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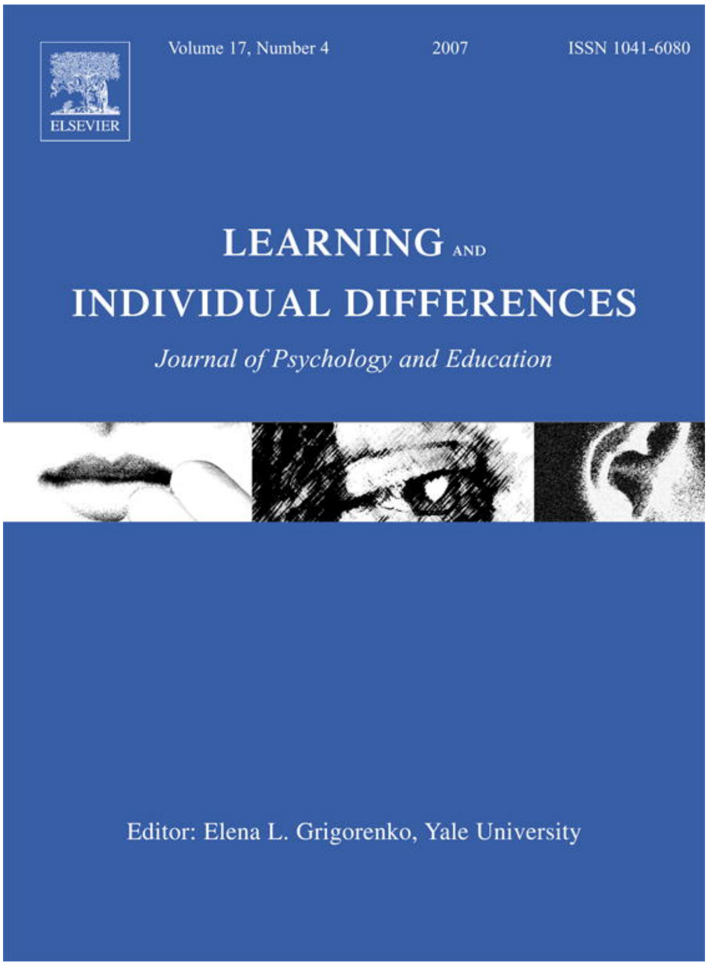
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Universals and specifics in learning strategies: Explaining adolescent mathematics, science, and reading achievement across 34 countries ☆

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Abstract

We examined whether strategies of memorization, transfer through elaboration, and metacognition accounted for reading, science, and mathematics achievement across 34 countries. 158,848 fifteen-year-olds completed a reading literacy test and a questionnaire. Of these students, 88,401 completed a science test, and 88,590 completed a mathematics test. We analyzed the data using multi-level regressions of Rasch-estimated test scores and modeled differences across countries and across schools. Students who reported using memorization strategies often scored lower in all subjects. Transfer through elaboration was not significantly linked to any achievement scores. Lastly, students reporting greater use of metacognitive strategies often scored higher. Compared to students in individualistic societies, to achievement scores of students in collective cultures were linked more strongly to schoolmates' use of metacognitive strategies and less strongly to their own use of metacognitive strategies. These results highlight how cultural contexts can moderate the links between adolescents' learning strategies and their academic achievement.

Keywords: Cultural differences; Learning strategies; Social environment; Economic factors; Secondary school students

Many educators agree that students' optimal learning should include reflective thinking and minimize rote memorization (e.g., Bloom, 1956; Bransford, Sherwood, Vye, & Rieser, 1986; Halpern, 1998; Snow, 2002). Nevertheless, teachers in many countries encourage students to learn by rote, and several researchers have touted its effectiveness in Asian cultures (e.g., Gow, Balla, & Hau, 1996). Though learning and achievement can differ substantially across countries (e.g., Gow et al., 1996; Politzer & McGroarty, 1985; Tharp, 1989), relatively little is known about the processes contributing to these differences. For instance, how various country-level factors and their links with students' learning strategies might influence student achievement remain open questions. Thus, this study examined how country properties (country income, inequality, and cultural values) and learning strategies (rote memorization, transfer through elaboration, and metacognition) might affect the academic achievement of 15-year-olds in 34 countries. Findings can show whether country properties or learning strategies are linked to student achievement

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and whether these learning strategies are universal or differ systematically along countries' economic or cultural dimensions. Hence, these results can help students choose suitable strategies to learn more.

