**Nonlinear Relations Between Achievement and Academic Self-Concepts in
Elementary and Secondary School: An Integrative Data Analysis Across 13 Countries**

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Abstract

It is well-documented that academic achievement is associated with students' self-perceptions of their academic abilities, that is, their academic self-concepts. However, low-achieving students may apply self-protective strategies to maintain a favorable academic self-concept when evaluating their academic abilities. Consequently, the relation between achievement and academic self-concept might not be linear across the entire achievement continuum. Capitalizing on representative data from three large-scale assessments (i.e., TIMSS, PIRLS, PISA; $N = 470,804$), we conducted an integrative data analysis to address nonlinear trends in the relations between achievement and the corresponding self-concepts in mathematics and the verbal domain across 13 countries and two age groups (i.e., elementary and secondary school students). Polynomial and interrupted regression analyses showed nonlinear relations in secondary school students, demonstrating that the relations between achievement and the corresponding self-concepts were weaker for lower achieving students than for higher achieving students. Nonlinear effects were also present in younger students, but the pattern of results was rather heterogeneous. We discuss implications for theory as well as for the assessment and interpretation of self-concept.

Keywords: academic achievement, academic self-concept, mathematics, reading, nonlinear relations

Educational Impact and Implications Statement

The present study significantly advances the understanding of how performance on a standardized achievement test in a certain academic domain is related to students' corresponding academic self-concept. In representative student samples, we show that the relations between achievement and self-concepts in mathematics and the verbal domain can be better approximated by nonlinear relations, demonstrating weaker relations for lower achieving students than for higher achieving students in secondary school (and to some extent also in elementary school). Practitioners should be aware that there is no general linear trend between students' achievement and their corresponding academic self-concepts and should take this into consideration when assessing and interpreting students' academic self-concepts in counseling contexts.

Nonlinear Relations Between Achievement and Academic Self-Concepts in Elementary and Secondary School: An Integrative Data Analysis Across 13 Countries

Students' academic achievement is a major determinant of their academic self-concepts¹ (e.g., Harter, 2012; Marsh, 1986; Marsh & Craven, 2006; Möller, Pohlmann, Köller, & Marsh, 2009; Shavelson, Hubner, & Stanton 1976; Trautwein & Möller, 2016). Typically, researchers implicitly assume linear relations between achievement and self-concepts (e.g., Huang, 2011; Marsh, 1986; Marsh & Hau, 2004; Möller et al., 2009; Möller, Zimmermann, & Köller, 2014; Skaalvik & Rankin, 1992). Linear relations between achievement and self-concepts imply that some constant amount of increase in achievement (e.g., an increase of one standard deviation) is associated with a constant increase in the corresponding self-concept (e.g., an increase of .30 standard deviations) across the entire achievement continuum. However, negative performance feedback can constitute a major threat to the self, which in turn may motivate lower achieving students to engage in self-protective strategies (Alicke & Sedikides, 2009). These self-protective strategies may weaken the potentially damaging effects of negative feedback on lower achieving students' self-concepts (Leary, 2007). Thus, it is likely that lower achieving students have more strongly inflated self-concepts than higher achieving students do. Consequently, linear models might not fully capture the relation between achievement and the corresponding self-concept for a large part of the student body. Rather, the relations between achievement and self-concepts may be better approximated by a nonlinear function that assumes weaker relations for lower achieving students and stronger positive relations for higher achieving students. Although nonlinear relations between achievement and self-concepts seem highly plausible, such relations have rarely been studied empirically. Therefore, the major aim of the present cross-national integrative

¹Unless otherwise indicated, the term "achievement" will be used to indicate "academic achievement" and the term "self-concept" to indicate "academic self-concept" for the remainder of the article.

data analysis was to substantially expand the body of knowledge on the forms of the functional relations between achievement and self-concepts. As a major strength of this study, we tested the generalizability of our hypothesis across domains (i.e., mathematical and verbal), age groups (i.e., elementary and secondary school students), and countries. In addition, we replicated our results in different data sets. To this end, we drew on representative student samples from several cycles of international large-scale assessments: the Trends in International Mathematics and Science Study (TIMSS), the Progress in International Reading Literacy Study (PIRLS), and the Programme for International Student Assessment (PISA). In doing so, the present results allowed us to draw reliable conclusions concerning theory (e.g., for models of self-concept formation) and the assessment and interpretation of self-concepts.

Integrative Data Analysis: A Tool for Enhancing the Robustness and Generalizability of Results

Scientific research is currently facing critical concerns about the replicability of results in many areas of psychology, education, and other fields (e.g., Ioannidis, 2005; Open Science Collaboration, 2015). Because any single study's results are influenced by that study's design, sample, measurement, and quantification of key constructs, we conducted a coordinated analysis to examine consistency in the findings across multiple data sets (Hofer & Piccinin, 2009). In a coordinated analysis—a form of integrative data analysis—several data sets that differ in samples and measures but assess similar constructs are first analyzed by applying an identical analysis protocol. Then, effect sizes are summarized across data sets using meta-analytic techniques to answer a specific research question (see also Graham et al., 2017). Similar to other tools that are used to synthesize research (e.g., meta-analysis or systematic literature reviews), coordinated analysis meets the need for a cumulative approach to scientific inquiry (Curran, 2009; Hunter & Schmidt, 1996; Meehl, 1978). Finally, the particular advantage of a coordinated analysis is that it

can be used to obtain multiple replications from independent data sets to thereby strengthen the confidence, robustness, and generalizability of findings.

Specifically, for the current investigation, we identified eight cycles from three international large-scale assessments that assessed both student achievement and students' self-concepts in mathematics and the verbal domain (i.e., TIMSS, PIRLS, and PISA) to examine the generalizability of nonlinear relations between achievement and the corresponding self-concepts across countries and time. In doing so, we took advantage of having access to individual participant data from representative probability samples of students. This allowed us to examine relations between achievement and self-concepts across the entire range of students' achievement and self-concepts because the data were not affected by range restrictions or selection bias. The present study involves the first integrative data analysis to use representative student data in the areas of student achievement and achievement motivation.

From Tools to Theories: Linear and Nonlinear Relations between Achievement and Self-Concepts

Theories are the starting point of scientific discoveries. Theory informs and guides scientific practices, such as the choice of methods that are applied to investigate a research question. However, theory is also shaped by scientific methods (tools-to-theories heuristic; Gigerenzer, 1991). This is exemplified in an allegory from Eddington (1939; see Cacioppo & Bernston, 1994) in which a hypothetical scientist attempted to determine the size of fish in the sea by sampling catches from a 2-inch net. After extensive fishing, the scientist did not find any fish smaller than 2 inches and therefore concluded that there were no fish smaller than 2 inches in the sea.

How is this allegory aligned with research on the relation between achievement and self-concept? Conducting a literature search in the data bases PsycINFO and ERIC for the term

“academic achievement” in combination with “academic self concept” resulted in a total of 1,229 peer-reviewed academic articles in PsycINFO and 1,005 peer-reviewed academic articles in ERIC published between 2009 and 2019, thus illustrating the large amount of research interest in this topic. Typically, researchers implicitly assume linear relations between achievement and self-concepts across the entire achievement continuum (e.g., Huang, 2011; Marsh, 1986; Marsh & Hau, 2004; Möller et al., 2009, 2014; Skaalvik & Rankin, 1992). In other words, most researchers have applied the “linear net” to study the relations between achievement and self-concepts. For example, a review of all studies ($N = 66^2$) that were included in the two most recent meta-analyses on the relations between achievement and self-concept by Huang (2011) and Möller et al. (2009) revealed that all of these studies analyzed only linear relations between achievement and self-concept. Findings from the vast majority of these studies indicated positive relations between domain-specific achievement tests and corresponding self-concepts. The meta-analysis by Möller et al. (2009) reported a mean path coefficient for the relations between achievement on mathematics tests and mathematics self-concept of $r = .57$, and for the relations between achievement on verbal tests and verbal self-concept of $r = .47$. In the meta-analysis by Huang (2011), the longitudinal correlation between prior achievement (as measured with standardized tests) and subsequent self-concepts ranged from $r = .19$ to $.23$.

Only a few published studies have used the “nonlinear net” when examining the relation between achievement and self-concept. These studies can be grouped by the analytic strategy they applied. The first group of studies examined mean-level differences in self-concepts in relation to achievement differences by splitting the achievement continuum into discrete groups (i.e., low-, average-, and high-achieving students) using planned contrasts, ANOVAs, or

²The coding scheme and the results of the review can be accessed via the Open Science Framework (Soderberg, 2018) at <https://osf.io/9cgzm/>. Of note, one dissertation included in the meta-analysis by Huang (2011) could not be found and was therefore not included in our review.

multigroup comparisons in structural equation models (Möller & Pohlmann, 2010; Prast, Van de Weijer-Bergsma, Miočević, Kroesbergen, & Van Luit, 2018; Schurtz, Pfof, & Artelt, 2014; Van der Beek, Van der Ven, Kroesbergen, & Leseman, 2017). The second group of studies investigated the relation between achievement and self-concept by using polynomial regression analyses (Marsh, 2004; Marsh & Rowe, 1996).

A series of studies by Möller and Pohlmann (2010) and Schurtz et al. (2014) examined the relation between achievement and self-concept in the verbal domain (Möller & Pohlmann, 2010; Schurtz et al., 2014) and in mathematics (Schurtz et al., 2014) by comparing groups of low-, average-, and high-achieving students. Their results provided initial evidence that the strength of the relation between achievement and self-concept varies with students' level of achievement with stronger relations for higher achieving students and lower relations for lower achieving students in German (native language education; Möller & Pohlmann, 2010; Schurtz et al., 2014). However, the findings were heterogeneous for English as a foreign language and for mathematics (Schurtz et al., 2014).

It is important to note that estimates of the strength of a relation between two variables are biased when a continuous variable, such as student achievement, is split into discrete groups (MacCallum, Zhang, Preacher, & Rucker, 2002; Preacher, Rucker, MacCallum, & Nicewander, 2005). This limitation was overcome in the second group of studies that (a) tackled the achievement continuum as a whole and (b) integrated polynomial components into their analyses of the relation between the two constructs (Marsh, 2004; Marsh & Rowe, 1996). In a study that drew on a representative U.S. sample of male students in Grade 10, Marsh and Rowe (1996) found a positive quadratic relation ($\beta = 0.274$) between students' ability (as measured with an ability test) and their general academic self-concept. This indicated that increments in achievement were more strongly related to the self-concept of students with higher ability than to

the self-concept of students with lower ability (Marsh & Rowe, 1996). In a representative Australian sample of 15-year-old students, Marsh (2004) found a positive quadratic relation ($\beta = 0.061$) between general academic achievement (as measured with an achievement test) and general academic self-concept. This finding again implied that the relation between achievement and self-concept was stronger for higher achieving students and weaker for lower achieving students (Marsh, 2004). In the following section, we will present a possible mechanism that may underlie nonlinear relations between achievement and the corresponding self-concepts.

Self-Protection

One major reason for why the relations between achievement and self-concepts might vary as a function of individual student achievement is that being asked to evaluate one's own abilities in self-concept questionnaires may trigger self-protective strategies. When students are asked to evaluate their abilities with items such as "I learn quickly in mathematics" or "Reading is easy for me," they infer their abilities from achievement indicators, such as grades, tests, or other achievement-related feedback (Duckworth & Yeager, 2015; Marsh & Craven, 2006; Möller et al., 2009, 2014), and from social comparisons with their peers (Festinger, 1954; Huguet et al., 2009; Suls, Martin, & Wheeler, 2002; Wheeler & Suls, 2005). Intuitively, one can expect that students with lower achievement in a specific domain should have lower evaluations of their abilities in this domain. However, a negative self-evaluation constitutes a major threat to the self. To protect their self-worth, low-achieving students are likely to engage in self-protective strategies that lead to more positive self-evaluations (Alicke & Sedikides, 2009). Self-protection originates from the assumption that people want to feel good or want to avoid feeling bad about themselves (Alicke & Sedikides, 2011). Self-protective strategies are aimed at avoiding, minimizing, and compensating for negative self-views (Hepper, Gramzow, & Sedikides, 2010). For example, by changing the comparison group (i.e., comparing oneself with groups that have

worse performances in the relevant dimensions; Tajfel & Turner, 1979), having poorer recall of self-threatening feedback than non-self-threatening feedback (Green & Sedikides, 2004), or downplaying the importance of a negative event (Alicke & Sedikides, 2009), students can weaken the negative effect of their low achievement on their corresponding self-concept.

Empirical research has supported these theoretical propositions: In a study by Hacker, Bol, Horgan, and Rakow (2000), university students repeatedly took exams in a course and rated how well they thought they would perform before and after each test. Better performing students were able to increase the accuracy of their predictions as the semester proceeded, whereas poorly performing students showed no increase in their predictions despite the feedback the students received on their exam results (Hacker et al., 2000). Another study compared university students' self-reported grades from the previous semester with their actual grades and found that students with poorer grades overestimated their grades more than students with better grades did (Gramzow, Elliot, Asher, & McGregor, 2003).

Furthermore, there is evidence that from the ages of 8 to 10, children already use self-protective strategies and that the need to use these strategies increases with students' (cognitive) development and life experience: In middle to late childhood, children develop many cognitive skills that enable them to integrate positive and negative information into their self-views (Harter, 2012). At about this age, most children have gathered experience with comparative grading practices and consequently with absolute failure or comparative performance feedback (Stipek & Daniels, 1988). However, achievement-related feedback becomes stricter and more varied in adolescence (Eccles, Midgley, & Adler, 1984). In addition, children's ability to draw social comparisons improves in middle to late childhood (Frey & Ruble, 1990; Harter, 2012; Ruble & Frey, 1990). Moreover, research has suggested that students at higher levels of cognitive maturation should show greater variability in their use of self-protective strategies (e.g., Alicke &

Sedikides, 2011; Harter, 2012). In contrast to children, adolescents possess the cognitive skills that enable them to engage in attributional biases, such as attributing their successes to internal, stable characteristics (e.g., intelligence) and their failures to external factors (e.g., the difficulty of a test; Harter, 2012). Furthermore, adolescents are able to protect their positive self-views by viewing their positive attributes as central and important and their negative characteristics as unimportant to their selves (Harter, 2012).

The Present Study

The overarching goal of the present study was to examine whether relations between achievement and corresponding self-concepts are nonlinear and to what extent the nonlinearity is generalizable across different domains, age groups, and countries. On the basis of theoretical considerations regarding strategies that support a positive self-view (e.g., Alicke & Sedikides, 2009), we expected that the relations between achievement and the corresponding self-concepts would be weaker for lower achieving students and stronger and positive for higher achieving students in the mathematical and verbal domains.

There are a few studies that have empirically supported this prediction to some extent (Marsh, 2004; Marsh & Rowe, 1996; Möller & Pohlmann, 2010; Schurtz et al., 2014). However, these studies have embodied several limitations. First, some of the studies used an analytical approach that can result in biased estimates (i.e., splitting the achievement continuum into discrete groups; Möller & Pohlmann, 2010; Schurtz et al., 2014). We capitalized on two analytical approaches that did not entail this limitation (i.e., quadratic and interrupted regressions). Second, other previous studies examined only general academic achievement and general academic self-concept (Marsh, 2004; Marsh & Rowe, 1996). However, self-concepts are highly domain-specific (e.g., Gogol, Brunner, Martin, Preckel, & Goetz, 2017). Therefore, we examined relations between achievement and self-concepts in mathematics and the verbal

domain. Third, previous research has only investigated the relation between achievement and self-concept in secondary school students (Marsh, 2004; Marsh & Rowe, 1996). Yet, self-evaluations and the use of self-protective strategies are subject to age-related changes (e.g., Eccles et al., 1984; Guay, Marsh, & Boivin, 2003; Harter, 2012; Marsh, 1989, 1990a; Wigfield & Eccles, 2002). Consequently, we examined the functional forms of the relations between achievement and self-concepts in different age groups (i.e., elementary and secondary school students). Fourth, a lesson learned from cross-cultural research is that “universality can never be assumed in advance” (Segall & Lonner, 1988, p. 1103; see also Henrich, Heine, & Norenzayan, 2010). It is not clear to what extent the findings from Australia (Marsh & Rowe, 1996) or the United States (Marsh, 2004) can be transferred to other countries. Thus, in the present study, we set out to examine the relations between achievement and self-concepts across 13 different countries. Fifth, given the current concerns about replicability (e.g., Ioannidis, 2005), we conducted an integrative data analysis (Curran & Hussong, 2009; Hofer & Piccinin, 2009) in which we applied the same analysis protocol to representative high-quality individual student data from three major large-scale assessments. This approach offered the advantage that we did not rely on findings based on a single study but rather integrated results across studies (Open Science Collaboration, 2015). To sum up, the results of the present study will significantly expand the body of knowledge on the functional forms of the relations between achievement and self-concepts in (a) different domains (i.e., mathematical and verbal), (b) age groups (i.e., elementary and secondary school students), and (c) countries.

Method

Samples

We used individual student data from three international large-scale assessments. The TIMSS, PIRLS, and PISA studies are designed and conducted to compare education systems

worldwide and to provide policy makers, educators, researchers, and practitioners with reliable information about trends in mathematics, science, and/or reading achievement and learning contexts over time (Mullis, Martin, Kennedy, Trong, & Sainsbury, 2009; Mullis, Martin, Ruddock, O'Sullivan, & Preuschoff, 2009; Organisation for Economic Co-Operation and Development [OECD], 2013). In TIMSS, students' skills and knowledge in mathematics and science are assessed every 4th year in Grades 4 and 8 (Mullis, Martin, Ruddock et al., 2009). The PIRLS studies assess students' reading skills in Grade 4 every 5th year (Mullis, Martin, Kennedy, et al., 2009), and PISA assesses students' skills and knowledge in the core domains mathematics, reading, and science at the age of 15 every 3rd year (OECD, 2013). In every TIMSS, PIRLS, and PISA cycle, the school staff, students, and parents were informed about the nature of the test and the test date, and parental permission was secured if requested by the school or education system (Martin & Mullis, 2012; OECD, 2002).

Besides assessing students' skills and knowledge, several TIMSS, PIRLS, and PISA cycles measured students' domain-specific self-concepts. In stark contrast to other cycles from these large-scale assessments, the data on achievement and self-concepts in both the mathematical and verbal domains were collected from the same students in TIMSS/PIRLS 2011 (fourth-graders) and in PISA 2000 (15-year-olds). In other words, each student provided both mathematical and verbal data. Using the same samples of students when analyzing the domain-specificity of the relation between achievement and the corresponding self-concept measure ensured that the respective relations could only be influenced by the domain (mathematical or verbal) because other potentially confounding, person-related factors (e.g., socioeconomic background, cognitive ability, cohort membership) were controlled for. Given this strength of the data, we selected the countries that participated in the TIMSS/PIRLS 2011 cycle and the PISA 2000 cycle for our analyses (see Table 1). On the basis of this selection criterion, Romania would

also have been included in the present analyses. However, preliminary analyses indicated severe problems with the PISA 2000 data such that there was a highly implausible relation between mathematics achievement and mathematics self-concept in Romania of $r = .00$. We therefore excluded the data from Romania from the present analyses.

