about math and reading.

Science Achievement—PISA measured participants using a test assessing multiple areas of science achievement. Item response theory was used to produce five sets of plausible values for latent science literacy proficiency. According to Nagengast and Marsh (2012), “Correct analyses of plausible values require that all models are run separately for each plausible value and the results integrated using principles of multiple imputation analysis” (p. 1037). Following Nagengast and Marsh, we used the *Mplus* multiple imputation function to achieve this (Muthén & Muthén, 1998 2012).

Science Interest and Science Self-Concept—. At each wave, PISA assesses a number of non cognitive traits focused around a specific subject area. In 2006, the focus was on science achievement. To index science interest, we selected all of the sub questions (items a, b, c, d, and e) from question 16, which was in “SECTION 3: YOUR VIEWS ON <BROAD SCIENCE>.” Instructions and question content were as follows:

This section asks about your views on various issues relating to <broad science>. <Broad science> refers to any topics that you might encounter in school, or outside of school (for example on television) that relate to space science, biology, chemistry, Earth science or physics.

Q16 How much do you agree with the statements below?

- a. I generally have fun when I am learning <broad science> topics.
- b. I like reading about <broad science>.
- c. I am happy doing <broad science> problems.
- d. I enjoy acquiring new knowledge in <broad science>.
- e. I am interested in learning about <broad science>.

To index science self concept, we selected all of the sub questions (items a, b, c, d, e, and f) from question 37, which was in “SECTION 7: TEACHING AND LEARNING SCIENCE.” Instructions and question content were as follows:

Q37 The following question asks about your experience in learning <school science> topics. How much do you agree with the statements below?

- a. Learning advanced <school science> topics would be easy for me
- b. I can usually give good answers to <test questions> on <school science> topics
- c. I learn <school science> topics quickly
- d. <School science> topics are easy for me
- e. When I am being taught <school science>, I can understand the concepts very well
- f. I can easily understand new ideas in <school science>

These are the same items that Nagengast and colleagues (2011) used to index science “value” and “expectancy,” respectively, in their analysis of “expectancy by value” interactions. There were no other items that we judged to directly index broad interest or self concept in science (there was one question, Q21, that we did not analyze, which asked about interest in specific science topics). Items were rated on a 1 4 Scale: (Strongly agree, Agree, Disagree, Strongly disagree). To create a composite reflecting science interest, we summed the sub questions from question 16 and reflected it such that higher scores indicated more interest. Cronbach's alpha for this composite was .905. To create a composite reflecting science self concept, we summed the sub questions from question 37 and reflected it such that higher scores indicated higher self concept. Cronbach's alpha for this composite was .910. Nagengast and colleagues (2011) have previously reported measurement invariance for these same items across all 57 PISA nations.

Family SES—PISA provides an “index of economic, social, and cultural status” which was derived from student reports of parental educational attainment, parental occupational status, and material possessions (e.g. books, computer, electronic equipment) in the home.

School SES—Consistent with best practices (van Ewijk & Sleegers, 2010), we calculated School SES for each school by averaging the “index of economic, social, and cultural status” across all individual PISA participants attending that school.

Country-Level Per Capita Gross Domestic Product (GDP)—Per capita GDP in U.S. Dollars for each country in 2006 was obtained from www.worldbank.org.² GDP was log transformed (logGDP) for all analyses and standardized relative to its between country *M* and *SD*.

²Per capita GDP was unavailable for Taiwan (Taipei; see <https://datahelpdesk.worldbank.org/knowledgebase/articles/114933> where are your data on taiwan). Otherwise, data on per capita GDP was complete.

Other Country-Level Social and Economic Indices—In addition to logGDP we also attempted to integrate other aspects of national social, educational, and economic opportunities (see Table S1 for values obtained for each country). We obtained the *Gini* index and *research and development* expenditures (R&D) from The World Bank, *social justice*, *access to education*, and *social cohesion* from the Sustainable Governance Indicators (SGI), and *democracy index* from The Economist. The Gini index reflects the extent of income inequality in that country, with larger values indicating greater inequality in income distribution (The World Bank, 2006a). R&D measures the aggregated expenditures on research and development across industries in a country (The World Bank, 2006b). Social justice, access to education, and social cohesion were only available for 31 (OECD member states) of our 57 nations. The social justice index measures the extent to which individuals have the opportunity to develop desired capabilities, with higher numbers indicating greater social justice (Schraad Tishler, 2011). It is a composite based on poverty rate, access to education, labor equalities, population diversity and integration, health and access to health services, and distribution of social burden in a country. Access to education measures the extent to which education is equally available to everyone in a country (Schraad Tishler, 2011). Social cohesion measures the extent to which individuals within a country perceive that they are a part of the community and receive fair treatment (Schraad Tishler, 2011). The democracy index measures the amount of freedom an individual has in contributing to the political environment and the extent to which an individual's rights are observed in a country (Kekic, 2007).