To replicate our results, we additionally included the following assessment cycles in which both achievement and self-concept were measured in either mathematics or the verbal domain. We added cycle 2015 for TIMSS, cycle 2016 for PIRLS, and cycles 2003 and 2012 for PISA (covering the mathematics domain) to our analyses. In PISA 2000, a mathematics achievement score was provided for (a random subsample of) 56% of the students in the public use file. This resulted in a smaller number of students compared with the other PISA cycles where a mathematics achievement score was provided for all students. Only eight (out of 13) countries participated in the TIMSS assessment for Grade 8 in 2011 and 2015 (see Table 1). Austria did not participate in the TIMSS 2015 Grade 4 assessment. Because PISA assessed students' self-concept in the verbal domain in the year 2000 cycle only, it was not possible to replicate these results. Finally, some information on students' gender was missing. In sum, 328 students were excluded from the analyses because information on their gender was missing (most of these cases came from PISA 2000 from which 239 students were excluded).

TIMSS, PIRLS, and PISA capitalize on a two-stage stratified sampling design to achieve representative probability samples (a detailed description of the sampling procedures can be found in the supplemental online materials [SOM], which can be accessed via the Open Science Framework (Soderberg, 2018) at <https://osf.io/9cgzm/>). All in all, our analyses were based on representative student samples comprising data from a total of 470,804 students in 23,307 classes or schools in which 50% of the students were female, and the mean age ranged from 10.30 years (TIMSS/PIRLS 2011, Grade 4) to 15.78 years (PISA 2003; see Table 1). Sample sizes,

percentages of female students, and numbers of participating schools and classes for each assessment cycle and each country can be found in Tables S1 and S2 in the SOM. Students' mean age in every assessment cycle is shown in Tables S3 to S10 in the SOM.

Measures

Achievement. Student achievement in mathematics and reading was measured with the standardized tests used in the respective TIMSS, PIRLS, and PISA assessments. In Grade 4, the TIMSS mathematics assessment contained the content domains number, geometric shapes and measure, and data display; in Grade 8, the assessment covered the domains number, algebra, geometry, and data and chance (Mullis, Martin, Ruddock, et al., 2009; Mullis & Martin, 2013). The PIRLS assessment framework focused on the two overarching purposes for reading in Grade 4: literary experience, and acquiring and using information (Mullis & Martin, 2015; Mullis, Martin, Kennedy, et al., 2009). In PISA cycles 2003 and 2012, mathematical content knowledge was assessed in four categories: change and relationships, space and shape, quantity, and uncertainty and data (OECD, 2003, 2013). In PISA 2000, the assessment covered just two categories: space and shape, and change and relationships. Reading literacy was assessed in three different categories in PISA: the abilities to access and retrieve information, integrate information and interpret texts, and reflect upon and evaluate texts (OECD, 2000).

The achievement assessments in TIMSS, PIRLS, and PISA were designed to pursue different goals: Whereas the TIMSS and PIRLS assessments are classroom- and curriculum-based, PISA focuses on literacy concepts, that is, students' abilities to apply their skills and knowledge in mathematics and reading to everyday life problems. Thus, at least for mathematics, for which secondary school students are tested in both PISA and TIMSS (Grade 8), PISA is considered a more challenging assessment (e.g., Else-Quest, Hyde, & Linn, 2010).

In all TIMSS, PIRLS, and PISA assessments, the achievement scores for mathematics and reading were scaled to have an international mean of 500 points and a standard deviation of 100 points (Martin, Mullis, & Hooper, 2016, 2017; OECD, 2014). All achievement scales underwent extensive field testing before being implemented in the respective assessments (Martin et al., 2016, 2017; OECD, 2014). Means and standard deviations for the achievement measures from all countries and assessments are reported in Tables S3 to S10 in the SOM. Table 2 shows the median reliability of mathematics and reading achievement and self-concept scales in each assessment. The reliabilities were satisfactory in all assessment cycles in all participating countries. The reliabilities of the achievement and self-concept scales in each country can be found in Tables S11 to S14 in the SOM.

To estimate students' achievement scores, TIMSS, PIRLS, and PISA used plausible values. Plausible values are representations of the range of abilities a student may reasonably have. Hence, TIMSS, PIRLS, and PISA estimated probability distributions for each student's true achievement score. Applying plausible values offers the methodological advantage of unbiased estimates of population parameters (e.g., means and standard deviations). Overall, TIMSS, PIRLS, and PISA provided five plausible values for each achievement scale.

Academic self-concept. To assess students' self-concepts in mathematics (TIMSS, PISA) and reading (PIRLS) or the verbal domain (PISA), students used 4-point rating scales to provide answers in all assessments with higher scores indicating a higher self-concept in the respective domain. The mathematics and verbal self-concept items used in the TIMSS, PIRLS, and PISA assessments rely on established items whose wordings were identical or similar to well-established and researched questionnaires such as the Self-Description Questionnaire (SDQ; e.g., Marsh, 1990b; Byrne, 1996, 2002; Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2006): e.g., "I learn quickly in [domain]" (used in the SDQ II), "I get good marks in [domain]," "I learn

[domain] quickly” (used in PISA 2000, 2003, 2012), or “I usually do well in [domain]” (used in PIRLS 2011, 2016; TIMSS 2011, 2015). All self-concept scales underwent extensive field testing before being implemented in the respective assessments (Martin et al., 2016, 2017; OECD, 2014). To create scale scores, the ratings for the single self-concept items were averaged. The reliabilities for all the TIMSS, PIRLS, and PISA self-concept scales were consistently satisfactory in all cycles and across all participating countries (see Tables S11 to S14). Means, standard deviations (Tables S3 to S10), item wording, and response scales (Tables S15 to S18) can be found in the SOM.

Data Analysis

As to be expected in any (large-scale) study, there were some missing data. Specifically, 4% to 8% of the self-concept data were missing in each sample, with one exception of 37% missing from PISA 2012 because students’ responses were missing by design in this cycle (OECD, 2014). The country-specific percentage of missing information in each assessment and cycle can be found in Tables S3 to S10 in the SOM. Missing data in students’ self-concepts were handled by applying nested multiple imputation (e.g., Weirich, Haag, Hecht, Böhme, Siegle, & Lüdtke, 2014) using the R package “miceadds” (version 2.14-26; Robitzsch, Grund, & Henke, 2018). For each plausible value representing students’ achievement, we imputed the missing self-concept data five times, yielding 25 nested imputations for every data set. We imputed the missing data in students’ self-concepts separately for female and male students because research has shown that female students typically report higher self-concepts in the verbal domain but lower self-concepts in mathematics in comparison with their male counterparts (e.g., Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002; Marsh & Yeung, 1998; Skaalvik, & Skaalvik, 2004). All analyses on the relation between achievement and self-concept in this study were computed

25 times, and then the results were integrated using standard procedures to obtain an average estimate as well as corresponding standard errors (Martin et al., 2016, 2017; OECD, 2014).

We conducted an integrative data analysis (see Curran & Hussong, 2009; Hofer & Piccinin, 2009) where we applied the same analysis protocol to investigate the functional forms of the relations between achievement and self-concept in mathematics and the verbal domain. Specifically, we proceeded in two ways. First, we ran domain-specific regression models for every country in every assessment and every cycle with achievement in mathematics or reading as the predictor variable and mathematics or reading/verbal self-concept as the outcome variable. The linear model specified a linear relation between achievement and self-concept; the quadratic model specified a nonlinear relation and included a linear term and a quadratic term. To analyze the regression models, we used the statistical software R (version 3.5.1; R Core Team, 2018) and the R package “BIFIEsurvey” (version 2.18-6; BIFIE, 2018). Before computing the regression models, we standardized ($M = 0.00$, $SD = 1.00$) students’ achievement and self-concept scores around each country mean in every TIMSS, PIRLS, and PISA cycle, respectively. In doing so, we (a) facilitated the comparison of regression parameters between achievement and self-concept scales across assessments and (b) removed nonessential multicollinearity, that is, the multicollinearity between a variable and the higher order function of the same variable (here: achievement) that exists merely because of the scaling (nonzero mean) of the variable (Cohen, Cohen, West, & Aiken, 2003). To evaluate the significance of the linear and quadratic regression coefficients, we computed 95% confidence intervals (CIs). If the 95% CI did not contain 0, the changes in achievement were interpreted as significantly related to changes in the corresponding self-concept (Cohen et al., 2003). The regression coefficients for single countries and cycles can be found in Tables S19 to S23 in the SOM.

Second, we ran interrupted regressions using the two-lines test (Simonsohn, 2018) with the R packages “mgcv” (version 1.8-24; Wood, 2017) and “survey” (version 3.34; Lumley, 2004) for every assessment and cycle. We used the interrupted regressions to explore other possible nonlinear trends apart from quadratic effects between students’ domain-specific achievement and the corresponding self-concept. In the two-lines test, an interrupted regression for low and high achievement scores is estimated by dividing the achievement continuum into two segments (Figure 1a). The breakpoint between segments is determined by the so-called Robin Hood algorithm, which maximizes the precision with which the regression parameters β_1 and β_2 are estimated. β_1 and β_2 describe the linear relation between achievement and self-concept within each segment, respectively. To this end, the algorithm allocates the observations between the two segments such that the standard errors of the regression parameters β_1 and β_2 are minimized without changing the values of β_1 and β_2 too much (Simonsohn, 2018). If β_1 and β_2 are equal, this would argue for a linear relation between achievement and the corresponding self-concept. Consequently, if β_1 and β_2 are not equal (e.g., β_1 is notably smaller than β_2), this would argue for a nonlinear relation between the two constructs. The breakpoint is particularly important for the latter case. Because the distribution of students’ achievement can be well-approximated by a (standard) normal distribution within each country (Figure 1a), we can estimate the proportion of students for which a single linear regression coefficient does not fully capture the relation between achievement and the corresponding self-concept. To provide a conservative estimate, we computed the proportion such that it represented the students whose achievement scores were located in the segment with fewer observations below or above the breakpoint, respectively. To this end, we computed the proportion of students under a standard normal distribution who had achievement scores below the breakpoint if the breakpoint was less than or equal to 0. For example, a breakpoint of $z = -1.04$ (as depicted in Figure 1a) suggests that for about 15% of the

students, the relation between achievement and self-concept was not accurately represented by a single linear regression coefficient. If the breakpoint was greater than 0, we computed the proportion of students under a standard normal distribution who had achievement scores above the breakpoint.

For both analytic strategies, we used meta-analytic techniques to integrate the results across 13 countries and several cycles for each domain and student group (i.e., Grade 4, Grade 8, 15-year-olds), respectively. In accordance with the analysis strategy proposed by Cheung and Jak (2016) for big data, we proceeded in two steps. First, we analyzed the individual student data according to the detailed TIMSS, PIRLS, and PISA guidelines for statistical analyses on how to apply population weights, compute standard errors, and compute regression coefficients with plausible values as achievement indicators (Martin & Mullis, 2012; OECD, 2014). Second, to obtain a single estimator within each student group (Grade 4, Grade 8, 15-year-olds), we computed weighted mean regression coefficients across countries (see Tables S19 to S23 and S29 to S33 in the SOM). To this end, we used three-level random-effects models with maximum likelihood estimation to account for the dependencies between regression coefficients when the regression coefficients were obtained for several cycles within countries (i.e., in TIMSS, PIRLS, PISA mathematics). Because verbal self-concepts were only measured in one PISA cycle (PISA 2000), there was no dependency in regression coefficients within countries. Thus, we conducted a two-level random-effects model with maximum likelihood estimation in this case. We applied random-effects models to allow the true effect to vary between (and within) countries (Borenstein, Hedges, Higgins, & Rothstein, 2009; Cheung, 2015). For the three-level random-effects models, estimates of the variability in the regression coefficients defined Level 1. Level 2 captured variability in regression coefficients between assessment cycles within countries, and Level 3 captured variability in regression coefficients between countries. For the two-level

random-effects model, Level 1 captured the estimates of the variability in the regression coefficients, and Level 2 captured the variability in regression coefficients between countries. We used the R package “metaSEM” (version 1.2.2; Cheung, 2015) to analyze the two- and three-level random-effects models.

We computed three statistics to assess the heterogeneity of the effect sizes: I^2 , τ , and Q (Borenstein et al., 2009). Higgins and Thompson’s (2002) measure of heterogeneity I^2 represents the proportion of observed heterogeneity that is real and not due to random noise. I^2 has a range of 0% to 100%, such that 30% to 60% may represent moderate heterogeneity, 50% to 90% may represent substantial heterogeneity, and 75% to 100% may represent considerable heterogeneity (Higgins & Green, 2011; Higgins & Thompson, 2002). In our study, I^2_{Level2} captured the heterogeneity between cycles within countries, I^2_{Level3} captured the heterogeneity between countries, and I^2_{total} captured the total heterogeneity (i.e., the sum of I^2_{Level2} and I^2_{Level3}). We also report the standard deviation of the regression coefficients τ (see Borenstein et al., 2009) to estimate heterogeneity in regression coefficients between cycles within countries (τ_{Level2}) and between countries (τ_{Level3}) plus the total heterogeneity (τ_{total} ; $\tau_{\text{total}} = \sqrt{\tau_{\text{Level2}}^2 + \tau_{\text{Level3}}^2}$). Finally, the Q test statistic (introduced by Cochran, 1954) is computed by summing the squared deviations of each individual effect size estimate from the corresponding overall (average) effect estimate where individual effect sizes are weighted by their sampling variance (Huedo-Medina, Sánchez-Meca, Marín-Martínez, & Botella, 2006). A statistically significant Q value indicates effect size heterogeneity (Borenstein et al., 2009).

All figures were produced using the R package “ggplot2” (version 3.1.0; Wickham, 2009). The R code for reproducing the results and figures from the present study can be accessed via the Open Science Framework (Soderberg, 2018) at <https://osf.io/9cgzm/>.

Results

Linear and Quadratic Regressions

Mathematics. Figure 2 displays the standardized linear and quadratic relations between mathematics achievement and mathematics self-concept. The results obtained for the linear model indicated that math achievement and self-concept were positively related for students in Grades 4 and 8 and for students at age 15: The higher students' achievement, the higher their corresponding self-concept.³

The results obtained for the quadratic model showed significant quadratic relations between achievement and self-concept in mathematics across countries. As shown in Figure 2, we observed positive quadratic relations in the group of 15-year-old students (mean $\beta = 0.12$, 95% CI [0.10, 0.14]) and Grade 8 students (mean $\beta = 0.12$, 95% CI [0.08, 0.15]), implying that the increase in students' mathematics self-concept was weaker for lower achieving students than for higher achieving students. Importantly, these quadratic relations were found across cycles and countries with very few exceptions (1 in 39 cases *ns* for PISA and 2 in 16 *ns* for TIMSS; Figures 2 and 3). The linear and quadratic terms demonstrated significant heterogeneity (Tables 3).

In younger students, the mean quadratic relation between mathematics achievement and mathematics self-concept was positive (mean $\beta = 0.04$, 95% CI [0.03, 0.06]). Similar to the group of older students, this indicated that the increase in students' mathematics self-concept in Grade 4 was lower for lower achieving students than it was for higher achieving students. However, across countries, positive quadratic relations were found less consistently for younger students than for older students; in 13 out of 25 cases, the quadratic relations were significant (see Table

³ In line with previous research (e.g., Marsh, 1986), in almost all countries, male students reported a higher self-concept in mathematics than female students did, whereas female students reported a higher self-concept in the verbal domain than male students did. The addition of students' gender as a predictor of their domain-specific self-concept did not change the functional forms of the relations between achievement and the corresponding self-concepts. Results of the linear and quadratic regression models when controlling for students' gender are presented in Tables S24 to S28 in the SOM.

S19 in the SOM). Heterogeneity analyses indicated significant heterogeneity in the linear and quadratic relations for students in Grade 4 (Table 3).

Verbal domain. Figure 4 shows the standardized linear and quadratic relations between reading achievement and reading self-concept for students in Grade 4 and between reading achievement and verbal self-concept in 15-year-olds. The direction of the quadratic relations differed between younger and older students. Whereas the average quadratic relation between reading achievement and verbal self-concept was significantly positive in the group of 15-year-olds (mean $\beta = 0.05$, 95% CI [0.03, 0.07], Figure 4), it was significantly negative in Grade 4 (mean $\beta = -0.02$, 95% CI [-0.03, -0.01]). For 15-year-old students, reading achievement was more strongly related to verbal self-concept for higher achieving students than for lower achieving students. The negative quadratic relation found in younger students implied that reading achievement and self-concept were to some extent more strongly related for lower achieving students than for higher achieving students.

Across countries, in the group of 15-year-olds, 6 out of 13 quadratic relations were significant. For fourth-graders, 5 out of 26 quadratic relations were significant (Figures 4 and 5, and Tables S22 and S23 in the SOM). For both fourth-graders and 15-year-olds, we observed significant heterogeneity in the linear and quadratic relations (Table 4).

Interrupted Regressions and Two-Lines Tests

Mathematics. The results from the interrupted regression models for 15-year-olds revealed that mathematics achievement was not significantly related to mathematics self-concept for lower achieving students, but the relation was significantly positive for higher achieving students (mean $\beta_1 = 0.03$, 95% CI [-0.01, 0.07]; mean $\beta_2 = 0.47$, 95% CI [0.41, 0.53]; Figure 1b). This finding held for the vast majority of countries across three assessment cycles (Figure 1b). We observed significant heterogeneity in both regression coefficients (i.e., β_1 and β_2 ; Table 5).

The mean percentage of students for whom a common linear model did not accurately describe the relation between achievement and self-concept in mathematics was 16%.

For students in Grade 8, the relation between achievement and self-concept in mathematics was stronger for higher achieving students than for lower achieving students (mean $\beta_1 = 0.25$, 95% CI [0.08, 0.42]; mean $\beta_2 = 0.58$, 95% CI [0.50, 0.66]; Figure 1b). We observed significant heterogeneity in both regression coefficients (i.e., β_1 and β_2 ; Table 5). In about half of the countries, β_1 (as obtained for lower achieving students) and β_2 (as obtained for higher achieving students) were both positive; in the other half of the countries, β_1 was close to zero, but β_2 was positive. The mean percentage of students for whom a single linear regression coefficient did not fully capture the relation between achievement and self-concept in mathematics was 12%.

For Grade 4, the achievement-related increase in mathematics self-concept was on average almost identical in magnitude for higher and lower achieving students (mean $\beta_1 = 0.32$, 95% CI [0.26, 0.39]; mean $\beta_2 = 0.34$, 95% CI [0.29, 0.38]; Figure 1b). This implied that the achievement-related increase in self-concept did not vary across the achievement distribution for students in Grade 4. Both regression coefficients exhibited significant heterogeneity that was entirely located between assessment cycles within countries (Table 5). There were three countries (i.e., Australia, Portugal, and Sweden in TIMSS 2011) in which the relation between mathematics achievement and mathematics self-concept was close to zero for lower achieving students but positive for higher achieving students. For an average of 17% of the students, a common linear model did not accurately describe the relation between achievement and self-concept in mathematics.

Verbal domain. The achievement-related increase in verbal self-concept in 15-year-olds was somewhat stronger for higher than for lower achieving students (mean $\beta_1 = 0.20$, 95% CI [0.14, 0.26]; mean $\beta_2 = 0.32$, 95% CI [0.25, 0.39]; Figure 1b). For some countries, the relation

between reading achievement and verbal self-concept was close to zero for lower achieving students but positive for higher achieving students, whereas in other countries, the relation was positive for both lower and higher achieving students (Figure 1b). Heterogeneity measures showed that the magnitudes of the regression coefficients varied significantly (Table 6). The mean percentage of students for whom a single linear regression coefficient did not fully capture the relation between reading achievement and verbal self-concept was 22%.

The relation between achievement and self-concept in reading was stronger for lower achieving students than for higher achieving students in Grade 4 (mean $\beta_1 = 0.45$, 95% CI [0.42, 0.48]; mean $\beta_2 = 0.27$, 95% CI [0.22, 0.31]; Figure 1b). Heterogeneity measures showed that the magnitudes of β_1 varied significantly, whereas the magnitudes of β_2 did not (Table 6). For an average of 13% of the students, a common linear model did not describe the relation between achievement and self-concept in reading very well. The results for single countries and cycles can be found in Tables S29 to S33 in the SOM.

Discussion

The major aim of the present integrative data analysis was to investigate whether the relations between achievement and self-concept are nonlinear and to what extent the nonlinearity can be generalized across (a) different domains (i.e., mathematics and verbal), (b) different age groups (i.e., elementary and secondary school students), and (c) 13 different countries. Most previous research applied a “linear net” to capture relations between achievement and self-concept measures. Yet, this approach fails to capture potential nonlinear relations between the two constructs and thus might not accurately describe the relations between achievement and self-concepts for a considerable proportion of the student body. In the present integrative data analysis, we capitalized on representative individual student data from eight assessment cycles of three major educational large-scale studies (i.e., TIMMS, PIRLS, PISA) and applied polynomial

and interrupted regression analyses as “nonlinear nets.” Our findings provided strong evidence of nonlinear relations between achievement and self-concepts for students in secondary schools in mathematical and verbal domains. Nonlinear effects were also present in younger students, but the result patterns were rather heterogeneous across countries and applied methods.

Implications for Theories of Self-Concept Formation

For secondary school students, the relations between achievement and the corresponding self-concepts in mathematics and the verbal domain were weaker for lower achieving students than for higher achieving students. This conclusion was supported by the quadratic and interrupted regression analyses. For 15-year-olds in mathematics, the relation between mathematics achievement and mathematics self-concept was even close to zero for lower achieving students but positive for higher achieving students. Importantly, we replicated the positive quadratic relation between achievement and self-concept in mathematics in secondary school students over three (PISA) and two (TIMSS) assessment cycles, underpinning the robustness of our findings (achievement and self-concept in the verbal domain were only assessed once in PISA 2000, and therefore, it was not possible to replicate the effect). Similar nonlinear findings have been reported for the association between global achievement and global academic self-concept for students in Grade 10 and 15-year-olds (Marsh, 2004; Marsh & Rowe, 1996).

One plausible explanation for the finding that lower achieving students’ self-concepts in mathematics and the verbal domain were only weakly related to their corresponding achievement is that lower achieving students are more likely to apply self-protective strategies to prevent the damaging effects of negative performance feedback on their self-views as has been shown, for example, in studies by Gramzow et al. (2003) and Hacker et al. (2000). Besides self-protective motives, students’ self-enhancing motives might also contribute to the nonlinearity between

achievement and the corresponding self-concepts to some extent. For instance, self-enhancing motives might motivate better performing students to increase the positivity of their self-concepts in response to positive performance feedback. However, there is evidence that lower achieving students are more inclined to apply self-serving strategies compared with higher achieving students (e.g., Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001; Gramzow et al., 2003; Hacker et al., 2000). This underscores the plausibility of self-protection as one driving mechanism that leads to nonlinear relations between achievement and self-concepts.

Nonlinear effects were also present in younger students, but the result patterns were rather heterogeneous. On average, we found a positive quadratic relation between achievement and self-concept in mathematics. However, in more than half of the countries, the quadratic regression coefficient was not significant. Further, the interrupted regression analyses indicated that the relations between achievement and self-concept in mathematics were positive and almost identical in magnitude for lower and higher achieving students.

In the verbal domain, we found a negative quadratic relation, indicating that reading achievement and reading self-concept were less strongly related for higher achieving students in elementary school than for lower achieving students. The results from the interrupted regressions confirmed these findings. On the one hand, these findings could support the assumption that there are age differences in nonlinear relations. On the other hand, the nonlinear effects in the verbal domain could differ for younger and older students because younger students were asked to rate their reading self-concept in PIRLS, whereas older students rated their national language class self-concept in PISA. Typically, students do not receive specific grades for their reading performance, but instead they receive a global assessment of their performance in diverse areas of their national language class (e.g., writing, reading, grammar). Because grades are usually the most salient source of performance feedback for students, younger students have probably gained

less comparative feedback experience that they can take into account when evaluating their reading performance. Consequently, we cannot distinguish whether the differences between younger and older students occurred for developmental reasons or due to differences in the assessed constructs (reading vs. verbal self-concept). More research and data in which verbal self-concepts are measured consistently across age groups are needed to answer this question.

In sum, the present results support two major conclusions. First, the results of the present study indicated that a linear regression model could not fully capture the relations between achievement and the corresponding self-concepts in mathematics and the verbal domain for a substantial proportion of the student body in secondary school. Considering the country-specific breakpoints from the interrupted regression analyses, the “substantial proportion” ranged from, on average, 12% (TIMSS, Grade 8) to 22% (PISA, verbal domain) of the students (see Tables S29 to S33). Consequently, it would be advisable to refine current models of self-concept formation that assume that the relations between achievement and self-concepts are solely linear. For example, the internal/external frame of reference model (Marsh, 1986) states that students’ self-concepts are formed by two processes: (a) an external (social) comparison process in which students compare their own achievement in a domain with their classmates’ achievement in the same domain and (b) an internal comparison process in which students compare their own achievement in different domains. For example, to better capture the relation between achievement and self-concept in this model, a quadratic term could be included in the regression of self-concept on achievement in the same domain when modeling the external comparison process.

Second, the findings of the present cross-sectional study were mixed regarding age differences in nonlinear relations between achievement and self-concepts in mathematics and the verbal domain. Given the great heterogeneity in results as observed for elementary school

students, we strongly recommend that nonlinear models also be specified for this student group. By using the “nonlinear net,” researchers will avoid missing any nonlinear relations between achievement and self-concept. Doing so will also improve current theories on self-concept formation because this approach will eventually help to identify the boundary conditions and moderating factors that lead to linear relations for elementary school students in some countries and nonlinear relations in others.

Implications for the Assessment of Self-Concepts

In addition to research contexts, self-concepts are also assessed in guidance and counseling contexts. Our findings showed that lower achieving secondary school students tended to overestimate their academic abilities in mathematics and the verbal domain relative to higher achieving students in these domains. The tendency to overestimate one’s own abilities can introduce a systematic bias when lower achieving students seek guidance or counseling, and school counselors, school psychologists, or teachers make recommendations for their further educational or occupational pathways on the basis of students’ scores on self-concept measures.

In the following, we suggest three methodological approaches that can be applied in practice to derive more nuanced interpretations of students’ scores on self-concept scales. One approach could be to compare a student’s self-reported self-concept with this student’s actual performance (e.g., the student’s grades or his or her achievement of performance benchmarks on tests). Another way could be to estimate students’ tendency to engage in self-protection. This could be done, for example, by measuring how strongly the self-view of a (low-achieving) student diverges from others’ (e.g., classmates’) assessments of this student’s academic abilities in a particular domain (e.g., Krueger & Wright, 2011). A self-protective tendency would be apparent when students evaluated their own abilities more positively than others did. Finally, students’ self-protective tendency could also be measured by using self-report scales that directly

assess students' application of self-protective strategies as suggested, for instance, by Hepper et al. (2010). These self-protection parameters could then be included when interpreting students' observed scores on self-concept scales.

Limitations and Outlook

Although this integrative data analysis significantly expands the body of knowledge on nonlinear relations between achievement and self-concepts in different domains, age groups, and countries, we see three limitations that should be addressed in future research.

Causal mechanisms. We drew on self-protection as the theoretical basis (e.g., Alicke & Sedikides, 2009) for expecting nonlinear relations between achievement and the corresponding self-concepts. However, given the limitations of our study design, we could not conclude that self-protective strategies caused the nonlinear relations found in this study. Other research designs would be needed to do so. If self-protective strategies caused the nonlinear relation between achievement and self-concept, we would expect that experimentally enhancing students' motives to apply these strategies would lead to a stronger degree of nonlinearity between achievement and self-concept. For example, performance feedback is known to activate the motive to apply self-protective strategies (Alike & Sedikides, 2009). Hence, using experimental manipulations, students could be randomly assigned to groups that either receive feedback or do not receive feedback on their actual performance on a standardized achievement test before they evaluate their self-concepts. We would expect the degree of nonlinearity between achievement and self-concepts (as expressed in the quadratic or interrupted regression models) to increase for students in the feedback group because the experimental manipulation has direct consequences for how students evaluate their achievement (e.g., performance feedback [vs. no performance feedback] should intensify the threat to the self for lower achieving students). Another nonexperimental study design that could be applied to approximate the causal mechanism is to

examine how (individual) differences in the application of self-protective strategies as measured with questionnaires (see Hepper et al., 2010) may moderate the functional form between achievement and self-concept.

Further influences on the functional form. By investigating students' self-concepts with data from TIMSS, PIRLS, and PISA, we were bound to the 4-point rating scales that were applied in these large-scale assessments. If a broader rating scale (e.g., a 6- or 7-point rating scale) had been used to measure the self-concepts, it may have been possible to find additional inflection points (e.g., at the high end of the achievement continuum). One possible reason for this is that the number of response categories seems to influence individuals' response behavior (Weijters, Cabooter, & Schillewaert, 2010). For example, Weijters et al. (2010) found that the tendency to choose extreme anchor points on rating scales was reduced when more response categories were added to a rating scale. Future research should investigate the extent to which response format influences the functional form of relations between achievement and corresponding self-concepts. In addition, future studies should take into account possible response styles. For example, a study by Buckley (2009) provided initial evidence that adjusting for students' response biases (acquiescence, disacquiescence, extreme response styles, noncontingent responding) tended to result in stronger nonlinear relations between science achievement and science attitude scales in PISA 2006. Moreover, the anchoring vignette approach is a promising way to control for response style effects (Bolt, Lu, & Kim, 2014; He, Buchholz, & Klieme, 2017) and was first applied in PISA 2012 (Kyllonen & Bertling, 2014; OECD, 2014). However, the anchoring vignette approach for self-concept scales still needs to be refined (e.g., He et al., 2017).

Heterogeneity in effects. Heterogeneity analyses revealed considerable heterogeneity in the linear and quadratic relations as well as in almost all interrupted regression coefficients in all

domains and especially in older students. In particular, even the magnitudes of the linear relations were subject to variation. This may have (at least) two probable reasons. One explanation could be that relations between achievement and self-concept are stronger for some countries (and/or successive student cohorts within countries) than for others because the curriculum in mathematics or the verbal domain better matches the conceptual frameworks defined and measured in PISA, TIMSS, or PIRLS. Another explanation could be that the culture of feedback in the classroom varies across countries (and/or successive student cohorts within countries). For example, countries might differ in the extent to which they emphasize social comparisons versus individualized performance feedback (Lüdtke & Köller, 2002; Lüdtke, Köller, Marsh, & Trautwein, 2005) or in how common it is to apply differentiated instruction (i.e., individually altering students' expectations and goals, varying the complexity of tasks; Roy, Guay, & Valois, 2015). In countries in which teachers provide individualized performance feedback and differentiated instruction, students' achievement and their corresponding self-concepts should be less strongly related than in countries in which teachers foster social comparisons and no differentiated instruction. Until now, little has been known about these cross-cultural variations (or variations within countries that differently affect successive student cohorts), and thus, this topic is an area for future research.

Conclusion

The present study makes three main contributions. First, given the size and representativeness of the applied data and our rigorous integrative data analysis, our results provide strong support for the generalizability of nonlinear relations between achievement and corresponding self-concepts in mathematics and the verbal domain across 13 countries at the secondary school level. Second, in light of the current focus on the replication and reproducibility of research results (e.g., Ioannidis, 2005), we used several PISA, TIMSS, and PIRLS cycles to

replicate our findings. This is of particular importance at this point in time, given the lack of findings that have been replicated in many areas of psychology, educational science, and other fields. Third, the present study advances the current theory in self-concept research. Nonlinear effects between achievement and domain-specific self-concepts have mostly been neglected in previous research (but see Marsh, 2004; Marsh & Rowe, 1996). From a theoretical point of view, the results of the present investigation suggest that models on self-concept formation may be refined by integrating nonlinear effects (e.g., quadratic effects) to better approximate empirical relations between achievement and corresponding self-concepts for all students.

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Table 1

Number of Examined Countries, Sample Sizes, Percentage of Female Students (%F), Number of Participating Classes or Schools, and Students' Mean Age for Individual Assessments and in Total

Assessment	$N_{\text{countries}}$	N	%F	$N_{\text{classes/schools}}$	Age _{mean}
Elementary school students					
TIMSS/PIRLS 2011 (Grade 4)	13 ^a	56,868	49	3,159	10.30
TIMSS 2015 (Grade 4)	12 ^b	55,642	49	3,104	10.38
PIRLS 2016 (Grade 4)	13 ^a	59,586	49	3,305	10.36
Secondary school students					
TIMSS 2011 (Grade 8)	8 ^c	39,317	49	1,990	14.35
TIMSS 2015 (Grade 8)	8 ^d	42,120	50	2,108	14.42
PISA 2000 (15-year-olds)	13 ^a	35,024	51	2,412	15.71
PISA 2003 (15-year-olds)	13 ^a	77,910	50	2,868	15.78
PISA 2012 (15-year-olds)	13 ^a	104,337	49	4,361	15.76
Total	13 ^a	470,804	50	23,307	

Note. In TIMSS and PIRLS, one or more intact classes of students were randomly sampled within randomly selected schools, whereas in PISA, students were randomly sampled within randomly selected schools.

^a Australia, Austria, Czech Republic, Finland, Germany, Hong Kong, Hungary, Ireland, Italy, Norway, Portugal, Russian Federation, Sweden.

^b Austria did not participate.

^c Australia, Czech Republic, Finland, Germany, Hong Kong, Hungary, Ireland, Italy, Norway, Portugal, Russian Federation, Sweden.

^d Australia, Hong Kong, Hungary, Ireland, Italy, Norway, Russian Federation, Sweden.

Table 2

Median Reliabilities (and Range) for Mathematics and Reading Achievement and Self-Concept Scales across the Examined Countries

Assessment	Achievement ^a		Self-concept ^b	
	Mathematics	Reading	Mathematics	Verbal/reading
Elementary school students				
TIMSS/PIRLS 2011(Grade 4)	.82 (.79-.87)	.87 (.81-.89)	.87 (.85-.90)	.72 (.64-.77)
TIMSS 2015 (Grade 4)	.83 (.81-.88)	—	.87 (.84-.89)	—
PIRLS 2016 (Grade 4)	—	.88 (.85-.91)	—	.80 (.72-.82)
Secondary school students				
TIMSS 2011 (Grade 8)	.89 (.83-.91)	—	.91 (.90-.93)	—
TIMSS 2015 (Grade 8)	.89 (.83-.91)	—	.91 (.89-.92)	—
PISA 2000 (15-year-olds)	.81	.89	.87 (.84-.93)	.76 (.66-.82)
PISA 2003 (15-year-olds)	.91 (.88-.93)	—	.89 (.81-.92)	—
PISA 2012 (15-year-olds)	.93 (.91-.94)	—	.89 (.82-.92)	—

Note. In PISA 2000, only averaged reliabilities were reported for the international PISA scales.

^a Reliability estimates were based on item response theory.

^b Reliability was measured as Cronbach's alpha.

Table 3

Meta-Analytic Results for Mathematics: Average Regression Coefficients and Corresponding Heterogeneity Measures (with 95% Confidence Intervals) from the Linear and Quadratic Regression Models for TIMSS and PISA

	Linear model		Quadratic model			
	Linear term		Linear term		Quadratic term	
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Elementary school students						
TIMSS 2011 & 2015 (Grade 4)						
β_{mean}	0.38	[0.35, 0.42]	0.39	[0.36, 0.42]	0.04	[0.03, 0.06]
Q	567.092	***	635.405	***	79.804	***
R^2_{total}	95.45	†††	95.80	†††	68.37	††
R^2_{Level2}	95.45	†††	95.80	†††	62.10	††
R^2_{Level3}	0		0		6.27	
τ_{total}	0.08		0.08		0.03	
τ_{Level2}	0.08		0.08		0.03	
τ_{Level3}	0		0		0.01	
k	25		25		25	
Secondary school students						
TIMSS 2011 & 2015 (Grade 8)						
β_{mean}	0.53	[0.48, 0.58]	0.56	[0.52, 0.61]	0.12	[0.08, 0.15]
Q	374.899	***	275.647	***	97.126	***
R^2_{total}	96.24	†††	94.69	†††	86.04	†††
R^2_{Level2}	0		0		20.99	
R^2_{Level3}	96.24	†††	94.69	†††	65.05	††
τ_{total}	0.08		0.06		0.05	
τ_{Level2}	0		0		0.03	
τ_{Level3}	0.08		0.06		0.05	
k	16		16		16	

(table continues)

Table 3 (Continued)

	Linear model		Quadratic model			
	Linear term		Linear term		Quadratic term	
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
PISA 2000, 2003, & 2012 (15-year-olds)						
β_{mean}	0.37	[0.32, 0.42]	0.38	[0.33, 0.43]	0.12	[0.10, 0.14]
Q	1627.021	***	1573.419	***	154.829	***
I^2_{total}	97.63	†††	97.60	†††	75.82	†††
I^2_{Level2}	46.65	†	42.60	†	18.44	
I^2_{Level3}	50.99	††	55.00	††	57.38	††
τ_{total}	0.11		0.10		0.03	
τ_{Level2}	0.07		0.07		0.02	
τ_{Level3}	0.08		0.08		0.03	
k	39		39		39	

Note. β_{mean} = Average regression coefficient, Q = Cochran's measure of homogeneity (Cochran, 1954), I^2_{total} = Higgins and Thompson's (2002) measure of (total) heterogeneity, I^2_{Level2} = Percentage of the variability in regression coefficients that is due to heterogeneity within countries rather than sampling error; I^2_{Level3} = Percentage of the variability in regression coefficients that is due to heterogeneity between countries rather than sampling error, τ_{total} = Total standard deviation of regression coefficients, τ_{Level2} = Within-country standard deviation of regression coefficients, τ_{Level3} = Between-country standard deviation of regression coefficients, k = number of countries.

† Moderate heterogeneity ($I^2 > 30\%$), †† Substantial heterogeneity ($I^2 > 50\%$), ††† Considerable heterogeneity ($I^2 > 75\%$).

*** $p < .001$.

Table 4

Meta-Analytic Results for the Verbal Domain: Average Regression Coefficients and Corresponding Heterogeneity Measures (with 95% Confidence Intervals) from the Linear and Quadratic Regression Models for PIRLS and PISA

	Linear model		Quadratic model			
	Linear term		Linear term		Quadratic term	
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Elementary school students						
PIRLS 2011 & 2016 (Grade 4)						
β_{mean}	0.44	[0.41, 0.46]	0.43	[0.41, 0.46]	-0.02	[-0.03, -0.01]
Q	248.447	***	244.134	***	57.989	***
I^2_{total}	88.41	†††	88.62	†††	54.48	††
I^2_{Level2}	14.29		12.34		46.42	†
I^2_{Level3}	74.12	††	76.28	†††	8.06	
τ_{total}	0.05		0.05		0.02	
τ_{Level2}	0.02		0.02		0.02	
τ_{Level3}	0.04		0.04		0.01	
k	26		26		26	
Secondary school students						
PISA 2000 (15-year-olds)						
β_{mean}	0.27	[0.23, 0.31]	0.28	[0.24, 0.32]	0.05	[0.03, 0.07]
Q	154.299	***	169.885	***	28.171	**
I^2_{total}	91.99	†††	92.67	†††	53.65	††
τ_{total}	0.07		0.08		0.03	
k	13		13		13	

Note. β_{mean} = Average regression coefficient, Q = Cochran's measure of homogeneity (Cochran, 1954), I^2_{total} = Higgins and Thompson's (2002) measure of (total) heterogeneity, I^2_{Level2} = Percentage of the variability in regression coefficients that is due to heterogeneity within countries rather than sampling error; I^2_{Level3} = Percentage of the variability in regression coefficients that is due to heterogeneity between countries rather than sampling error, τ_{total} = Total standard deviation of regression coefficients, τ_{Level2} = Within-country standard deviation of regression coefficients, τ_{Level3} = Between-country standard deviation of regression coefficients, k = number of countries.