Results

All analyses used individual student weights available in the PISA dataset to account for unequal participation probabilities associated with both student and school driven selective participation and explicit oversampling that was conducted for national reporting purposes. All predictors that varied within country were centered within country in order to avoid confusing between country effects for within country effects. We report results using two different methods of scaling: U.S. *SDs* and cross nationally pooled *SDs*. The former puts coefficients on a scale that is comparable to those reported in previous studies, which have predominantly been conducted in the U.S. and similarly industrialized western countries. The latter puts coefficients on a scale that is prototypical of all countries in the PISA dataset (but not specifically representative of any single country). Scaling was carried out by dividing each variable by the relevant *SD* prior to creating product terms and fitting models. Scaling parameters relative to each country's specific *SD* would have been inappropriate, as cross national differences in the magnitude of association would have become confounded with cross national differences in the magnitude of variation.

Within-Country SES-by-Interest Interactions

In an initial model (Model 1) we predicted science achievement from science interest, family SES, and logGDP, a family SES by science interest interaction, and a logGDP by science interest interaction, using the complex survey of *Mplus* to account for the nonindependence of observations due to nesting of data across the three levels of analysis (individuals, schools, and nations). Results are presented in Table 1. It can be seen that the

population average regression effect of interest on science achievement was estimated to be of modest magnitude (.167 scaled relative to U.S. *SDs*, .149 scaled relative to pooled *SDs*), and that the population average regression effect of SES on science achievement was estimated to be of moderate magnitude (.278 scaled relative to U.S. *SDs*, .304 scaled relative to pooled *SDs*). Importantly, a sizable family SES by science interest interaction was detected. The magnitude of this interaction can be gauged by calculating simple slopes for interest at high and low values of family SES. Holding logGDP constant at the between nation mean, among children from low SES families ($SES = 2$), the regression effect of interest on science achievement was .079 when computed with U.S. *SDs* and .061 when computed with pooled *SDs*. Again, holding logGDP constant at the between nation mean, among children from high SES families ($SES = 2$), the regression effect of interest on science achievement was .255 when computed with U.S. *SDs* and .237 when computed with pooled *SDs*. In more resource rich home environments, interest in science was more strongly linked to actual science achievement. Of course, these interaction effects also varied across countries.

To estimate within country parameters for each individual country, we made use of the multiple group feature of *Mplus* to estimate unconstrained country specific regressions of science achievement on science interest (centered within country), student SES (centered within country), and a within country student SES by science interest interaction, using the complex survey option to correct standard errors for nonindependence of observations associated with nesting of data across two within country levels of analysis (individuals within schools). Results indicated that the Czech Republic displayed the largest family SES by science interest interaction (.084 scaled relative to U.S. *SDs*, .082 scaled relative to pooled *SDs*). Among Czech children from low SES families ($SES = 2$), the regression effect of interest on science achievement was .010 when computed with U.S. *SDs* and .005 when computed with pooled *SDs*. Among Czech children from high SES families ($SES = 2$), the regression effect of interest on science achievement was .346 when computed with U.S. *SDs* and .323 when computed with pooled *SDs*. Other sizeable SES by science interest interactions (effect $> .050$ for both forms of scaling) were found for the United States, New Zealand, the United Kingdom, and Bulgaria. Alternatively, near zero SES by science interest interaction effects were found for Hong Kong, Finland, Jordan, Montenegro, Taipei, and Azerbaijan. One country (Kyrgyzstan) had an appreciably negative SES by science interest interaction (.074 scaled relative to U.S. *SDs*, .073 scaled relative to pooled *SDs*), along with an appreciably negative main effect of interest on science achievement (.215 scaled relative to U.S. *SDs*, .192 scaled relative to pooled *SDs*). Kyrgyzstan is also the country in the PISA dataset with the lowest GDP. Figure 1 presents example simple slope plots for countries of varying magnitudes of the interaction between SES and interest and main effect of interest. Full country specific parameter estimates from the multiple group models are presented in the Supplemental Materials (Tables S2-3).

Between-Country GDP-by-Interest Interactions

In addition to indicating main and moderating effects of family SES, Model 1 also indicated both a strong main effect of logGDP (.375 scaled relative to both U.S. and pooled *SDs*) and a strong moderating effect of logGDP on science interest (.095 scaled relative to U.S. *SDs*

and .085 scaled relative to pooled *SDs*) in predicting science achievement. This interaction indicated that students' levels of science interest were more highly related to their science achievement in more economically prosperous countries. Holding family level SES constant at each country's mean, science interest among students from rich countries ($\log\text{GDP} = 2$) translated strongly into science achievement (expected regression effect = .357 when calculated with U.S. *SDs*, .319 when calculated with pooled *SDs*), but among students from poorer countries ($\log\text{GDP} = 2$), science interest had no bearing on science knowledge (expected regression effect = .023 when calculated with U.S. *SDs*, .021 when calculated with pooled *SDs*). Using the country specific interest parameter estimates from the multiple group model described earlier, Figure 2 plots the regression coefficient of science achievement on science interest, against $\log\text{GDP}$. Importantly, this is not a plot of levels of science performance across countries. The y axis represents the magnitude of the regression relation between science interest and science performance (scaled in U.S. *SDs*). It can be seen that there was a strong correlation ($r = .753$; 95% CI = [.639, .867]) between $\log\text{GDP}$ and the country specific science interest achievement regression coefficient (this correlation is identical when country specific regression coefficients are scaled in pooled *SDs*). Interest was more strongly associated with science achievement in higher GDP countries. In countries with a relatively low GDP, the association between science interest and science achievement was relatively flat. A much weaker correlation ($r = .276$, 95% CI = [.034, .518]) was found between the family SES by science interest effect size and country $\log\text{GDP}$, leaving much unexplained heterogeneity in cross national differences in the science interest by family SES interaction effect.

Testing School-Level SES as a Mediator of Family SES-by-Interest Interactions

To test whether school level SES mediated family SES by science interest interactions, we added school SES and a school SES by science interest interaction as predictors. As reported in Table 1, in this model (Model 2) the family SES by science interest interaction was reduced to near zero and the school SES by science interest interaction was slightly larger in magnitude than the family SES by science interest interaction in Model 1. Thus, in the sample as a whole, school SES nearly entirely mediated the family SES by science interest interaction.³ The $\log\text{GDP}$ by science interest interaction persisted at close to full strength in this model.

Distinguishing Interest-by-SES Interactions from Nonlinear Effects and “Expectancy-by-Value” Interactions

Nagengast and Marsh (2012) previously reported a nonlinear relation between science interest and science achievement in this dataset. Nagengast et al. (2011) previously reported that science interest and science self concept interacted in the prediction of science motivation (as indexed by enrollment in extra curricular activities and career aspirations) in this dataset. To distinguish the SES by science interest and GDP by science interest interactions reported above from these previous findings, we added a quadratic term for

³In a follow up multiple group model that included terms for both family SES by science interest and school SES by science interest interactions, the countries with moderate to large (effect > .030 for both forms of scaling) family SES by science interest interactions unique of school SES were Latvia, Sweden, Liechtenstein, Poland, Denmark, the United Kingdom, and New Zealand. For these countries, school SES did not entirely mediate the family SES by science interest interaction.

interest, a quadratic term for SES, a main effect of science self concept, and a science interest by science self concept interaction to our model. Results from this model (Model 3) were very similar to those for Model 2. The school SES by science interest and the logGDP by science interest interactions persisted at close to full strength.