[†] Moderate heterogeneity ($I^2 > 30\%$), ^{††} Substantial heterogeneity ($I^2 > 50\%$), ^{†††} Considerable heterogeneity ($I^2 > 75\%$).

** $p < .01$. *** $p < .001$.

Table 5

Meta-Analytic Results for Mathematics: Average Regression Coefficients and Corresponding Heterogeneity Measures (with 95% Confidence Intervals) from the Interrupted Regressions for TIMSS and PISA

	β_1		β_2	
	Estimate	95% CI	Estimate	95% CI
Elementary school				
TIMSS 2011 & 2015 (Grade 4)				
β_{mean}	0.32	[0.26, 0.39]	0.34	[0.29, 0.38]
Q	160.911	***	37.352	*
I^2_{total}	92.14	†††	41.16	†
I^2_{Level2}	92.14	†††	41.16	†
I^2_{Level3}	0		0	
τ_{total}	0.14		0.05	
τ_{Level2}	0.14		0.05	
τ_{Level3}	0		0	
k	25		25	
Secondary school				
TIMSS 2011 & 2015 (Grade 8)				
β_{mean}	0.25	[0.08, 0.42]	0.58	[0.50, 0.66]
Q	294.514	***	107.031	***
I^2_{total}	98.24	†††	89.41	†††
I^2_{Level2}	46.29	†	67.39	††
I^2_{Level3}	51.94	††	22.03	
τ_{total}	0.28		0.12	
τ_{Level2}	0.19		0.11	
τ_{Level3}	0.20		0.06	
k	16		16	
PISA 2000, 2003, & 2012 (15-year-olds)				
β_{mean}	0.03	[-0.01, 0.07]	0.47	[0.41, 0.53]
Q	84.347	***	1281.493	***
I^2_{total}	52.68	††	97.22	†††
I^2_{Level2}	49.29	†	22.84	
I^2_{Level3}	3.40		74.39	††
τ_{total}	0.08		0.12	
τ_{Level2}	0.08		0.06	
τ_{Level3}	0.02		0.10	
k	39		39	

Note. β_{mean} = Average regression coefficient, Q = Cochran's measure of homogeneity (Cochran, 1954), I^2_{total} = Higgins and Thompson's (2002) measure of (total) heterogeneity, I^2_{Level2} = Percentage of the variability in regression coefficients that is due to heterogeneity within countries rather than sampling error; I^2_{Level3} = Percentage of the variability in regression coefficients that is due to heterogeneity between countries rather than sampling error, τ_{total} = Total standard deviation of regression coefficients, τ_{Level2} = Within-country standard deviation of regression coefficients, τ_{Level3} = Between-country standard deviation of regression coefficients, k = number of countries.

† Moderate heterogeneity ($I^2 > 30\%$), †† Substantial heterogeneity ($I^2 > 50\%$), ††† Considerable heterogeneity ($I^2 > 75\%$).

* $p < .05$. *** $p < .001$.

Table 6

Meta-Analytic Results for the Verbal Domain: Average Regression Coefficients and Corresponding Heterogeneity Measures (with 95% Confidence Intervals) from the Interrupted Regressions for PIRLS and PISA

	β_1		β_2	
	Estimate	95% CI	Estimate	95% CI
Elementary school				
PIRLS 2011 & 2016 (Grade 4)				
β_{mean}	0.45	[0.42, 0.48]	0.27	[0.22, 0.31]
Q	130.861	***	6.737	
I^2_{total}	77.01	†††	0	
I^2_{Level2}	11.84		0	
I^2_{Level3}	65.16	††	0	
τ_{total}	0.05		0	
τ_{Level2}	0.02		0	
τ_{Level3}	0.05		0	
k	26		26	
Secondary school				
PISA 2000 (15-year-olds)				
β_{mean}	0.20	[0.14, 0.26]	0.32	[0.25, 0.39]
Q	40.103	***	23.551	*
I^2_{total}	84.03	†††	51.64	††
τ_{total}	0.08		0.05	
k	13		13	

Note. β_{mean} = Average regression coefficient, Q = Cochran's measure of homogeneity (Cochran, 1954), I^2_{total} = Higgins and Thompson's (2002) measure of (total) heterogeneity, I^2_{Level2} = Percentage of the variability in regression coefficients that is due to heterogeneity within countries rather than sampling error; I^2_{Level3} = Percentage of the variability in regression coefficients that is due to heterogeneity between countries rather than sampling error, τ_{total} = Total standard deviation of regression coefficients, τ_{Level2} = Within-country standard deviation of regression coefficients, τ_{Level3} = Between-country standard deviation of regression coefficients, k = number of countries.

†† Substantial heterogeneity ($I^2 > 50\%$), ††† Considerable heterogeneity ($I^2 > 75\%$).

* $p < .05$. *** $p < .001$.

Figure 1. Domain-specific pattern of slopes as obtained from the interrupted regressions: (A) Example graph for a single country (Australia in PISA 2000). The density plot shows the math achievement distribution for the first plausible value. (B) Summary of results depicted separately for mathematics (TIMSS and PISA) and the verbal domain (PIRLS and PISA) and for elementary school students (TIMSS and PIRLS) and secondary school students (TIMSS and PISA). β_1 represents the regression coefficient to the left of the breakpoint (i.e., relatively lower achieving students), β_2 the regression coefficient to the right of the breakpoint (i.e., relatively higher achieving students). Symbols above the diagonal indicate that the relation between achievement and self-concept was weaker for lower achieving students than for higher achieving students in a certain country or assessment. Mean values are depicted in black, country-specific values in grey.

Figure 2. Country-specific relations between mathematics achievement and mathematics self-concept for different age groups (left: TIMSS 2011/2015 Grade 4, middle: TIMSS 2011/2015 Grade 8, right: PISA 2000/2003/2012). AUS = Australia, AUT = Austria, CZE = Czech Republic, FIN = Finland, DEU = Germany, HKG = Hong Kong, HUN = Hungary, IRL = Ireland, ITA = Italy, NOR = Norway, PRT = Portugal, RUS = Russian Federation, SWE = Sweden, M = weighted mean.

Figure 3. Country-specific quadratic regression lines for the mathematics domain (TIMSS and PISA assessments). Significant quadratic effects are depicted as solid lines, nonsignificant quadratic effects as dashed lines.

Figure 4. Country-specific relations between reading achievement and reading self-concept (left: PIRLS 2011/2016) or verbal self-concept (right: PISA 2000). AUS = Australia, AUT = Austria, CZE = Czech Republic, FIN = Finland, DEU = Germany, HKG = Hong Kong, HUN = Hungary, IRL = Ireland, ITA = Italy, NOR = Norway, PRT = Portugal, RUS = Russian Federation, SWE = Sweden, M = weighted mean.

Figure 5. Country-specific quadratic regression lines for the verbal domain (PIRLS and PISA assessments). Significant quadratic effects are depicted as solid lines, nonsignificant quadratic effects as dashed lines.

Supplemental Online Materials

Nonlinear Relations Between Achievement and Academic Self-Concepts in Elementary and Secondary School: An Integrative Data Analysis Across 13 Countries

Lena Keller, Franzis Preckel, & Martin Brunner

Method**Samples**

Sampling procedures. The TIMSS, PIRLS, and PISA studies differ in their target populations and sampling procedures. The sampling of the data in TIMSS and PIRLS was based on the grade selection of whole classrooms, whereas PISA used an age-based selection of students in schools. TIMSS and PIRLS are designed to represent the population of students after 4 or 8 years of regular schooling, with a mean age at the time of testing of at least 9.5 or 13.5 years, respectively. PISA is designed to represent the population of 15-year-old students, defined as all students from the age of 15 years and 3 months to 16 years and 2 months at the beginning of the assessment period (Mullis & Martin, 2013, 2015; OECD, 2013).

In all three assessments, high quality standards for collecting representative probability samples were met. For TIMSS and PIRLS, precision requirements were typically met with a school sample of 150 schools and a student sample of 4,000 students per country (Martin & Mullis, 2012). For PISA, precision requirements were typically met with a school sample of at least 150 schools and a student sample of at least 4,500 students (OECD, 2014). In TIMSS, PIRLS, and PISA, a two-stage sampling design was applied in most countries. In all three assessments, in the first stage, individual schools that had students enrolled in the target population were systematically sampled from a stratified list of all schools with sampling probabilities that were proportional to the number of target students enrolled. Strata were specific

for each country and included, for example, geographic regions or school type. In the second stage, one or more classes were then randomly sampled within a selected school in TIMSS and PIRLS. In PISA, about 35 students at age 15 were randomly selected within schools and if a school had fewer than 35 students at age 15, all students in this age group were selected. In every TIMSS, PIRLS, and PISA cycle, the school staff, students, and parents were informed about the nature of the test and the test date, and parental permission was secured if requested by the school or education system (Martin & Mullis, 2012; OECD, 2002).

Table S1

Sample Size, Percentage of Female Students, and Number of Participating Classes for Each Country and in Total for TIMSS and PIRLS (Based on the Imputed Data Sets)

Country	TIMSS 2011						TIMSS 2015						PIRLS 2016		
	Grade 4*			Grade 8			Grade 4			Grade 8			Grade 4		
	<i>N</i>	% _F	<i>N_c</i>	<i>N</i>	% _F	<i>N_c</i>	<i>N</i>	% _F	<i>N_c</i>	<i>N</i>	% _F	<i>N_c</i>	<i>N</i>	% _F	<i>N_c</i>
Australia	5,943	50	438	7,556	50	490	6,057	49	498	10,331	50	645	6,341	50	505
Austria	4,587	49	276	—	—	—	—	—	—	—	—	—	4,360	48	257
Czech Republic	4,433	50	235	—	—	—	5,202	50	265	—	—	—	5,537	48	269
Finland	4,541	49	267	4,266	49	258	5,015	49	300	—	—	—	4,896	49	295
Germany	3,928	50	205	—	—	—	3,942	48	213	—	—	—	3,959	49	221
Hong Kong	3,802	47	133	4,015	50	121	3,600	45	145	4,155	48	145	3,349	49	145
Hungary	5,149	50	249	5,178	50	251	5,036	50	241	4,893	51	241	4,623	50	209
Ireland	4,383	49	220	—	—	—	4,344	47	214	4,704	52	204	4,607	49	219
Italy	4,125	51	239	3,979	48	205	4,371	49	257	4,481	50	230	3,940	49	217
Norway	3,054	51	197	3,862	49	170	4,329	50	222	4,697	50	216	4,230	50	215
Portugal	3,991	49	240	—	—	—	4,693	49	321	—	—	—	4,642	49	318
Russian Federation	4,450	49	209	4,893	49	229	4,921	50	217	4,780	48	221	4,577	50	208
Sweden	4,482	48	251	5,568	48	266	4,132	50	211	4,079	48	206	4,525	50	227
Total	56,868	49	3,159	39,317	49	1,990	55,642	49	3,104	42,120	50	2,108	59,586	49	3,305

Note. %_F = percentage of female students; *N_c* = number of participating classes.

*Descriptive statistics from TIMSS 2011 also apply to PIRLS 2011.

Table S2

Sample Size, Percentage of Female Students, and Number of Participating Schools for Each Country and in Total for PISA (Based on the Imputed Data Sets)

Country	PISA 2000			PISA 2003			PISA 2012		
	<i>N</i>	% _F	<i>N_s</i>	<i>N</i>	% _F	<i>N_s</i>	<i>N</i>	% _F	<i>N_s</i>
Australia	2,836	47	231	12,551	50	321	14,481	49	775
Austria	2,607	50	212	4,597	50	193	4,755	50	191
Czech Republic	3,056	53	229	6,320	49	260	5,327	50	297
Finland	2,703	52	155	5,796	51	197	8,829	49	311
Germany	2,793	52	219	4,614	50	216	5,001	49	230
Hong Kong	2,438	50	140	4,478	50	145	4,670	46	148
Hungary	2,780	48	194	4,765	47	253	4,810	53	204
Ireland	2,111	52	139	3,880	49	145	5,016	51	183
Italy	2,747	52	170	11,639	52	406	31,073	49	1,194
Norway	2,269	51	175	4,064	50	182	4,686	49	197
Portugal	2,524	53	149	4,608	52	153	5,722	50	195
Russian Federation	3,713	50	245	5,974	52	212	5,231	50	227
Sweden	2,447	50	154	4,624	49	185	4,736	50	209
Total	35,024	51	2,412	77,910	50	2,868	104,337	49	4,361

Note. %_F = percentage of female students; *N_s* = number of participating schools.

Table S3

(Pooled) Descriptive Statistics for TIMSS/PIRLS 2011 Based on the Imputed Data Sets

Country	N	Mathematics achievement		Reading achievement		Mathematics self-concept			Reading self-concept			Age	
		M	SD	M	SD	M	SD	%missing	M	SD	%missing	M	SD
Australia	5943	514.20	89.67	510.31	89.89	3.11	0.74	6	3.24	0.56	7	9.99	0.44
Austria	4587	505.19	65.81	512.23	71.12	3.20	0.71	6	3.36	0.55	6	10.25	0.45
Czech Republic	4433	508.28	73.11	530.42	68.15	3.03	0.70	5	3.20	0.57	4	10.37	0.43
Finland	4541	543.47	70.09	555.88	71.05	3.06	0.73	4	3.39	0.47	5	10.79	0.34
Germany	3928	524.82	64.73	526.22	73.61	3.14	0.74	20	3.33	0.55	17	10.37	0.52
Hong Kong	3802	605.43	62.63	559.31	67.23	2.85	0.76	3	2.98	0.56	3	10.12	0.50
Hungary	5149	512.36	92.28	524.05	87.31	3.15	0.76	5	3.22	0.62	4	10.67	0.49
Ireland	4383	525.82	80.42	538.11	82.67	3.19	0.71	6	3.31	0.53	5	10.34	0.41
Italy	4125	503.84	75.06	526.57	73.94	3.10	0.64	6	3.16	0.51	7	9.73	0.36
Norway	3054	490.96	71.41	487.59	68.20	3.29	0.62	7	3.31	0.50	7	9.72	0.29
Portugal	3991	529.74	71.36	525.63	73.86	2.96	0.66	5	3.22	0.51	4	10.02	0.49
Russian Federation	4450	539.59	76.40	556.23	72.83	3.01	0.75	4	3.13	0.53	3	10.75	0.43
Sweden	4482	501.95	68.20	527.07	71.40	3.24	0.61	8	3.38	0.49	6	10.74	0.33
(Weighted) mean	4374	523.52	73.83	529.18	74.60	3.10	0.70	7	3.25	0.53	6	10.30	0.42

Table S4

(Pooled) Descriptive Statistics for TIMSS 2015 (Grade 4) Based on the Imputed Data Sets

Country	N	Mathematics achievement		Mathematics self-concept			Age		
		M	SD	M	SD	%missing	M	SD	%missing
Australia	6,057	517.23	83.47	2.96	0.72	9	10.04	0.39	0
Czech Republic	5,202	528.14	69.86	2.92	0.69	5	10.40	0.42	0
Finland	5,015	535.29	66.65	3.04	0.65	8	10.75	0.32	0
Germany	3,942	521.60	65.38	3.07	0.73	24	10.36	0.51	0
Hong Kong	3,600	614.52	65.64	2.78	0.71	4	10.07	0.44	1
Hungary	5,036	529.19	87.97	3.09	0.72	5	10.65	0.50	0
Ireland	4,344	547.34	73.13	3.14	0.66	8	10.45	0.39	0
Italy	4,371	506.91	71.54	3.14	0.67	9	9.72	0.35	0
Norway	4,329	549.08	70.58	3.28	0.61	9	10.72	0.29	0
Portugal	4,693	541.20	72.45	2.88	0.73	7	9.86	0.51	0
Russian Federation	4,921	563.92	72.72	2.96	0.72	4	10.78	0.38	0
Sweden	4,132	518.69	69.10	3.19	0.61	9	10.77	0.32	0
(Weighted) mean	4,637	539.41	72.27	3.04	0.68	8	10.38	0.40	0

Table S5

(Pooled) Descriptive Statistics for TIMSS 2011 (Grade 8) Based on the Imputed Data Sets

Country	N	Mathematics achievement		Mathematics self-concept			Age	
		M	SD	M	SD	%missing	M	SD
Australia	7,556	504.80	85.42	2.74	0.72	7	13.99	0.47
Finland	4,266	514.03	64.85	2.59	0.76	5	14.78	0.35
Hong Kong	4,015	585.57	84.47	2.41	0.70	3	14.22	0.70
Hungary	5,178	504.81	89.59	2.57	0.79	4	14.71	0.62
Italy	3,979	498.38	73.17	2.64	0.71	4	13.85	0.52
Norway	3,862	474.64	64.73	2.81	0.75	8	13.74	0.38
Russian Federation	4,893	538.98	81.13	2.64	0.70	3	14.74	0.48
Sweden	5,568	484.34	67.55	2.76	0.68	11	14.77	0.40
(Weighted) mean	4,915	513.12	76.04	2.64	0.72	6	14.35	0.49

Table S6

(Pooled) Descriptive Statistics for TIMSS 2015 (Grade 8) Based on the Imputed Data Sets

Country	N	Mathematics achievement		Mathematics self-concept			Age	
		M	SD	M	SD	%missing	M	SD
Australia	10,331	504.97	82.35	2.64	0.73	8	13.98	0.46
Hong Kong	4,155	594.25	78.41	2.45	0.74	3	14.24	0.66
Hungary	4,893	514.41	93.39	2.70	0.77	4	14.70	0.53
Ireland	4,704	523.49	73.95	2.65	0.75	5	14.43	0.43
Italy	4,481	494.39	74.54	2.65	0.82	4	13.81	0.50
Norway	4,697	511.54	70.05	2.78	0.81	16	14.73	0.32
Russian Federation	4,780	538.00	81.71	2.59	0.70	3	14.75	0.44
Sweden	4,079	500.92	71.84	2.68	0.77	11	14.75	0.36
(Weighted) mean	5,265	522.60	78.21	2.64	0.76	7	14.42	0.46

Table S7

(Pooled) Descriptive Statistics for PIRLS 2016 Based on the Imputed Data Sets

Country	N	Reading achievement		Reading self-concept			Age	
		M	SD	M	SD	%missing	M	SD
Australia	6,341	544.36	83.60	3.26	0.64	4	10.05	0.41
Austria	4,360	540.80	65.43	3.35	0.63	10	10.29	0.48
Czech Republic	5,537	543.35	68.04	3.21	0.61	4	10.31	0.44
Finland	4,896	566.01	67.11	3.41	0.56	4	10.79	0.34
Germany	3,959	537.33	77.98	3.31	0.65	17	10.34	0.51
Hong Kong	3,349	568.58	63.71	3.06	0.67	3	9.93	0.47
Hungary	4,623	554.16	74.62	3.22	0.66	2	10.63	0.47
Ireland	4,607	566.60	73.77	3.33	0.63	4	10.47	0.39
Italy	3,940	548.01	65.01	3.24	0.61	3	9.74	0.35
Norway	4,230	559.01	65.43	3.31	0.63	6	10.80	0.30
Portugal	4,642	527.80	65.15	3.10	0.62	3	9.80	0.49
Russian Federation	4,577	580.77	66.31	3.18	0.62	2	10.81	0.43
Sweden	4,525	555.16	67.06	3.47	0.54	8	10.74	0.30
(Weighted) mean	4,584	553.25	69.33	3.27	0.62	5	10.36	0.41