Examining Other Country-Level Social and Economic Indices

We found strong positive correlations between the science interest parameter and democracy index ($r = .574$), R&D expenditures ($r = .625$), social justice ($r = .505$), and social coherence ($r = .625$). The results were less consistent for the Gini index ($r = .296$) and access to education ($r = .228$), which were the two indices that were not strongly correlated with logGDP ($r = .259$ and $r = .274$, respectively). Because of their high multicollinearity with logGDP, we examined the contribution of each of these six indicators that was shared and unique of that of logGDP to between country variance in interest achievement associations through commonality analysis. We chose commonality analysis rather than common factor analysis because we were interested in examining both common and unique effects of each predictor. In this analysis, the regression coefficients on interest from the multiple group model described earlier were specified to be the dependent variable (see Table S4). Results indicated that logGDP, but not the other six country level indicators, had a strong *unique* influence on the country specific interest knowledge association. Variance that logGDP shared with R&D, social coherence, social justice, and the democracy index, each explained over 30% of the variance in the interest parameter.

Discussion

Previous research on the predictors of science achievement has routinely highlighted roles for both interest and socioeconomic opportunity. Crucially, however, few researchers have examined interactions between these factors. We examined whether differences in family SES, school SES, and national GDP were associated with the magnitude of the association between high schoolers' science interest and their science achievement. Our rationale was that in higher socioeconomic contexts, individuals have greater opportunity to select, evoke, and attend to scientific educational opportunities, whereas in deprived contexts, the process by which students transform their science interest into actual science knowledge is disrupted. Consistent with this prediction, we found evidence for an interaction between science interest and family SES in the prediction of science achievement, which was nearly entirely mediated by an interaction between science interest and school SES. Moreover, we found considerable evidence for an interaction between individual science interest and national GDP in the prediction of science achievement. The magnitude of the person by nation interaction was outstandingly large. The correlation between logGDP and the magnitude of the interest achievement association was .753. In economically prosperous nations, the association between science interest and science knowledge was approximately .35, but in poorer economies, there was essentially no relation between interest in science and science performance. Thus at both the intra national and inter national levels, the joint effect of individual science interest and macro environmental opportunity on scientific knowledge is greater than the sum of the individual effects.

Nagengast and colleagues (2011) originally reported that science interest and science self concept interact in the prediction of science motivation, an “expectancy $\times$ value” interaction. We found that this interest by self concept interaction also holds in the prediction of science achievement. It was conceivable, that the interest by School SES interaction that was a main focus of the current report was an epiphenomenon of “expectancy $\times$ value” interaction (e.g., it is possible that SES is positively associated with academic concept, and it is self concept that is the true moderator). However, we found that the interest by school SES interaction persisted at close to full strength after the addition of the interest by self concept interaction to the model. In fact, the interest by school SES interaction was approximately double the magnitude of the interest by self concept interaction.

Strengths, Limitations and Future Directions

The current study has a number of important strengths. An extremely large sample was used with subgroups that were representative of 57 countries. This allowed for precise effect size estimates, even for cross level interactions. Further, the science achievement outcome was well validated psychometrically and is often used as the gold standard for international comparisons (e.g., Friedman, 2013; Hanushek, 2014). However, our study also has some limitations that are important to discuss.

One major limitation is that the current study is based entirely on correlational data from students at one point in time. For instance, from the current results alone, it is not possible to determine whether SES moderates a causal effect of science interest on science achievement, or a causal effect of science achievement on science interest. Importantly, however, the current project is preceded by a number of longitudinal studies in single nations, demonstrating evidence for cross lagged effects of interest, and related motivational factors, on later achievement (Marsh & Martin, 2011; Marsh & O'Mara, 2008; Marsh et al., 2005). Thus, the interest achievement associations documented here are likely to at least partially represent directional effects of interest on knowledge acquisition.

The issue of direction of causation also applies to the cross national results. We hypothesized that interest achievement associations would be stronger in higher GDP countries because national prosperity allows countries to provide more educational opportunities for individuals to pursue their science interest. However, it is also possible that countries with stronger interest achievement associations (for instance because of strong cultural emphases on allowing children to pursue their educational interests) become more prosperous over time as a result, for instance, of higher levels of achievement.

An additional limitation concerns the nature of the school SES effect. We found that family SES by science interest interactions, previously reported in the literature (e.g. Tucker Drob & Briley, 2012) were nearly entirely mediated by school SES by science interest interactions. This finding indicates that, in a statistical sense, disadvantage at the school level is the driving force behind family SES by science interest interactions. However, the precise mechanism underlying this school SES effect is unknown. School SES effects may reflect effects of peer composition on individual achievement processes, or because a school's budget may be directly or indirectly linked to the average SES of its student body it may reflect effects of educational resources (e.g. class size, teacher quality, and availability

of books, supplies, and technology) on individual achievement processes. It is also possible that school SES effects are driven by familial processes. For example, it is possible that parents who choose to live in higher income school districts or choose to send their children to higher resource schools provide their children with greater extracurricular opportunities for science learning, even holding family SES constant.

Future research would do well to test proximal mechanisms by which national, school, and family socioeconomic economic opportunity might facilitate person driven learning processes. For example, what national policies and resources allow wealthy countries to better facilitate the transformation of scientific interest into knowledge? A better understanding of the process of how social and economic contexts influence psychological development is crucial to informing policies to promote science achievement and technological competitiveness.

Broader Implications

Finally, it is important to discuss the implications of these striking cross national differences in effect sizes for psychological research more generally. Much psychological research is conducted in positively selected samples (Sears, 1986) from the United States and Western Europe, and may therefore not generalize to less fortunate individuals and individuals living in less wealthy nations. Indeed, a well cited meta analysis (Schiefele, Krapp, & Winteler, 1992) placed the magnitude of the science interest achievement associations at .35, which is nearly identical to that documented for the wealthiest nations in the PISA sample. Although it may be tempting to interpret meta analytic estimates as highly generalizable, the current results suggest that such results may not at all generalize to individuals situated within lower socioeconomic contexts, where interest achievement associations are essentially non existent. Thus the current results add to the growing body of evidence (Heinrich, Hein, & Norenzayan, 2010; Klein et al, 2014) indicating that substantial heterogeneity in psychological effect sizes is not simply a logical possibility, but in many cases an empirical reality.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

- Altonji, JG.; Mansfield, RK. The role of family, school, and community characteristics in inequality in education and labor market outcomes.. In: Duncan, GJ.; Murnane, RJ., editors. *Wither opportunity?*. Russell Sage Foundation; New York: 2011. p. 339-358.
- Bradley RH, Corwyn RF. Socioeconomic status and child development. *Annual Review of Psychology*. 2002; 53:371–399.
- Cattell, RB. *Abilities: Their Structure, Growth, and Action*. Houghton Mifflin; Boston, MA: 1971.