Table S8

(Pooled) Descriptive Statistics for PISA 2000 Based on the Imputed Data Sets

Country	Mathematics achievement			Reading achievement		Mathematics self-concept			Verbal self-concept			Age		
	<i>N</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	%missing	<i>M</i>	<i>SD</i>	%missing	<i>M</i>	<i>SD</i>	%missing
Australia	2,836	533.81	89.92	528.53	102.95	2.60	0.78	6	2.93	0.60	6	15.69	0.28	1
Austria	2,607	515.95	91.88	510.22	94.80	2.38	0.92	7	2.93	0.76	6	15.78	0.29	0
Czech Republic	3,056	497.78	96.29	494.86	97.43	2.32	0.87	11	2.70	0.75	11	15.72	0.28	6
Finland	2,703	536.16	80.32	548.66	91.08	2.40	1.00	4	2.88	0.70	4	15.63	0.29	0
Germany	2,793	490.23	102.5	483.13	113.48	2.46	0.95	9	2.83	0.76	9	15.71	0.28	1
Hong Kong	2,438	560.45	93.67	532.05	85.13	2.40	0.95	2	2.71	0.66	1	15.72	0.30	0
Hungary	2,780	488.25	97.97	481.32	95.12	2.13	0.91	7	2.80	0.72	7	15.71	0.28	0
Ireland	2,111	503.56	83.42	528.17	93.94	2.38	0.96	3	3.09	0.77	3	15.70	0.28	1
Italy	2,747	457.89	89.94	487.34	91.26	2.49	0.99	2	3.10	0.77	2	15.73	0.28	3
Norway	2,269	500.61	90.88	503.73	104.26	2.34	1.02	9	2.87	0.76	8	15.72	0.28	1
Portugal	2,524	454.58	90.86	467.46	97.85	2.24	0.95	4	2.88	0.70	3	15.63	0.28	1
Russian Federation	3,713	478.52	103.99	457.32	92.37	2.47	0.96	7	2.97	0.74	6	15.70	0.28	0
Sweden	2,447	510.41	93.06	515.60	92.90	2.39	0.85	5	2.97	0.62	5	15.73	0.28	0
(Weighted) mean	2,694	502.24	92.50	503.05	96.39	2.39	0.93	6	2.90	0.72	5	15.71	0.28	1

Table S9

(Pooled) Descriptive Statistics for PISA 2003 Based on the Imputed Data Sets

Country	N	Mathematics achievement		Mathematics self-concept			Age	
		M	SD	M	SD	%missing	M	SD
Australia	12,551	524.27	95.42	2.51	0.69	4	15.77	0.29
Austria	4,597	505.61	93.09	2.45	0.80	5	15.84	0.29
Czech Republic	6,320	516.46	95.94	2.32	0.70	5	15.89	0.28
Finland	5,796	544.29	83.68	2.42	0.78	2	15.71	0.29
Germany	4,614	503.42	102.33	2.50	0.84	9	15.77	0.28
Hong Kong	4,478	550.38	100.19	2.21	0.68	1	15.80	0.29
Hungary	4,765	490.01	93.51	2.29	0.64	2	15.74	0.29
Ireland	3,880	502.84	85.26	2.38	0.70	5	15.71	0.28
Italy	11,639	465.66	95.69	2.41	0.75	3	15.71	0.28
Norway	4,064	495.19	92.04	2.27	0.82	7	15.79	0.28
Portugal	4,608	466.02	87.63	2.27	0.70	4	15.87	0.28
Russian Federation	5,974	468.41	92.25	2.51	0.58	4	15.82	0.28
Sweden	4,624	509.05	94.75	2.50	0.75	6	15.74	0.28
(Weighted) mean	5,993	503.21	93.02	2.39	0.73	4	15.78	0.28

Table S10

(Pooled) Descriptive Statistics for PISA 2012 Based on the Imputed Data Sets

Country	N	Mathematics achievement		Mathematics self-concept			Age	
		M	SD	M	SD	%missing	M	SD
Australia	14,481	504.15	96.29	2.52	0.74	37	15.79	0.29
Austria	4,755	505.54	92.48	2.46	0.83	37	15.80	0.29
Czech Republic	5,327	498.96	94.94	2.29	0.78	36	15.75	0.28
Finland	8,829	518.75	85.29	2.48	0.8	46	15.71	0.28
Germany	5,001	513.53	96.30	2.51	0.86	37	15.83	0.29
Hong Kong	4,670	561.24	96.31	2.32	0.73	35	15.74	0.29
Hungary	4,810	477.04	93.62	2.35	0.70	35	15.72	0.29
Ireland	5,016	501.50	84.58	2.41	0.74	35	15.70	0.28
Italy	31,073	485.32	92.78	2.46	0.76	35	15.76	0.29
Norway	4,686	489.37	90.48	2.37	0.85	40	15.79	0.29
Portugal	5,722	487.06	93.95	2.37	0.72	36	15.75	0.29
Russian Federation	5,231	482.17	86.37	2.53	0.65	35	15.81	0.29
Sweden	4,736	478.26	91.75	2.54	0.77	39	15.73	0.28
(Weighted) mean	8,026	500.22	91.85	2.43	0.76	37	15.76	0.29

Table S11

Reliabilities for the Achievement and Self-Concept Scales as Observed in TIMSS 2011 in Grades 4 and 8

Country	Grade 4		Grade 8	
	Mathematics achievement ^a	Mathematics self-concept ^b	Mathematics achievement ^a	Mathematics self-concept ^b
Australia	.86	.86	.90	.90
Austria	.79	.87	—	—
Czech Republic	.82	.87	—	—
Finland	.82	.89	.86	.93
Germany	.81	.89	—	—
Hong Kong	.80	.87	.91	.90
Hungary	.87	.88	.90	.92
Ireland	.84	.86	—	—
Italy	.82	.81	.87	.91
Norway	.80	.83	.83	.91
Portugal	.83	.86	—	—
Russian Federation	.83	.88	.90	.90
Sweden	.80	.85	.85	.91

^a Reliability estimates are based on item response theory.

^b Reliability was estimated in terms of Cronbach's Alpha.

Table S12

Reliabilities for the Achievement and Self-Concept Scales as Observed in TIMSS 2015 in Grades 4 and 8

Country	Grade 4		Grade 8	
	Mathematics achievement ^a	Mathematics self-concept ^b	Mathematics achievement ^a	Mathematics self-concept ^b
Australia	.86	.87	.89	.90
Czech Republic	.83	.88	—	—
Finland	.81	.86	—	—
Germany	.82	.89	—	—
Hong Kong	.81	.86	.89	.91
Hungary	.88	.88	.91	.91
Ireland	.84	.85	.88	.89
Italy	.82	.85	.86	.92
Norway	.81	.84	.83	.91
Portugal	.84	.86	—	—
Russian Federation	.84	.89	.89	.91
Sweden	.81	.87	.86	.92

^a Reliability estimates are based on item response theory.

^b Reliability was estimated in terms of Cronbach's Alpha.

Table S13

Reliabilities for the Mathematics Achievement and Self-Concept Scales as Observed in PISA 2000, 2003, and 2012

Country	2000		2003		2012	
	Mathematics self-concept ^b	Verbal self-concept ^b	Mathematics achievement ^a	Mathematics self-concept ^b	Mathematics achievement ^a	Mathematics self-concept ^b
Australia	.85	.76	.91	.89	.94	.89
Austria	.88	.81	.92	.89	.93	.90
Czech Republic	.84	.74	.91	.89	.94	.91
Finland	.93	.80	.89	.92	.92	.92
Germany	.90	.82	.93	.91	.94	.91
Hong Kong	—	—	.92	.89	.92	.89
Hungary	.87	.66	.90	.81	.94	.82
Ireland	.87	.79	.91	.89	.92	.89
Italy	.87	.82	.91	.91	.93	.88
Norway	.90	.74	.90	.90	.92	.91
Portugal	.87	.74	.90	.89	.93	.89
Russian Federation	.87	.67	.88	.89	.91	.83
Sweden	.88	.75	.90	.89	.92	.89

Note. In PISA 2000, only averaged reliabilities were reported for the international PISA scales; mathematics achievement: $\alpha = .81^a$; reading achievement: $\alpha = .89^a$.

^a Reliability estimates are based on item response theory.

^b Reliability was estimated in terms of Cronbach's Alpha.

Table S14

Reliabilities for the Achievement and Self-Concept Scales as Observed in PIRLS 2011 and 2016

Country	2011		2016	
	Reading achievement ^a	Reading self-concept ^b	Reading achievement ^a	Reading self-concept ^b
Australia	.90	.72	.91	.81
Austria	.87	.75	.86	.81
Czech Republic	.86	.77	.88	.79
Finland	.85	.69	.88	.80
Germany	.89	.76	.90	.82
Hong Kong	.86	.69	.85	.80
Hungary	.90	.77	.89	.82
Ireland	.89	.71	.89	.82
Italy	.87	.66	.87	.75
Norway	.86	.67	.87	.79
Portugal	.86	.73	.87	.72
Russian Federation	.88	.64	.87	.79
Sweden	.87	.74	.88	.82

^a Reliability estimates are based on item response theory.

^b Reliability was estimated in terms of Cronbach's Alpha.

Table S15

Mathematics Self-Concept Items as Used in TIMSS

Item wording	Cycles (grades)
<i>How much do you agree with these statements about mathematics?</i>	
I usually do well in mathematics.	2011 (4, 8), 2015 (4, 8)
Mathematics is harder for me than for many of my classmates. (R)	2011 (4, 8), 2015 (4, 8)
I am are just not good at mathematics. (R)	2011 (4), 2015 (4)
I learn things quickly in mathematics.	2011 (4, 8), 2015 (4, 8)
I am good at working out difficult mathematics problems.	2011 (4, 8), 2015 (4, 8)
My teacher tells me I am good at mathematics.	2011 (4, 8), 2015 (4, 8)
Mathematics is harder for me than any other subject. (R)	2011 (4, 8), 2015 (4, 8)
Mathematics makes me nervous. (R)	2015 (4, 8)
Mathematics makes me confused. (R)	2015 (4, 8)
Mathematics makes me confused and nervous. (R)	2011 (8)
Mathematics is not one of my strengths. (R)	2011 (8), 2015 (8)
My teacher thinks I can do well in mathematics <programs/classes/lessons> ^a with difficult materials.	2011 (8)

Note. Responses given on a 4-point rating scale: 4 = *agree a lot*, 3 = *agree a little*, 2 = *disagree a little*, 1 = *disagree a lot*. (R) = reversed.

^a The terms in brackets < > were replaced in the national versions of the TIMSS questionnaires by the corresponding national equivalent.

Table S16

Mathematics Self-Concept Items as Used in PISA

Item wording	Cycles
I get good <marks> ^c in mathematics. ^{a, b}	2000, 2003, 2012
Mathematics is one of my best subjects. ^a	2000
I have always done well in mathematics. ^a	2000
I am just not good at mathematics. (R) ^b	2003, 2012
I learn mathematics quickly. ^b	2003, 2012
I have always believed that mathematics is one of my best subjects. ^b	2003, 2012
In my mathematics class, I understand even the most difficult work. ^b	2003, 2012

Note. (R) = reversed.

^a 4-point rating scale (1 = *disagree* to 4 = *agree*).

^b 4-point rating scale (1 = *strongly disagree* to 4 = *strongly agree*).

^c The terms in brackets < > were replaced in the national versions of the PISA questionnaires by the corresponding national equivalent.

Table S17

Reading Self-Concept Items as Used in PIRLS 2011 and 2016

Item wording	Cycles
I usually do well in reading.	2011, 2016
Reading is easy for me.	2011, 2016
Reading is harder for me than for many of my classmates. (R)	2011, 2016
If a book is interesting, I don't care how hard it is to read.	2011
I have trouble reading stories with difficult words. (R)	2011, 2016
My teacher tells me that I am a good reader.	2011
Reading is harder for me than any other subject. (R)	2016
I am just not good at reading. (R)	2016

Note. Responses given on a 4-point rating scale: 4 = *agree a lot*, 3 = *agree a little*, 2 = *disagree a little*, 1 = *disagree a lot*. (R) = reversed.

Table S18

Verbal Self-Concept Items as Used in PISA 2000

Item wording
I'm hopeless in <test language> ^a . (R)
I learn things quickly in the <test language> ^a classes.
I get good marks in the <test language> ^a .

Note. Responses given on a 4-point rating scale (1 = *disagree* to 4 = *agree*).

(R) = reversed.

^aThe terms in brackets < > were replaced in the national versions of the PISA questionnaires by the corresponding national equivalent.

Table S19

Standardized Regression Coefficients from Linear and Quadratic Regression Models (Mathematics Self-Concept on Mathematics Achievement) with Confidence Intervals (95% CI) and Explained Variance (R^2) in TIMSS (Grade 4)

Country	Cycle	Linear model			Quadratic model				
		Linear effect		R^2	Linear effect		Quadratic effect		R^2
		β	95% CI		β	95% CI	β	95% CI	
Australia	2011	0.28	[0.25, 0.32]	.080	0.29	[0.26, 0.33]	0.08	[0.05, 0.11]	.087
	2015	0.45	[0.42, 0.48]	.202	0.45	[0.42, 0.49]	0.09	[0.05, 0.12]	.209
Austria	2011	0.34	[0.31, 0.38]	.118	0.34	[0.31, 0.38]	-0.01	[-0.04, 0.03]	.118
Czech Republic	2011	0.30	[0.25, 0.35]	.091	0.32	[0.28, 0.36]	0.06	[-0.02, 0.14]	.095
	2015	0.45	[0.42, 0.48]	.202	0.45	[0.42, 0.48]	0.02	[0.00, 0.05]	.202
Finland	2011	0.36	[0.32, 0.40]	.133	0.38	[0.35, 0.41]	0.10	[0.06, 0.15]	.144
	2015	0.45	[0.41, 0.48]	.198	0.46	[0.43, 0.49]	0.07	[0.04, 0.11]	.204
Germany	2011	0.36	[0.32, 0.39]	.126	0.37	[0.34, 0.40]	0.07	[0.02, 0.11]	.131
	2015	0.46	[0.42, 0.49]	.211	0.46	[0.42, 0.49]	-0.02	[-0.06, 0.03]	.211
Hong Kong	2011	0.30	[0.27, 0.34]	.092	0.31	[0.28, 0.35]	0.06	[0.02, 0.10]	.095
	2015	0.45	[0.39, 0.50]	.199	0.46	[0.41, 0.51]	0.09	[0.04, 0.13]	.206
Hungary	2011	0.45	[0.43, 0.48]	.206	0.48	[0.45, 0.51]	0.07	[0.03, 0.10]	.210
	2015	0.54	[0.50, 0.57]	.287	0.56	[0.53, 0.59]	0.05	[0.00, 0.11]	.289
Ireland	2011	0.27	[0.23, 0.31]	.075	0.29	[0.25, 0.33]	0.07	[0.03, 0.11]	.079
	2015	0.45	[0.42, 0.48]	.202	0.45	[0.42, 0.48]	0.01	[-0.02, 0.05]	.202
Italy	2011	0.27	[0.23, 0.31]	.073	0.25	[0.21, 0.29]	0.04	[-0.02, 0.10]	.061
	2015	0.35	[0.31, 0.39]	.122	0.35	[0.31, 0.39]	0.00	[-0.03, 0.03]	.122
Norway	2011	0.24	[0.20, 0.28]	.060	0.43	[0.38, 0.48]	0.08	[0.03, 0.14]	.185
	2015	0.45	[0.41, 0.48]	.199	0.45	[0.41, 0.48]	0.00	[-0.05, 0.05]	.199
Portugal	2011	0.42	[0.38, 0.47]	.178	0.31	[0.28, 0.35]	0.00	[-0.04, 0.04]	.099
	2015	0.52	[0.50, 0.55]	.274	0.52	[0.50, 0.55]	0.05	[0.02, 0.09]	.276
Russian Federation	2011	0.31	[0.28, 0.35]	.099	0.26	[0.23, 0.29]	0.05	[0.01, 0.09]	.070
	2015	0.42	[0.39, 0.45]	.177	0.42	[0.39, 0.45]	-0.01	[-0.05, 0.02]	.177

(table continues)

Table S19 (Continued)

Country	Cycle	Linear model			Quadratic model				
		Linear effect			Linear effect		Quadratic effect		R^2
		β	95% CI	R^2	β	95% CI	β	95% CI	
Sweden	2011	0.26	[0.23, 0.29]	.067	0.27	[0.24, 0.31]	0.03	[0.00, 0.06]	.073
	2015	0.39	[0.36, 0.43]	.155	0.40	[0.37, 0.44]	0.05	[0.00, 0.10]	.157
Weighted mean		0.38	[0.35, 0.42]	.152	0.39	[0.36, 0.42]	0.04	[0.03, 0.06]	.155

Table S20

Standardized Regression Coefficients from Linear and Quadratic Regression Models (Mathematics Self-Concept on Mathematics Achievement) with Confidence Intervals (95% CI) and Explained Variance (R^2) in TIMSS (Grade 8)

Country	Cycle	Linear model			Quadratic model				
		Linear effect		R^2	Linear effect		Quadratic effect		R^2
		β	95% CI		β	95% CI	β	95% CI	
Australia	2011	0.55	[0.52, 0.58]	.302	0.54	[0.51, 0.58]	0.03	[-0.02, 0.09]	.303
	2015	0.53	[0.50, 0.56]	.278	0.54	[0.51, 0.56]	0.10	[0.07, 0.14]	.289
Finland	2011	0.63	[0.60, 0.65]	.391	0.64	[0.61, 0.67]	0.13	[0.10, 0.17]	.409
Hong Kong	2011	0.39	[0.35, 0.44]	.156	0.47	[0.43, 0.51]	0.18	[0.10, 0.27]	.184
	2015	0.39	[0.35, 0.42]	.149	0.45	[0.40, 0.50]	0.18	[0.11, 0.25]	.178
Hungary	2011	0.53	[0.50, 0.57]	.283	0.62	[0.59, 0.66]	0.25	[0.19, 0.30]	.335
	2015	0.55	[0.52, 0.58]	.302	0.60	[0.57, 0.64]	0.17	[0.11, 0.22]	.327
Ireland	2015	0.45	[0.41, 0.50]	.207	0.51	[0.48, 0.55]	0.18	[0.12, 0.25]	.236
Italy	2011	0.53	[0.50, 0.56]	.281	0.54	[0.51, 0.58]	0.08	[0.04, 0.12]	.287
	2015	0.50	[0.47, 0.54]	.255	0.53	[0.50, 0.57]	0.13	[0.09, 0.16]	.270
Norway	2011	0.64	[0.61, 0.66]	.406	0.65	[0.62, 0.68]	0.07	[0.03, 0.10]	.410
	2015	0.63	[0.61, 0.65]	.394	0.64	[0.62, 0.66]	0.09	[0.05, 0.13]	.402
Russian	2011	0.49	[0.47, 0.52]	.245	0.50	[0.47, 0.53]	0.04	[0.01, 0.08]	.246
Federation	2015	0.46	[0.43, 0.49]	.213	0.46	[0.43, 0.50]	0.03	[-0.01, 0.06]	.214
Sweden	2011	0.61	[0.59, 0.63]	.375	0.62	[0.60, 0.64]	0.09	[0.06, 0.12]	.383
	2015	0.61	[0.58, 0.64]	.372	0.64	[0.61, 0.67]	0.15	[0.11, 0.19]	.394
Weighted mean		0.53	[0.48, 0.58]	.289	0.56	[0.52, 0.61]	0.12	[0.08, 0.15]	.306

Table S21

Standardized Regression Coefficients from Linear and Quadratic Regression Models (Mathematics Self-Concept on Mathematics Achievement) with Confidence Intervals (95% CI) and Explained Variance (R^2) in PISA

Country	Cycle	Linear model			Quadratic model				
		Linear effect		R^2	Linear effect		Quadratic effect		R^2
		β	95% CI		β	95% CI	β	95% CI	
Australia	2000	0.29	[0.24, 0.33]	.082	0.29	[0.25, 0.34]	0.10	[0.05, 0.15]	.092
	2003	0.41	[0.39, 0.43]	.169	0.42	[0.39, 0.44]	0.08	[0.05, 0.10]	.175
	2012	0.45	[0.43, 0.47]	.199	0.43	[0.41, 0.45]	0.08	[0.06, 0.11]	.206
Austria	2000	0.23	[0.18, 0.27]	.051	0.23	[0.18, 0.28]	0.12	[0.08, 0.17]	.066
	2003	0.30	[0.27, 0.34]	.091	0.32	[0.28, 0.35]	0.11	[0.08, 0.14]	.103
	2012	0.36	[0.33, 0.40]	.131	0.37	[0.33, 0.40]	0.10	[0.06, 0.13]	.141
Czech Republic	2000	0.27	[0.23, 0.32]	.074	0.28	[0.23, 0.32]	0.08	[0.02, 0.13]	.080
	2003	0.40	[0.37, 0.43]	.163	0.42	[0.40, 0.45]	0.07	[0.03, 0.10]	.167
	2012	0.46	[0.42, 0.50]	.214	0.49	[0.45, 0.52]	0.07	[0.00, 0.13]	.218
Finland	2000	0.48	[0.43, 0.52]	.226	0.50	[0.47, 0.54]	0.14	[0.09, 0.20]	.246
	2003	0.58	[0.56, 0.60]	.336	0.58	[0.56, 0.61]	0.12	[0.09, 0.14]	.349
	2012	0.55	[0.52, 0.57]	.301	0.53	[0.50, 0.56]	0.17	[0.14, 0.20]	.330
Germany	2000	0.16	[0.11, 0.22]	.027	0.20	[0.15, 0.25]	0.10	[0.05, 0.16]	.036
	2003	0.25	[0.22, 0.29]	.064	0.28	[0.24, 0.31]	0.10	[0.06, 0.15]	.074
	2012	0.34	[0.30, 0.38]	.114	0.35	[0.31, 0.39]	0.10	[0.06, 0.15]	.126
Hong Kong	2000	0.22	[0.17, 0.26]	.048	0.27	[0.22, 0.31]	0.15	[0.11, 0.19]	.067
	2003	0.35	[0.32, 0.39]	.123	0.40	[0.36, 0.44]	0.13	[0.09, 0.17]	.138
	2012	0.35	[0.32, 0.38]	.124	0.38	[0.34, 0.41]	0.10	[0.07, 0.14]	.134
Hungary	2000	0.26	[0.21, 0.32]	.070	0.26	[0.21, 0.31]	0.14	[0.10, 0.18]	.088
	2003	0.26	[0.22, 0.30]	.068	0.26	[0.23, 0.29]	0.14	[0.11, 0.17]	.087
	2012	0.37	[0.32, 0.41]	.134	0.38	[0.34, 0.42]	0.23	[0.18, 0.27]	.186
Ireland	2000	0.24	[0.19, 0.29]	.056	0.28	[0.24, 0.32]	0.17	[0.10, 0.23]	.083
	2003	0.39	[0.35, 0.43]	.152	0.40	[0.36, 0.44]	0.10	[0.07, 0.14]	.163

(table continues)

Table S21 (Continued)

Country	Cycle	Linear model			Quadratic model				
		Linear effect		R^2	Linear effect		Quadratic effect		R^2
		β	95% CI		β	95% CI	β	95% CI	
Ireland	2012	0.40	[0.37, 0.43]	.162	0.41	[0.38, 0.44]	0.14	[0.11, 0.17]	.181
Italy	2000	0.25	[0.22, 0.29]	.065	0.27	[0.23, 0.31]	0.08	[0.03, 0.13]	.071
	2003	0.27	[0.24, 0.30]	.074	0.31	[0.28, 0.33]	0.08	[0.05, 0.11]	.079
	2012	0.34	[0.32, 0.36]	.118	0.36	[0.34, 0.37]	0.10	[0.08, 0.12]	.128
Norway	2000	0.45	[0.41, 0.49]	.201	0.47	[0.43, 0.51]	0.16	[0.10, 0.22]	.226
	2003	0.57	[0.54, 0.60]	.323	0.58	[0.55, 0.60]	0.17	[0.14, 0.21]	.353
	2012	0.61	[0.58, 0.64]	.374	0.62	[0.59, 0.65]	0.13	[0.10, 0.16]	.392
Portugal	2000	0.23	[0.18, 0.28]	.053	0.26	[0.22, 0.31]	0.15	[0.10, 0.19]	.074
	2003	0.39	[0.36, 0.43]	.152	0.39	[0.36, 0.42]	0.16	[0.12, 0.19]	.177
	2012	0.45	[0.42, 0.48]	.202	0.45	[0.42, 0.48]	0.15	[0.11, 0.19]	.224
Russian Federation	2000	0.27	[0.23, 0.31]	.073	0.27	[0.23, 0.31]	0.03	[0.00, 0.07]	.074
	2003	0.33	[0.30, 0.36]	.109	0.33	[0.30, 0.36]	0.08	[0.05, 0.12]	.116
	2012	0.37	[0.34, 0.40]	.137	0.37	[0.34, 0.40]	0.09	[0.05, 0.13]	.145
Sweden	2000	0.39	[0.35, 0.42]	.151	0.42	[0.39, 0.46]	0.19	[0.15, 0.24]	.188
	2003	0.50	[0.47, 0.53]	.250	0.51	[0.48, 0.54]	0.14	[0.11, 0.17]	.270
	2012	0.49	[0.46, 0.52]	.237	0.49	[0.46, 0.52]	0.12	[0.09, 0.15]	.252
Weighted mean		0.37	[0.32, 0.42]	.146	0.38	[0.33, 0.43]	0.12	[0.10, 0.14]	.161

Table S22

Standardized Regression Coefficients from Linear and Quadratic Regression Models (Reading Self-Concept on Reading Achievement) with Confidence Intervals (95% CI) and Explained Variance (R^2) in PIRLS

Country	Cycle	Linear model			Quadratic model				
		Linear effect			Linear effect		Quadratic effect		R^2
		β	95% CI	R^2	β	95% CI	β	95% CI	
Australia	2011	0.50	[0.47, 0.54]	.253	0.50	[0.46, 0.53]	-0.02	[-0.05, 0.01]	.253
	2016	0.56	[0.54, 0.59]	.315	0.55	[0.53, 0.58]	-0.04	[-0.07, -0.01]	.317
Austria	2011	0.39	[0.36, 0.43]	.154	0.39	[0.35, 0.42]	-0.03	[-0.06, 0.00]	.155
	2016	0.42	[0.40, 0.45]	.179	0.42	[0.40, 0.45]	0.01	[-0.03, 0.05]	.179
Czech Republic	2011	0.42	[0.38, 0.46]	.179	0.43	[0.39, 0.47]	0.01	[-0.05, 0.07]	.179
	2016	0.43	[0.40, 0.46]	.187	0.43	[0.40, 0.46]	-0.01	[-0.06, 0.04]	.187
Finland	2011	0.41	[0.37, 0.45]	.167	0.41	[0.37, 0.44]	-0.02	[-0.06, 0.03]	.167
	2016	0.44	[0.41, 0.47]	.194	0.44	[0.41, 0.47]	0.00	[-0.04, 0.03]	.194
Germany	2011	0.42	[0.39, 0.46]	.180	0.42	[0.39, 0.45]	-0.01	[-0.05, 0.03]	.180
	2016	0.46	[0.41, 0.51]	.214	0.45	[0.41, 0.49]	-0.04	[-0.09, 0.02]	.216
Hong Kong	2011	0.38	[0.35, 0.41]	.145	0.39	[0.36, 0.43]	0.03	[0.00, 0.07]	.146
	2016	0.41	[0.37, 0.44]	.165	0.42	[0.39, 0.46]	0.04	[0.00, 0.09]	.167
Hungary	2011	0.53	[0.49, 0.56]	.278	0.53	[0.50, 0.57]	0.02	[-0.03, 0.06]	.278
	2016	0.51	[0.47, 0.54]	.257	0.50	[0.46, 0.53]	-0.03	[-0.06, 0.00]	.258
Ireland	2011	0.42	[0.39, 0.46]	.180	0.42	[0.39, 0.45]	-0.01	[-0.05, 0.03]	.180
	2016	0.46	[0.43, 0.49]	.210	0.45	[0.41, 0.48]	-0.04	[-0.08, 0.00]	.212
Italy	2011	0.34	[0.31, 0.37]	.115	0.34	[0.31, 0.37]	0.01	[-0.02, 0.05]	.115
	2016	0.34	[0.31, 0.38]	.119	0.33	[0.30, 0.36]	-0.05	[-0.09, -0.01]	.121
Norway	2011	0.41	[0.37, 0.45]	.170	0.41	[0.37, 0.45]	-0.02	[-0.08, 0.04]	.170
	2016	0.48	[0.44, 0.51]	.229	0.47	[0.44, 0.49]	-0.06	[-0.11, -0.01]	.232
Portugal	2011	0.46	[0.43, 0.49]	.212	0.46	[0.42, 0.49]	-0.02	[-0.06, 0.02]	.212
	2016	0.44	[0.40, 0.47]	.193	0.44	[0.40, 0.47]	-0.05	[-0.09, -0.01]	.195

(table continues)

Table S22 (Continued)

Country	Cycle	Linear model			Quadratic model				
		Linear effect			Linear effect		Quadratic effect		R^2
		β	95% CI	R^2	β	95% CI	β	95% CI	
Russian Federation	2011	0.40	[0.36, 0.44]	.162	0.40	[0.36, 0.44]	0.00	[-0.03, 0.03]	.162
	2016	0.46	[0.42, 0.49]	.208	0.44	[0.41, 0.47]	-0.04	[-0.09, 0.00]	.210
Sweden	2011	0.42	[0.39, 0.45]	.177	0.42	[0.38, 0.45]	-0.01	[-0.06, 0.03]	.177
	2016	0.44	[0.41, 0.47]	.194	0.42	[0.39, 0.45]	-0.08	[-0.11, -0.05]	.200
Weighted mean		0.44	[0.41, 0.46]	.193	0.43	[0.41, 0.46]	-0.02	[-0.03, -0.01]	.194

Table S23

Standardized Regression Coefficients from Linear and Quadratic Regression Models (Verbal Self-Concept on Reading Achievement) with Confidence Intervals (95% CI) and Explained Variance (R^2) in PISA

Country	Cycle	Linear model			Quadratic model				
		Linear effect			Linear effect		Quadratic effect		R^2
		β	95% CI	R^2	β	95% CI	β	95% CI	
Australia	2000	0.28	[0.23, 0.33]	.081	0.29	[0.24, 0.34]	0.05	[0.01, 0.10]	.084
Austria	2000	0.27	[0.23, 0.30]	.071	0.28	[0.24, 0.31]	0.08	[0.04, 0.12]	.077
Czech Republic	2000	0.26	[0.21, 0.32]	.069	0.29	[0.23, 0.34]	0.07	[0.01, 0.13]	.074
Finland	2000	0.38	[0.34, 0.42]	.147	0.41	[0.37, 0.45]	0.10	[0.01, 0.18]	.156
Germany	2000	0.20	[0.15, 0.25]	.042	0.23	[0.19, 0.28]	0.06	[-0.01, 0.14]	.046
Hong Kong	2000	0.14	[0.10, 0.19]	.021	0.15	[0.10, 0.20]	0.01	[-0.04, 0.06]	.021
Hungary	2000	0.28	[0.24, 0.32]	.078	0.29	[0.25, 0.33]	0.07	[0.02, 0.12]	.084
Ireland	2000	0.10	[0.06, 0.15]	.011	0.11	[0.07, 0.16]	0.03	[-0.03, 0.08]	.012
Italy	2000	0.27	[0.23, 0.31]	.072	0.26	[0.22, 0.30]	-0.03	[-0.07, 0.02]	.073
Norway	2000	0.37	[0.33, 0.40]	.134	0.38	[0.34, 0.42]	0.05	[0.00, 0.10]	.136
Portugal	2000	0.30	[0.27, 0.34]	.092	0.31	[0.27, 0.35]	0.02	[-0.02, 0.07]	.093
Russian Federation	2000	0.27	[0.24, 0.31]	.073	0.27	[0.24, 0.31]	0.03	[-0.01, 0.07]	.074
Sweden	2000	0.33	[0.28, 0.37]	.107	0.35	[0.31, 0.39]	0.10	[0.06, 0.15]	.117
Weighted mean		0.27	[0.23, 0.31]	.075	0.28	[0.24, 0.32]	0.05	[0.03, 0.07]	.079

Table S24

Standardized Regression Coefficients from Linear and Quadratic Regression Models (Mathematics Self-Concept on Mathematics Achievement), Confidence Intervals (95% CI) and Explained Variance (R^2) in TIMSS (Grade 4) Controlling for Students' Gender

Country	Cycle	Linear model					Quadratic model						
		Linear effect		Gender effect		R^2	Linear effect		Quadratic effect		Gender effect		R^2
		β	95% CI	β	95% CI		β	95% CI	β	95% CI	β	95% CI	
Australia	2011	0.28	[0.25, 0.31]	0.10	[0.06, 0.13]	.089	0.29	[0.26, 0.32]	0.08	[0.05, 0.11]	0.09	[0.06, 0.12]	.096
	2015	0.44	[0.41, 0.47]	0.14	[0.10, 0.17]	.221	0.45	[0.41, 0.48]	0.08	[0.05, 0.11]	0.13	[0.10, 0.17]	.227
Austria	2011	0.33	[0.30, 0.37]	0.15	[0.12, 0.19]	.141	0.33	[0.30, 0.37]	-0.01	[-0.05, 0.02]	0.15	[0.12, 0.19]	.141
Czech Republic	2011	0.29	[0.24, 0.34]	0.13	[0.08, 0.17]	.107	0.31	[0.26, 0.35]	0.05	[-0.03, 0.14]	0.12	[0.08, 0.16]	.109
	2015	0.44	[0.42, 0.47]	0.11	[0.08, 0.15]	.215	0.45	[0.42, 0.48]	0.02	[0.00, 0.05]	0.11	[0.08, 0.15]	.215
Finland	2011	0.35	[0.31, 0.39]	0.19	[0.16, 0.22]	.168	0.37	[0.33, 0.40]	0.10	[0.05, 0.15]	0.18	[0.16, 0.21]	.178
	2015	0.46	[0.42, 0.49]	0.16	[0.12, 0.19]	.223	0.47	[0.44, 0.50]	0.07	[0.03, 0.10]	0.16	[0.12, 0.19]	.228
Germany	2011	0.34	[0.31, 0.37]	0.18	[0.15, 0.22]	.160	0.35	[0.32, 0.38]	0.06	[0.01, 0.11]	0.18	[0.15, 0.21]	.164
	2015	0.45	[0.42, 0.49]	0.16	[0.14, 0.19]	.238	0.45	[0.42, 0.49]	-0.02	[-0.06, 0.02]	0.16	[0.14, 0.19]	.238
Hong Kong	2011	0.29	[0.26, 0.33]	0.21	[0.18, 0.25]	.137	0.30	[0.26, 0.34]	0.04	[0.00, 0.08]	0.21	[0.18, 0.24]	.139
	2015	0.43	[0.38, 0.48]	0.17	[0.14, 0.20]	.227	0.44	[0.39, 0.49]	0.08	[0.04, 0.12]	0.17	[0.13, 0.20]	.233
Hungary	2011	0.45	[0.43, 0.48]	0.08	[0.06, 0.11]	.213	0.48	[0.45, 0.51]	0.06	[0.03, 0.10]	0.08	[0.05, 0.11]	.216
	2015	0.53	[0.50, 0.57]	0.11	[0.08, 0.14]	.298	0.55	[0.52, 0.58]	0.05	[-0.01, 0.10]	0.11	[0.08, 0.13]	.300
Ireland	2011	0.27	[0.23, 0.31]	0.07	[0.03, 0.11]	.080	0.29	[0.25, 0.33]	0.06	[0.02, 0.11]	0.07	[0.03, 0.11]	.084
	2015	0.45	[0.42, 0.48]	0.06	[0.03, 0.10]	.206	0.45	[0.42, 0.48]	0.01	[-0.02, 0.05]	0.06	[0.03, 0.10]	.206
Italy	2011	0.24	[0.20, 0.28]	0.08	[0.03, 0.12]	.066	0.25	[0.21, 0.29]	0.03	[-0.03, 0.10]	0.07	[0.03, 0.12]	.067
	2015	0.34	[0.30, 0.37]	0.09	[0.05, 0.12]	.129	0.34	[0.30, 0.37]	0.00	[-0.04, 0.03]	0.09	[0.05, 0.12]	.129
Norway	2011	0.42	[0.37, 0.46]	0.13	[0.09, 0.18]	.195	0.43	[0.38, 0.48]	0.08	[0.02, 0.13]	0.13	[0.08, 0.17]	.201
	2015	0.45	[0.41, 0.48]	0.06	[0.03, 0.10]	.203	0.45	[0.41, 0.48]	-0.01	[-0.05, 0.04]	0.06	[0.03, 0.10]	.203
Portugal	2011	0.32	[0.28, 0.35]	0.09	[0.05, 0.13]	.107	0.31	[0.28, 0.35]	-0.01	[-0.04, 0.03]	0.09	[0.06, 0.13]	.107
	2015	0.51	[0.49, 0.54]	0.13	[0.10, 0.16]	.290	0.51	[0.49, 0.54]	0.05	[0.01, 0.08]	0.13	[0.09, 0.16]	.293
Russian Federation	2011	0.26	[0.22, 0.29]	0.04	[0.01, 0.08]	.069	0.26	[0.23, 0.29]	0.05	[0.01, 0.09]	0.04	[0.00, 0.08]	.071
	2015	0.42	[0.39, 0.45]	0.10	[0.07, 0.13]	.186	0.42	[0.39, 0.45]	-0.02	[-0.05, 0.02]	0.10	[0.07, 0.13]	.187

(table continues)

Table S24 (Continued)

Country	Cycle	Linear model					Quadratic model						
		Linear effect		Gender effect		R^2	Linear effect		Quadratic effect		Gender effect		R^2
		β	95% CI	β	95% CI		β	95% CI	β	95% CI	β	95% CI	
Sweden	2011	0.26	[0.23, 0.30]	0.11	[0.08, 0.15]	.085	0.27	[0.23, 0.30]	0.03	[0.00, 0.06]	0.11	[0.08, 0.14]	.086
	2015	0.39	[0.36, 0.43]	0.06	[0.02, 0.10]	.159	0.40	[0.37, 0.44]	0.05	[0.00, 0.10]	0.06	[0.02, 0.10]	.161
Weighted mean		0.38	[0.34, 0.41]	0.12	[0.10, 0.14]	.168	0.38	[0.35, 0.42]	0.04	[0.02, 0.05]	0.12	[0.09, 0.14]	.170