- Coleman, JS. Equality of Educational Opportunity. U.S. Government Printing Office; Washington, D.C.: 1966.
- Eccles JS, Wigfield A. Motivational beliefs, values, and goals. *Annual Review of Psychology*. 2002; 53:109–132. doi: 10.1146/annurev.psych.53.100901.135153.
- Fredricks JA, Eccles JS. Children's competence and value beliefs from childhood through adolescence: Growth trajectories in two male-sex-typed domains. *Developmental Psychology*. 2002; 38:519–533. doi: 10.1037/0012-1649.38.4.519. [PubMed: 12090482]
- Friedman, TL. Can't we do better?. *The New York Times*; Dec 7. 2013 p. SR11
- Hanushek EA. Why the U.S. results on PISA matter. *Education Week*. 2014; 33:20–21.
- Henrich J, Heine SJ, Norenzayan A. The weirdest people in the world? *Behavioral and Brain Sciences*. 2010; 33(2-3):61–83. [PubMed: 20550733]
- Hulleman CS, Harackiewicz JM. Promoting interest and performance in high school science classes. *Science*. 2009; 326:1410–1412. doi: 10.1126/science.1177067. [PubMed: 19965759]
- Jacobs, JE.; Eccles, JS. Parents, task values, and real life achievement related choices.. In: Sansone, C.; Harackiewicz, JM., editors. *Intrinsic motivation*. Academic Press; San Diego, CA: 2000. p. 405-439.
- Kekic, L. [December 30, 2011] The Economist Intelligence Unit's Index of Democracy.. The World in 2007. 2007. from http://www.economist.com/media/pdf/DEMOCRACY_INDEX_2007_v3.pdf
- Klein, RA.; Ratliff, K.; Nosek, BA.; Vianello, M.; Pilati, R.; Devos, T.; Galliani, EM., et al. Investigating variation in replicability: The “Many Labs” Replication Project. 2014. Retrieved from Open Science Framework, <https://osf.io/wx7ck/files/ManyLabsManuscript.pdf/>
- Knudsen EI, Heckman JJ, Cameron JL, Shonkoff JP. Economic, neurobiological, and behavioral perspectives on building America's future workforce. *Proceedings of the National Academy of Sciences of the United States of America*. 2006; 103:10155–10162. doi: 10.1073/pnas.0600888103. [PubMed: 16801553]
- Marsh HW, O'Mara A. Reciprocal effects between academic self concept, self esteem, achievement, and attainment over seven adolescent years: Unidimensional and multidimensional perspectives of self concept. *Personality and Social Psychology Bulletin*. 2008; 34:542–552. doi: 10.1177/0146167207312313. [PubMed: 18340036]
- Marsh HW, Martin AJ. Academic self-concept and academic achievement: Relations and causal ordering. *British Journal of Educational Psychology*. 2011; 81:59–77. doi: 10.1348/000709910X503501. [PubMed: 21391964]
- Marsh HW, Trautwein U, Lüdtke O, Köller O, Baumert J. Academic self-concept, interests, grades, and standardized test scores: Reciprocal effects models of causal ordering. *Child Development*. 2005; 76:397–416. doi: 10.1111/j.1467-8624.2005.00853.x. [PubMed: 15784090]
- Muthén, LK.; Muthén, BO. *Mplus User's Guide*. Muthén & Muthén; Los Angeles, CA: 1998-2012.
- Nagengast B, Marsh HW. Big fish in little ponds aspire more: Mediation and cross-cultural generalizability of school-average ability effects on self-concept and career aspirations in science. *Journal of Educational Psychology*. 2012; 104:1033–1053. doi: 10.1037/a0027697.
- Nagengast B, Marsh HW, Scalas LF, Xu MK, Hau KT, Trautwein U. Who took the “×” out of expectancy-value theory? A psychological mystery, a substantive-methodological synergy, and a cross national generalization. *Psychological Science*. 2011; 22:1058–1066. doi: 10.1177/0956797611415540. [PubMed: 21750248]
- National Science Board. Preparing the next generation of STEM innovators: Identifying and developing our nation's human capital. Arlington, VA: 2010. Retrieved from www.nsf.gov/nsb/publications/2010/nsb1033.pdf
- Organization for Economic Co-operation and Development. Assessing scientific, reading and mathematical literacy: A framework for PISA 2006. Author; Paris: 2006. doi: 10.1787/9789264026407-en
- Organization for Economic Co-operation and Development. PISA 2006: Vol. 2. Data. Author; Paris, France: 2007.
- Organization for Economic Co-operation and Development. PISA 2006 technical report. Author; Paris: 2009.

- Schiefele, U.; Krapp, A.; Winteler, A. Interest as predictor of academic achievement: A meta analysis of research.. In: Renninger, KA.; Hidi, S.; Krapp, A., editors. *The Role of Interest in Learning and Development*. Erlbaum; Hillsdale, NJ: 1992. p. 183-212.
- Schraad-Tischler, D. [December 30, 2011] Social Justice in the OECD – How Do the Member States Compare?. 2011. from http://www.sgi-network.org/pdf/SGI11_Social_Justice_OECD.pdf
- Sears DO. College sophomores in the laboratory: Influences of a narrow data base on social psychology's view of human nature. *Journal of Personality and Social Psychology*. 1986; 51:515.
- Sirin SR. Socioeconomic status and academic achievement. A meta analytic review of research. *Review of Educational Research*. 2005; 75:417–453. doi: 10.3102/00346543075003417.
- The World Bank. GINI Index [Data file]. 2006a. Available from The World Bank Web site, data.worldbank.org
- The World Bank. Research and Development Expenditure (% of GDP) [Data file]. 2006b. Available from The World Bank Web site, data.worldbank.org
- Tucker-Drob EM, Briley DA. Socioeconomic status modifies interest knowledge associations among adolescents. *Personality and Individual Differences*. 2012; 53:9–15. doi: 10.1016/j.paid.2012.02.004. [PubMed: 22711964]
- Tucker-Drob EM, Harden KP. Intellectual interest mediates gene $\times$ socioeconomic status interaction on adolescent academic achievement. *Child Development*. 2012a; 83:743–757. doi: 10.1111/j.1467-8624.2011.01721.x. [PubMed: 22288554]
- Tucker-Drob EM, Harden KP. Learning motivation mediates gene-by-socioeconomic status interaction on mathematics achievement in early childhood. *Learning and Individual Differences*. 2012b; 22:37–45. doi: 10.1016/j.lindif.2011.11.015. [PubMed: 22611326]
- Tucker-Drob EM, Briley DA, Harden KP. Genetic and environmental influences on cognition across development and context. *Current Directions in Psychological Science*. 2013; 22:349–355. doi: 10.1177/0963721413485087. [PubMed: 24799770]
- van Ewijk R, Sleegers P. The effect of peer socioeconomic status on student achievement: A meta-analysis. *Educational Research Review*. 2010; 5:134–150.
- von Stumm S, Ackerman PL. Investment and intellect: A review and meta-analysis. *Psychological Bulletin*. 2013; 139:841–869. doi: 10.1037/a0030746. [PubMed: 23231531]