Table S25

Standardized Regression Coefficients from Linear and Quadratic Regression Models (Mathematics Self-Concept on Mathematics Achievement), Confidence Intervals (95% CI) and Explained Variance (R^2) in TIMSS (Grade 8) Controlling for Students' Gender

Country	Cycle	Linear model					Quadratic model						
		Linear effect		Gender effect		R^2	Linear effect		Quadratic effect		Gender effect		R^2
		β	95% CI	β	95% CI		β	95% CI	β	95% CI	β	95% CI	
Australia	2011	0.54	[0.51, 0.57]	0.13	[0.10, 0.16]	.320	0.54	[0.50, 0.57]	0.03	[-0.03, 0.08]	0.13	[0.10, 0.16]	.321
	2015	0.53	[0.50, 0.55]	0.17	[0.14, 0.19]	.306	0.54	[0.51, 0.56]	0.10	[0.07, 0.14]	0.16	[0.14, 0.19]	.316
Finland	2011	0.63	[0.60, 0.66]	0.13	[0.10, 0.15]	.407	0.64	[0.62, 0.67]	0.13	[0.09, 0.17]	0.12	[0.10, 0.15]	.424
Hong Kong	2011	0.40	[0.35, 0.45]	0.22	[0.19, 0.26]	.206	0.47	[0.43, 0.51]	0.17	[0.09, 0.26]	0.22	[0.19, 0.25]	.231
	2015	0.38	[0.34, 0.42]	0.16	[0.13, 0.20]	.176	0.44	[0.39, 0.49]	0.16	[0.10, 0.23]	0.15	[0.11, 0.19]	.200
Hungary	2011	0.53	[0.49, 0.56]	0.10	[0.07, 0.13]	.292	0.62	[0.58, 0.65]	0.24	[0.19, 0.30]	0.09	[0.07, 0.12]	.344
	2015	0.55	[0.51, 0.58]	0.06	[0.04, 0.09]	.306	0.60	[0.57, 0.64]	0.17	[0.11, 0.22]	0.06	[0.03, 0.08]	.331
Ireland	2015	0.45	[0.41, 0.49]	0.09	[0.06, 0.12]	.215	0.51	[0.47, 0.54]	0.18	[0.11, 0.24]	0.08	[0.05, 0.12]	.243
Italy	2011	0.52	[0.49, 0.55]	0.12	[0.09, 0.15]	.295	0.53	[0.50, 0.57]	0.08	[0.04, 0.12]	0.12	[0.08, 0.15]	.301
	2015	0.50	[0.47, 0.53]	0.10	[0.07, 0.14]	.266	0.53	[0.50, 0.56]	0.12	[0.08, 0.16]	0.10	[0.07, 0.13]	.280
Norway	2011	0.64	[0.61, 0.67]	0.10	[0.07, 0.13]	.416	0.65	[0.62, 0.68]	0.06	[0.03, 0.10]	0.10	[0.07, 0.13]	.420
	2015	0.63	[0.61, 0.65]	0.15	[0.13, 0.18]	.417	0.64	[0.62, 0.66]	0.09	[0.05, 0.13]	0.15	[0.12, 0.17]	.425
Russian Federation	2011	0.49	[0.47, 0.52]	0.04	[0.01, 0.07]	.246	0.50	[0.47, 0.53]	0.04	[0.01, 0.08]	0.04	[0.00, 0.07]	.248
Sweden	2015	0.46	[0.42, 0.49]	0.05	[0.02, 0.08]	.215	0.46	[0.43, 0.50]	0.03	[-0.01, 0.06]	0.05	[0.02, 0.08]	.216
	2011	0.62	[0.60, 0.64]	0.15	[0.12, 0.17]	.396	0.63	[0.61, 0.65]	0.09	[0.06, 0.12]	0.15	[0.12, 0.17]	.405
	2015	0.60	[0.58, 0.63]	0.16	[0.12, 0.19]	.397	0.63	[0.60, 0.66]	0.15	[0.11, 0.19]	0.15	[0.12, 0.19]	.417
Weighted mean		0.53	[0.48, 0.58]	0.12	[0.09, 0.15]	.305	0.56	[0.52, 0.61]	0.12	[0.08, 0.15]	0.12	[0.09, 0.14]	.321

Table S26

Standardized Regression Coefficients from Linear and Quadratic Regression Models (Mathematics Self-Concept on Mathematics Achievement), Confidence Intervals (95% CI) and Explained Variance (R²) in PISA Controlling for Students' Gender

Country	Cycle	Linear model					Quadratic model						
		Linear effect		Gender effect		R ²	Linear effect		Quadratic effect		Gender effect		R ²
		β	95% CI	β	95% CI		β	95% CI	β	95% CI	β	95% CI	
Australia	2000	0.29	[0.22, 0.36]	0.12	[0.08, 0.16]	.096	0.31	[0.24, 0.37]	0.09	[0.01, 0.18]	0.11	[0.06, 0.17]	.106
	2003	0.45	[0.40, 0.49]	0.16	[0.14, 0.18]	.196	0.46	[0.41, 0.50]	0.07	[0.04, 0.11]	0.16	[0.13, 0.19]	.201
	2012	0.49	[0.46, 0.52]	0.18	[0.16, 0.20]	.232	0.49	[0.46, 0.52]	0.07	[0.05, 0.10]	0.17	[0.15, 0.19]	.238
Austria	2000	0.23	[0.16, 0.30]	0.12	[0.08, 0.17]	.066	0.26	[0.19, 0.33]	0.14	[0.07, 0.21]	0.13	[0.07, 0.18]	.081
	2003	0.35	[0.31, 0.40]	0.20	[0.17, 0.24]	.137	0.38	[0.33, 0.42]	0.10	[0.05, 0.16]	0.20	[0.15, 0.24]	.147
	2012	0.37	[0.31, 0.43]	0.16	[0.12, 0.20]	.158	0.41	[0.35, 0.46]	0.13	[0.07, 0.18]	0.17	[0.13, 0.22]	.168
Czech Republic	2000	0.29	[0.24, 0.35]	0.12	[0.08, 0.16]	.090	0.31	[0.26, 0.37]	0.08	[0.01, 0.16]	0.12	[0.07, 0.18]	.095
	2003	0.38	[0.33, 0.43]	0.15	[0.12, 0.18]	.184	0.43	[0.39, 0.47]	0.11	[0.05, 0.16]	0.17	[0.14, 0.21]	.189
	2012	0.46	[0.40, 0.53]	0.11	[0.08, 0.15]	.228	0.50	[0.44, 0.55]	0.07	[-0.02, 0.17]	0.12	[0.06, 0.17]	.232
Finland	2000	0.50	[0.43, 0.56]	0.16	[0.12, 0.19]	.251	0.53	[0.48, 0.58]	0.53	[0.47, 0.59]	0.16	[0.10, 0.22]	.271
	2003	0.60	[0.56, 0.64]	0.20	[0.18, 0.22]	.376	0.61	[0.57, 0.65]	0.13	[0.09, 0.17]	0.20	[0.18, 0.23]	.387
	2012	0.62	[0.58, 0.65]	0.20	[0.17, 0.23]	.341	0.60	[0.57, 0.64]	0.16	[0.11, 0.21]	0.19	[0.16, 0.22]	.365
Germany	2000	0.12	[0.05, 0.20]	0.20	[0.16, 0.25]	.069	0.18	[0.11, 0.26]	0.12	[0.04, 0.21]	0.22	[0.16, 0.28]	.078
	2003	0.30	[0.26, 0.35]	0.23	[0.20, 0.26]	.123	0.36	[0.31, 0.40]	0.16	[0.11, 0.21]	0.27	[0.23, 0.31]	.135
	2012	0.38	[0.31, 0.45]	0.23	[0.19, 0.26]	.169	0.41	[0.35, 0.47]	0.12	[0.06, 0.19]	0.23	[0.19, 0.28]	.180
Hong Kong	2000	0.19	[0.14, 0.25]	0.17	[0.12, 0.21]	.076	0.26	[0.19, 0.32]	0.14	[0.07, 0.21]	0.16	[0.11, 0.22]	.090
	2003	0.37	[0.31, 0.42]	0.16	[0.13, 0.20]	.151	0.40	[0.34, 0.46]	0.11	[0.05, 0.16]	0.15	[0.11, 0.19]	.162
	2012	0.38	[0.33, 0.43]	0.21	[0.17, 0.24]	.168	0.42	[0.37, 0.47]	0.11	[0.06, 0.16]	0.21	[0.17, 0.25]	.176
Hungary	2000	0.30	[0.23, 0.38]	0.05	[0.01, 0.10]	.074	0.32	[0.25, 0.38]	0.17	[0.11, 0.23]	0.07	[0.01, 0.13]	.094
	2003	0.26	[0.21, 0.32]	0.11	[0.07, 0.14]	.079	0.28	[0.23, 0.33]	0.14	[0.08, 0.20]	0.10	[0.06, 0.15]	.098
	2012	0.38	[0.32, 0.44]	0.13	[0.10, 0.17]	.153	0.42	[0.37, 0.47]	0.24	[0.17, 0.31]	0.13	[0.09, 0.17]	.203
Ireland	2000	0.23	[0.15, 0.31]	0.03	[-0.01, 0.07]	.058	0.31	[0.23, 0.38]	0.22	[0.11, 0.32]	0.06	[0.00, 0.11]	.086
	2003	0.37	[0.31, 0.42]	0.08	[0.05, 0.11]	.159	0.38	[0.33, 0.44]	0.09	[0.03, 0.15]	0.07	[0.03, 0.12]	.169
	2012	0.42	[0.36, 0.47]	0.11	[0.07, 0.14]	.174	0.44	[0.38, 0.49]	0.13	[0.07, 0.19]	0.09	[0.05, 0.13]	.193

(table continues)

Table S26 (Continued)

Country	Cycle	Linear model					Quadratic model						
		Linear effect		Gender effect		R^2	Linear effect		Quadratic effect		Gender effect		R^2
		β	95% CI	β	95% CI		β	95% CI	β	95% CI	β	95% CI	
Italy	2000	0.26	[0.21, 0.32]	0.06	[0.02, 0.11]	.069	0.28	[0.22, 0.34]	0.07	[0.00, 0.13]	0.06	[0.00, 0.11]	.075
	2003	0.29	[0.24, 0.33]	0.04	[0.01, 0.07]	.076	0.34	[0.29, 0.38]	0.09	[0.04, 0.13]	0.03	[0.00, 0.07]	.082
	2012	0.38	[0.35, 0.41]	0.09	[0.07, 0.11]	.128	0.41	[0.38, 0.44]	0.10	[0.07, 0.14]	0.08	[0.06, 0.11]	.138
Norway	2000	0.46	[0.41, 0.52]	0.20	[0.15, 0.24]	.240	0.51	[0.45, 0.56]	0.19	[0.09, 0.28]	0.21	[0.15, 0.26]	.262
	2003	0.61	[0.57, 0.65]	0.19	[0.16, 0.22]	.361	0.63	[0.58, 0.67]	0.17	[0.13, 0.22]	0.18	[0.15, 0.22]	.388
	2012	0.67	[0.63, 0.71]	0.14	[0.11, 0.17]	.397	0.68	[0.64, 0.71]	0.14	[0.09, 0.19]	0.14	[0.10, 0.18]	.413
Portugal	2000	0.26	[0.19, 0.32]	0.04	[0.00, 0.08]	.056	0.31	[0.25, 0.37]	0.14	[0.07, 0.21]	0.02	[-0.03, 0.08]	.079
	2003	0.45	[0.40, 0.49]	0.08	[0.04, 0.12]	.161	0.46	[0.41, 0.51]	0.14	[0.09, 0.19]	0.05	[0.01, 0.09]	.186
	2012	0.49	[0.44, 0.54]	0.10	[0.07, 0.14]	.214	0.51	[0.46, 0.55]	0.15	[0.09, 0.22]	0.10	[0.05, 0.14]	.236
Russian Federation	2000	0.30	[0.23, 0.37]	-0.04	[-0.11, 0.02]	.074	0.30	[0.23, 0.37]	0.01	[-0.05, 0.07]	-0.01	[-0.06, 0.03]	.076
	2003	0.33	[0.29, 0.38]	-0.08	[-0.14, -0.02]	.109	0.35	[0.30, 0.39]	0.09	[0.03, 0.15]	0.01	[-0.03, 0.05]	.116
	2012	0.38	[0.33, 0.42]	-0.07	[-0.12, -0.02]	.142	0.37	[0.33, 0.42]	0.08	[0.04, 0.13]	0.06	[0.02, 0.10]	.150
Sweden	2000	0.44	[0.39, 0.49]	0.19	[0.16, 0.23]	.192	0.48	[0.43, 0.53]	0.18	[0.13, 0.23]	0.19	[0.14, 0.23]	.228
	2003	0.54	[0.49, 0.58]	0.16	[0.13, 0.19]	.277	0.55	[0.51, 0.60]	0.14	[0.10, 0.19]	0.16	[0.12, 0.20]	.295
	2012	0.54	[0.50, 0.58]	0.18	[0.15, 0.20]	.270	0.54	[0.50, 0.58]	0.11	[0.05, 0.17]	0.17	[0.14, 0.21]	.283
Weighted mean		0.39	[0.34, 0.44]	0.13	[0.09, 0.17]	.168	0.42	[0.37, 0.47]	0.13	[0.11, 0.16]	0.13	[0.10, 0.17]	.183

Table S27

Standardized Regression Coefficients from Linear and Quadratic Regression Models (Reading Self-Concept on Reading Achievement), Confidence Intervals (95% CI) and Explained Variance (R^2) in PIRLS Controlling for Students' Gender

Country	Cycle	Linear model					Quadratic model						
		Linear effect		Gender effect		R^2	Linear effect		Quadratic effect		Gender effect		R^2
		β	95% CI	β	95% CI		β	95% CI	β	95% CI	β	95% CI	
Australia	2011	0.50	[0.47, 0.53]	-0.03	[-0.06, 0.00]	.254	0.49	[0.46, 0.53]	-0.02	[-0.05, 0.01]	-0.03	[-0.06, 0.00]	.254
	2016	0.56	[0.54, 0.59]	0.00	[-0.02, 0.03]	.315	0.55	[0.53, 0.58]	-0.04	[-0.07, -0.01]	0.00	[-0.02, 0.03]	.317
Austria	2011	0.39	[0.35, 0.42]	-0.11	[-0.14, -0.08]	.166	0.38	[0.35, 0.41]	-0.03	[-0.06, 0.01]	-0.11	[-0.14, -0.08]	.167
	2016	0.42	[0.39, 0.45]	-0.06	[-0.09, -0.03]	.182	0.42	[0.40, 0.45]	0.01	[-0.03, 0.05]	-0.06	[-0.09, -0.03]	.183
Czech Republic	2011	0.42	[0.38, 0.46]	-0.03	[-0.06, 0.00]	.180	0.43	[0.38, 0.47]	0.01	[-0.05, 0.07]	-0.03	[-0.06, 0.00]	.180
	2016	0.43	[0.40, 0.46]	-0.01	[-0.05, 0.02]	.187	0.43	[0.40, 0.46]	-0.01	[-0.06, 0.04]	-0.01	[-0.05, 0.02]	.188
Finland	2011	0.40	[0.36, 0.44]	-0.04	[-0.07, -0.01]	.169	0.40	[0.36, 0.44]	-0.02	[-0.06, 0.03]	-0.04	[-0.07, -0.01]	.169
	2016	0.44	[0.41, 0.47]	-0.03	[-0.06, 0.00]	.195	0.43	[0.41, 0.46]	0.00	[-0.04, 0.03]	-0.03	[-0.06, 0.00]	.195
Germany	2011	0.42	[0.39, 0.45]	-0.07	[-0.11, -0.03]	.185	0.42	[0.39, 0.45]	-0.01	[-0.05, 0.03]	-0.07	[-0.11, -0.03]	.185
	2016	0.46	[0.41, 0.51]	-0.04	[-0.08, 0.00]	.216	0.44	[0.40, 0.48]	-0.04	[-0.09, 0.02]	-0.04	[-0.08, 0.00]	.217
Hong Kong	2011	0.37	[0.33, 0.40]	-0.11	[-0.14, -0.07]	.156	0.38	[0.34, 0.41]	0.04	[0.01, 0.07]	-0.11	[-0.14, -0.07]	.157
	2016	0.40	[0.37, 0.44]	-0.06	[-0.09, -0.03]	.168	0.42	[0.38, 0.45]	0.05	[0.00, 0.09]	-0.06	[-0.09, -0.03]	.170
Hungary	2011	0.52	[0.48, 0.55]	-0.08	[-0.11, -0.05]	.284	0.53	[0.49, 0.56]	0.02	[-0.03, 0.06]	-0.08	[-0.11, -0.05]	.285
	2016	0.51	[0.47, 0.54]	0.01	[-0.02, 0.04]	.257	0.50	[0.46, 0.53]	-0.03	[-0.06, 0.00]	0.01	[-0.02, 0.04]	.258
Ireland	2011	0.43	[0.40, 0.46]	0.02	[-0.02, 0.06]	.181	0.43	[0.39, 0.46]	-0.01	[-0.05, 0.03]	0.02	[-0.02, 0.06]	.181
	2016	0.46	[0.43, 0.49]	0.01	[-0.03, 0.05]	.210	0.45	[0.41, 0.48]	-0.04	[-0.07, 0.00]	0.01	[-0.03, 0.05]	.212
Italy	2011	0.34	[0.30, 0.37]	-0.07	[-0.10, -0.04]	.121	0.34	[0.31, 0.37]	0.01	[-0.02, 0.05]	-0.08	[-0.10, -0.05]	.121
	2016	0.34	[0.30, 0.38]	-0.06	[-0.09, -0.03]	.122	0.33	[0.30, 0.36]	-0.05	[-0.09, -0.01]	-0.06	[-0.09, -0.02]	.124
Norway	2011	0.41	[0.37, 0.46]	0.02	[-0.03, 0.07]	.170	0.41	[0.37, 0.45]	-0.02	[-0.08, 0.04]	0.02	[-0.03, 0.07]	.170
	2016	0.48	[0.45, 0.51]	0.01	[-0.04, 0.05]	.229	0.47	[0.44, 0.50]	-0.06	[-0.11, -0.01]	0.01	[-0.04, 0.05]	.232
Portugal	2011	0.45	[0.42, 0.49]	-0.06	[-0.10, -0.02]	.215	0.45	[0.41, 0.49]	-0.01	[-0.05, 0.03]	-0.06	[-0.10, -0.02]	.216
	2016	0.44	[0.40, 0.47]	-0.06	[-0.09, -0.03]	.196	0.44	[0.40, 0.47]	-0.05	[-0.08, -0.01]	-0.06	[-0.08, -0.03]	.198
Russian Federation	2011	0.39	[0.35, 0.43]	-0.09	[-0.12, -0.06]	.170	0.39	[0.35, 0.43]	0.00	[-0.03, 0.04]	-0.09	[-0.12, -0.06]	.170
	2016	0.45	[0.41, 0.49]	-0.06	[-0.09, -0.04]	.212	0.43	[0.40, 0.47]	-0.05	[-0.09, -0.01]	-0.06	[-0.09, -0.04]	.214

(table continues)

Table S27 (Continued)

Country	Cycle	Linear model					Quadratic model						
		Linear effect		Gender effect		R^2	Linear effect		Quadratic effect		Gender effect		R^2
		β	95% CI	β	95% CI		β	95% CI	β	95% CI	β	95% CI	
Sweden	2011	0.42	[0.38, 0.45]	-0.04	[-0.07, -0.01]	.179	0.41	[0.38, 0.45]	-0.01	[-0.06, 0.03]	-0.04	[-0.07, -0.01]	.179
	2016	0.44	[0.41, 0.48]	0.01	[-0.02, 0.04]	.194	0.42	[0.39, 0.46]	-0.08	[-0.11, -0.05]	0.01	[-0.02, 0.04]	.200
Weighted mean		0.43	[0.41, 0.46]	-0.04	[-0.06, -0.02]	.196	0.43	[0.41, 0.46]	-0.02	[-0.03, 0.00]	-0.04	[-0.06, -0.02]	.197

Table S28

Standardized Regression Coefficients from Linear and Quadratic Regression Models (Verbal Self-Concept on Reading Achievement), Confidence Intervals (95% CI) and Explained Variance (R^2) in PISA Controlling for Students' Gender

Country	Cycle	Linear model					Quadratic model						
		Linear effect		Gender effect		R^2	Linear effect		Quadratic effect		Gender effect		R^2
		β	95% CI	β	95% CI		β	95% CI	β	95% CI	β	95% CI	
Australia	2000	0.28	[0.33, -0.04]	-0.04	[0.01, 0.08]	.082	0.28	[0.34, 0.05]	0.05	[0.10, -0.04]	-0.04	[0.01, 0.09]	.085
Austria	2000	0.24	[0.28, -0.15]	-0.15	[-0.11, 0.09]	.094	0.25	[0.29, 0.07]	0.07	[0.11, -0.15]	-0.15	[-0.11, 0.10]	.099
Czech Republic	2000	0.24	[0.29, -0.13]	-0.13	[-0.08, 0.09]	.085	0.26	[0.31, 0.07]	0.07	[0.13, -0.13]	-0.13	[-0.08, 0.09]	.090
Finland	2000	0.35	[0.39, -0.13]	-0.13	[-0.08, 0.16]	.162	0.37	[0.41, 0.09]	0.09	[0.16, -0.12]	-0.12	[-0.08, 0.17]	.169
Germany	2000	0.18	[0.23, -0.17]	-0.17	[-0.12, 0.07]	.069	0.20	[0.25, 0.06]	0.06	[0.13, -0.16]	-0.16	[-0.12, 0.07]	.072
Hong Kong	2000	0.14	[0.18, -0.09]	-0.09	[-0.04, 0.03]	.028	0.14	[0.19, 0.01]	0.01	[0.06, -0.09]	-0.09	[-0.04, 0.03]	.029
Hungary	2000	0.26	[0.30, -0.12]	-0.12	[-0.07, 0.09]	.092	0.27	[0.31, 0.07]	0.07	[0.12, -0.12]	-0.12	[-0.07, 0.10]	.097
Ireland	2000	0.10	[0.14, -0.05]	-0.05	[-0.01, 0.01]	.014	0.10	[0.15, 0.03]	0.03	[0.08, -0.05]	-0.05	[-0.01, 0.02]	.015
Italy	2000	0.23	[0.27, -0.15]	-0.15	[-0.10, 0.10]	.095	0.23	[0.27, -0.03]	-0.03	[0.02, -0.15]	-0.15	[-0.10, 0.10]	.095
Norway	2000	0.34	[0.38, -0.13]	-0.13	[-0.08, 0.15]	.149	0.35	[0.39, 0.06]	0.06	[0.11, -0.13]	-0.13	[-0.08, 0.15]	.152
Portugal	2000	0.29	[0.33, -0.12]	-0.12	[-0.08, 0.11]	.107	0.30	[0.33, 0.02]	0.02	[0.07, -0.12]	-0.12	[-0.08, 0.11]	.108
Russian Federation	2000	0.23	[0.27, -0.18]	-0.18	[-0.14, 0.10]	.104	0.24	[0.27, 0.04]	0.04	[0.08, -0.18]	-0.18	[-0.14, 0.11]	.105
Sweden	2000	0.30	[0.35, -0.13]	-0.13	[-0.09, 0.12]	.123	0.33	[0.37, 0.10]	0.10	[0.14, -0.13]	-0.13	[-0.09, 0.13]	.133
Weighted mean		0.25	[0.32, -0.12]	-0.12	[-0.10, 0.09]	.091	0.26	[0.30, 0.05]	0.05	[0.07, -0.12]	-0.12	[-0.10, 0.10]	.095

Table S29

Results from Interrupted Regressions (Mathematics Self-Concept on Mathematics Achievement) for TIMSS (Grade 4) with 95% Confidence Intervals (95% CI)

Country	Cycle	β_1	95% CI	β_2	95% CI	Breakpoint	% _{NFC}
Australia	2011	0.01	[-0.16, 0.17]	0.36	[0.30, 0.41]	-1.00	16
	2015	0.27	[-0.16, 0.69]	0.44	[0.18, 0.71]	-0.05	48
Austria	2011	0.36	[0.30, 0.41]	0.22	[0.04, 0.41]	1.19	12
Czech Republic	2011	0.28	[0.21, 0.36]	0.19	[-0.05, 0.43]	1.14	13
	2015	0.45	[0.40, 0.50]	0.38	[0.06, 0.70]	1.20	11
Finland	2011	-0.13	[-0.39, 0.13]	0.46	[0.41, 0.52]	-1.04	15
	2015	0.39	[0.18, 0.61]	0.29	[-0.04, 0.62]	0.90	18
Germany	2011	0.24	[-0.20, 0.68]	0.34	[0.18, 0.49]	0.72	24
	2015	0.47	[0.41, 0.54]	0.23	[0.01, 0.46]	1.19	12
Hong Kong	2011	0.16	[-0.19, 0.50]	0.28	[-0.02, 0.58]	0.16	44
	2015	0.10	[-0.19, 0.39]	0.50	[0.37, 0.63]	-0.97	17
Hungary	2011	0.43	[0.39, 0.47]	0.27	[0.12, 0.42]	1.15	13
	2015	0.53	[0.44, 0.62]	0.27	[0.06, 0.47]	1.15	12
Ireland	2011	0.11	[-0.09, 0.31]	0.35	[0.29, 0.41]	-0.94	17
	2015	0.46	[0.40, 0.51]	0.33	[0.04, 0.61]	1.16	12
Italy	2011	0.25	[0.20, 0.30]	0.33	[0.10, 0.55]	1.17	12
	2015	0.36	[0.29, 0.43]	0.21	[-0.02, 0.44]	1.16	12
Norway	2011	0.22	[0.04, 0.39]	0.23	[-0.13, 0.58]	0.96	17
	2015	0.46	[0.39, 0.53]	0.25	[0.04, 0.46]	1.18	12
Portugal	2011	-0.03	[-0.28, 0.23]	0.48	[0.24, 0.71]	-0.95	17
	2015	0.51	[0.45, 0.57]	0.25	[-0.02, 0.52]	1.24	11
Russian Federation	2011	0.34	[0.28, 0.39]	0.21	[0.00, 0.43]	1.13	13
	2015	0.45	[0.38, 0.52]	0.27	[-0.07, 0.62]	1.14	13
Sweden	2011	0.06	[-0.35, 0.48]	0.31	[0.26, 0.36]	-1.15	13
	2015	0.38	[0.29, 0.47]	0.30	[0.02, 0.58]	1.17	12
Weighted mean		0.32	[0.26, 0.39]	0.34	[0.29, 0.38]		17

Note. %_{NFC} = Percentage of students for which a single linear regression coefficient did **not** fully capture the relation between achievement and the corresponding measure of self-concept.

Table S30

Results from Interrupted Regressions (Mathematics Self-Concept on Mathematics Achievement) for TIMSS (Grade 8) with 95% Confidence Intervals (95% CI)

Country	Cycle	β_1	95% CI	β_2	95% CI	Breakpoint	% _{NFC}
Australia	2011	0.57	[0.51, 0.63]	0.19	[-0.07, 0.45]	1.25	10
	2015	0.10	[-0.17, 0.38]	0.66	[0.58, 0.73]	-1.21	11
Finland	2011	-0.08	[-0.26, 0.10]	0.76	[0.72, 0.80]	-1.09	14
Hong Kong	2011	-0.06	[-0.39, 0.28]	0.55	[0.50, 0.61]	-1.17	12
	2015	-0.13	[-0.32, 0.05]	0.57	[0.47, 0.66]	-1.03	15
Hungary	2011	-0.02	[-0.15, 0.10]	0.76	[0.69, 0.82]	-0.92	18
	2015	0.02	[-0.19, 0.23]	0.70	[0.62, 0.78]	-1.02	15
Ireland	2015	-0.05	[-0.36, 0.25]	0.59	[0.52, 0.65]	-1.19	12
Italy	2011	0.51	[0.45, 0.57]	0.30	[0.08, 0.53]	1.21	11
	2015	0.11	[-0.21, 0.43]	0.61	[0.54, 0.68]	-1.18	12
Norway	2011	0.64	[0.60, 0.68]	0.39	[0.21, 0.57]	1.21	11
	2015	0.61	[0.57, 0.66]	0.40	[0.22, 0.57]	1.22	11
Russian Federation	2011	0.48	[0.44, 0.53]	0.44	[0.23, 0.65]	1.21	11
	2015	0.46	[0.39, 0.53]	0.44	[0.08, 0.79]	1.19	12
Sweden	2011	0.59	[0.55, 0.62]	0.54	[0.37, 0.71]	1.22	11
	2015	0.04	[-0.30, 0.37]	0.73	[0.67, 0.80]	-1.22	11
Weighted mean		0.25	[0.08, 0.42]	0.58	[0.50, 0.66]		12

Note. %_{NFC} = Percentage of students for which a single linear regression coefficient did **not** fully capture the relation between achievement and the corresponding measure of self-concept.

Table S31

Results from Interrupted Regressions (Mathematics Self-Concept on Mathematics Achievement) for PISA with 95% Confidence Intervals (95% CI)

Country	Cycle	β_1	95% CI	β_2	95% CI	Breakpoint	% _{NFC}
Australia	2000	-0.13	[-0.32, 0.06]	0.37	[0.33, 0.42]	-1.04	15
	2003	0.22	[0.11, 0.34]	0.49	[0.47, 0.52]	-1.19	12
	2012	0.10	[-0.07, 0.27]	0.52	[0.49, 0.54]	-1.18	12
Austria	2000	0.00	[-0.17, 0.17]	0.37	[0.30, 0.44]	-0.65	26
	2003	0.02	[-0.12, 0.15]	0.37	[0.33, 0.40]	-1.10	14
	2012	0.11	[-0.11, 0.32]	0.43	[0.38, 0.48]	-1.06	14
Czech Republic	2000	0.00	[-0.32, 0.32]	0.36	[0.28, 0.44]	-0.74	23
	2003	0.37	[0.17, 0.57]	0.53	[0.11, 0.96]	1.05	15
	2012	0.40	[0.06, 0.74]	0.57	[0.26, 0.87]	0.94	17
Finland	2000	0.03	[-0.15, 0.21]	0.60	[0.57, 0.63]	-1.09	14
	2003	0.08	[-0.30, 0.46]	0.66	[0.50, 0.83]	-0.84	20
	2012	-0.01	[-0.16, 0.14]	0.72	[0.68, 0.76]	-1.03	15
Germany	2000	-0.05	[-0.20, 0.10]	0.27	[0.22, 0.32]	-0.71	24
	2003	0.20	[-0.07, 0.46]	0.32	[0.28, 0.37]	-1.08	14
	2012	0.03	[-0.21, 0.28]	0.41	[0.37, 0.46]	-1.12	13
Hong Kong	2000	-0.15	[-0.24, -0.06]	0.37	[0.33, 0.42]	-0.75	23
	2003	0.02	[-0.11, 0.16]	0.45	[0.42, 0.48]	-1.15	13
	2012	0.02	[-0.14, 0.17]	0.44	[0.41, 0.47]	-1.17	12
Hungary	2000	0.04	[-0.10, 0.18]	0.39	[0.29, 0.50]	-0.63	26
	2003	-0.06	[-0.13, 0.02]	0.41	[0.35, 0.46]	-0.68	25
	2012	-0.10	[-0.25, 0.04]	0.62	[0.53, 0.70]	-0.61	27
Ireland	2000	-0.12	[-0.28, 0.04]	0.41	[0.35, 0.47]	-0.67	25
	2003	0.06	[-0.11, 0.24]	0.47	[0.44, 0.50]	-1.12	13
	2012	0.13	[0.00, 0.25]	0.50	[0.47, 0.54]	-1.11	13
Italy	2000	0.03	[-0.14, 0.19]	0.32	[0.27, 0.37]	-0.94	17
	2003	0.10	[0.01, 0.20]	0.32	[0.30, 0.35]	-1.21	11
	2012	0.01	[-0.10, 0.12]	0.40	[0.38, 0.43]	-1.22	11
Norway	2000	-0.09	[-0.27, 0.09]	0.63	[0.56, 0.69]	-0.87	19
	2003	-0.07	[-0.28, 0.15]	0.71	[0.67, 0.74]	-1.10	13
	2012	0.18	[0.03, 0.32]	0.70	[0.67, 0.73]	-1.19	12
Portugal	2000	-0.07	[-0.19, 0.05]	0.41	[0.36, 0.47]	-0.54	30
	2003	-0.11	[-0.21, -0.01]	0.52	[0.50, 0.55]	-0.98	16
	2012	-0.02	[-0.24, 0.20]	0.56	[0.52, 0.60]	-1.04	15
Russian Federation	2000	0.12	[-0.27, 0.51]	0.23	[0.06, 0.41]	0.08	47
	2003	0.08	[-0.04, 0.20]	0.40	[0.37, 0.42]	-1.13	13
	2012	0.13	[-0.08, 0.35]	0.44	[0.38, 0.51]	-0.96	17
Sweden	2000	-0.05	[-0.16, 0.07]	0.60	[0.55, 0.64]	-0.83	20
	2003	0.07	[-0.11, 0.26]	0.60	[0.57, 0.63]	-1.15	12
	2012	0.15	[-0.04, 0.33]	0.58	[0.54, 0.62]	-1.07	14
Weighted mean		0.03	[-0.01, 0.07]	0.47	[0.41, 0.53]		16

Note. %_{NFC} = Percentage of students for which a single linear regression coefficient did not fully capture the relation between achievement and the corresponding measure of self-concept.

Table S32

*Results from Interrupted Regressions (Reading Self-Concept on Reading Achievement)
for PIRLS with 95% Confidence Intervals (95% CI)*

Country	Cycle	β_1	95% CI	β_2	95% CI	Breakpoint	% _{NFC}
Australia	2011	0.53	[0.49, 0.58]	0.31	[0.10, 0.52]	1.14	13
	2016	0.61	[0.57, 0.66]	0.18	[-0.05, 0.40]	1.12	13
Austria	2011	0.41	[0.37, 0.46]	0.30	[0.06, 0.53]	1.16	12
	2016	0.45	[0.38, 0.52]	0.15	[-0.11, 0.41]	1.14	13
Czech Republic	2011	0.44	[0.38, 0.50]	0.37	[0.11, 0.63]	1.13	13
	2016	0.44	[0.37, 0.52]	0.17	[-0.04, 0.38]	1.14	13
Finland	2011	0.42	[0.37, 0.48]	0.18	[-0.08, 0.43]	1.18	12
	2016	0.47	[0.40, 0.53]	0.30	[0.06, 0.53]	1.13	13
Germany	2011	0.44	[0.38, 0.49]	0.25	[0.04, 0.46]	1.17	12
	2016	0.47	[0.40, 0.54]	0.31	[0.09, 0.54]	1.14	13
Hong Kong	2011	0.39	[0.34, 0.43]	0.31	[0.06, 0.57]	1.12	13
	2016	0.39	[0.33, 0.46]	0.27	[-0.07, 0.61]	1.12	13
Hungary	2011	0.53	[0.49, 0.58]	0.35	[0.19, 0.51]	1.12	13
	2016	0.52	[0.46, 0.58]	0.31	[0.12, 0.50]	1.15	12
Ireland	2011	0.44	[0.39, 0.50]	0.28	[0.05, 0.51]	1.16	12
	2016	0.48	[0.41, 0.55]	0.21	[-0.09, 0.52]	1.14	13
Italy	2011	0.34	[0.29, 0.38]	0.36	[0.06, 0.67]	1.18	12
	2016	0.37	[0.30, 0.43]	0.24	[-0.06, 0.54]	1.15	13
Norway	2011	0.43	[0.37, 0.49]	0.33	[0.06, 0.60]	1.16	12
	2016	0.53	[0.46, 0.61]	0.24	[0.02, 0.46]	1.15	13
Portugal	2011	0.47	[0.42, 0.52]	0.20	[-0.09, 0.50]	1.17	12
	2016	0.46	[0.40, 0.53]	0.15	[-0.15, 0.46]	1.20	11
Russian Federation	2011	0.41	[0.36, 0.47]	0.27	[0.06, 0.49]	1.14	13
	2016	0.49	[0.42, 0.57]	0.26	[0.04, 0.49]	1.15	13
Sweden	2011	0.43	[0.38, 0.48]	0.28	[0.07, 0.49]	1.17	12
	2016	0.50	[0.42, 0.57]	0.24	[0.01, 0.47]	1.11	13
Weighted mean		0.45	[0.42, 0.48]	0.27	[0.22, 0.31]		13

Note. %_{NFC} = Percentage of students for which a single linear regression coefficient did **not** fully capture the relation between achievement and the corresponding measure of self-concept.

Table S33

Results from Interrupted Regressions (Verbal Self-Concept on Reading Achievement) for PISA with 95% Confidence Intervals (95% CI)

Country	Cycle	β_1	95% CI	β_2	95% CI	Breakpoint	% _{NFC}
Australia	2000	0.24	[-0.01, 0.49]	0.16	[-0.28, 0.60]	0.88	19
Austria	2000	0.05	[-0.20, 0.29]	0.34	[0.29, 0.39]	-0.98	16
Czech Republic	2000	0.09	[-0.27, 0.44]	0.29	[0.05, 0.53]	-0.10	46
Finland	2000	0.20	[-0.22, 0.62]	0.29	[-0.15, 0.74]	0.14	44
Germany	2000	0.09	[-0.12, 0.29]	0.22	[0.05, 0.38]	-0.76	22
Hong Kong	2000	0.13	[0.05, 0.21]	0.20	[-0.11, 0.50]	0.77	22
Hungary	2000	0.10	[-0.11, 0.31]	0.33	[0.27, 0.38]	-1.00	16
Ireland	2000	0.08	[-0.06, 0.23]	0.21	[-0.17, 0.59]	-0.43	33
Italy	2000	0.29	[0.26, 0.33]	0.24	[-0.05, 0.54]	1.07	14
Norway	2000	0.34	[0.19, 0.48]	0.30	[0.05, 0.56]	0.96	17
Portugal	2000	0.29	[0.26, 0.32]	0.16	[-0.09, 0.40]	1.14	13
Russian Federation	2000	0.25	[0.22, 0.28]	0.23	[-0.01, 0.48]	1.21	11
Sweden	2000	0.03	[-0.18, 0.24]	0.43	[0.39, 0.46]	-1.09	14
Weighted mean		0.20	[0.14, 0.26]	0.32	[0.25, 0.39]		22

Note. %_{NFC} = Percentage of students for which a single linear regression coefficient did **not** fully capture the relation between achievement and the corresponding measure of self-concept.

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