Figure 1.

Example simple slope plots for countries with varying magnitudes of interactions between SES and interest (columns) and varying magnitudes of main effect of interest (rows) in the prediction of science achievement. Both interest and SES are centered at each country's mean (such that 0 represents the average interest for each country) and is scaled in *SD* units relative to the *SD*'s observed in the United States subsample. Low SES, Average SES, and High SES represent SES = 2, 0, and 2, respectively. Science achievement is z scored relative to the *M* and *SD* observed in the U.S. subsample. Centering predictors within country avoids confounding between country effects for within country effects. Scaling estimates relative to a reference distribution from a single subsample (the United States) allows results to be meaningfully compared across countries.

Figure 2.

Regression of the science interest → science achievement coefficient on Log Per Capita GDP, with 95% confidence interval. Individual country specific datapoints are represented by country names or, when appropriate, red dots (with country named displaced to improve readability). LogGDP (x axis) is scaled relative to between country SD s. Interest achievement associations (y axis) are scaled relative to the SD observed in the US subsample. Scaling estimates relative to a reference distribution from a single subsample (the United States) allows results to be meaningfully compared across countries.

Table 1

Parameter estimates for stepwise models of SES, GDP, science interest, science self-concept and science achievement.

Predictor	Model 1		Model 2		Model 3	
	b [95% CI] scaled relative to U.S. SDs	b [95% CI] scaled relative to Pooled SDs	b [95% CI] scaled relative to U.S. SDs	b [95% CI] scaled relative to Pooled SDs	b [95% CI] scaled relative to US SD's	b [95% CI] scaled relative to Pooled SD's
Main Effects						
Family SES	.278 [.266,.290]	.304 [.292,.316]	.113 [.105,.121]	.124 [.116,.132]	.106 [.098,.114]	.116 [.108,.124]
School SES			.242 [.226,.258]	.296 [.278,.314]	.241 [.225,.257]	.295 [.275,.315]
LogGDP	.375 [.353,.397]	.375 [.353,.397]	.363 [.343,.383]	.363 [.343,.383]	.355 [.335,.375]	.354 [.334,.374]
Interest	.167 [.155,.179]	.149 [.139,.159]	.183 [.173,.193]	.163 [.155,.171]	.161 [.151,.171]	.144 [.134,.154]
Self-Concept					.054 [.042,.066]	.047 [.037,.057]
Quadratic Effects						
Family SES ²						
Interest ²					-.032 [-.038,-.026]	-.039 [-.047,-.031]
					-.017 [-.025,-.009]	-.013 [-.019,-.007]
Within Country Interactions						
Interest × Self-Concept					.030 [.020,.040]	.024 [.016,.031]
Interest × Family SES	.044 [.036,.052]	.044 [.036,.052]	.009 [.001,.017]	.009 [.001,.017]	.009 [.001,.017]	.009 [.001,.017]
Interest × School SES			.050 [.040,.060]	.055 [.043,.067]	.046 [.036,.056]	.050 [.038,.062]
Person-by-Nation Interaction						
Interest × LogGDP	.095 [.081,.109]	.085 [.073,.097]	.083 [.071,.095]	.074 [.064,.084]	.081 [.069,.093]	.072 [.060,.084]

All predictors that varied within country were centered at within country. LogGDP was standardized relative to its between-country *M* and *SD*. All models used the complex survey of *Mplus* to account for the nonindependence of observations due to nesting of data across three levels of analysis (individuals, schools, and nations).