1. Learning strategies

Learning strategies refer to the mental processes which help learners understand new information. Past studies have shown that students who use learning strategies that are more sophisticated typically show higher achievement (e.g., Lau & Chan, 2001; Valentine, DuBois & Cooper, 2004; Vermunt & Vermetten, 2004). For example, seventh grade students who more often used cognitive and metacognitive strategies, such as summarization and reading monitoring, scored higher in reading (Lau & Chan, 2003). Likewise, compared to regular students, gifted students more often used self-regulated learning strategies (e.g., organize information, transform information, seek peer assistance, review notes; in Zimmerman and Martinez-Pons's (1990) study of 5th, 8th and 11th graders). Thus, some strategies promote learning more effectively than others.

1.1. Memorization

Although researchers have devised various classification systems for learning strategies (e.g., Kang, 1997; Oxford, 1990), nearly all of them include surface cognitive strategies, deep cognitive strategies (Gall, Gall, Jacobsen, & Bullock, 1990; Pintrich, 1988), and metacognitive strategies (Yildirim, 1998). Surface cognitive strategies refer to memorization skills, of which the most common is rehearsal (which includes repeating and reciting, e.g., Craik & Watkins, 1973; Nolen, 1988; Graham & Golan, 1991). As memorizing information adds to one's knowledge base, especially during its early development, strategies that enhance memory performance are important for learning (Bloom, 1956; Kantrowitz & Wingert, 1991). For example, memorization of mathematics rules fosters the mastery of basic mathematics skills, which provide a foundation to help students to solve more complex mathematics problems (Kantrowitz & Wingert, 1991).

However, some researchers have argued that rote memorization might make delayed retrieval more difficult, especially in complex tasks (Czuchry & Dansereau, 1998). Thus, relying too much on rote memorization can adversely affect academic achievement (e.g., Isaacs & Carroll, 1999). Therefore, researchers from different cultures tend to stress the importance of minimizing rote learning and emphasizing deeper level learning strategies (e.g., Morrison & Tang, 2002; Skuy, Fridjhon, & O'Carroll, 1998). One possible way of increasing learning is to transfer previously learned information to new situations through elaboration, a deep cognitive strategy.

1.2. Elaboration

Elaboration strategies are cognitive processes that link new and old information (e.g., paraphrase, compare and contrast concepts, use personal examples, and so on). These strategies create more ways to access or recall the linked information. Furthermore, elaboration strategies help students process information more deeply and flexibly transform it to facilitate successful problem solving (Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Mayer, 1980; Stein, Morris, & Bransford, 1978). For instance, Chi, de Leeuw, Chiu, and Lavancher (1994) showed that self-explanation enhanced declarative knowledge acquisition of 8th graders. Likewise, Wong, Lawson, and Keeves (2002) demonstrated that self-explanation facilitated 9th graders' problem solving in mathematics. Students who use elaboration strategies tend to learn more and develop more coherent understanding of concepts, compared to those who rely on rote memorization (e.g., BouJaoude, 1992). Thus, researchers often recommend teaching elaboration strategies to students to improve their problem solving and to facilitate application of their knowledge to new problems (*transfer*; Bransford et al., 1986; Halpern, 1998).

However, facilitating transfer through elaboration is difficult to achieve and requires effort and concentration, as shown in many studies of problem-solving (e.g., Bransford et al., 1986; Halpern, 1998). When teachers do not give strong prompts or do not explicitly demonstrate how to apply previously learned knowledge and strategies to new situations, such transfer often fails to occur (Bransford et al., 1986; Garner, 1990). Indeed, even faced with problems that are conceptually similar to earlier ones, students without specific transfer training rarely use elaboration strategies to transfer previously learned knowledge (Bransford et al., 1986; Halpern, 1998). Perhaps one key to the problem of transfer is metacognition (Bransford et al., 1986; Halpern, 1998).

1.3. Metacognition

Metacognition is the knowledge and regulation of one's cognition (Hacker, 1998). Specifically, metacognitive knowledge is the understanding of one's memory and learning, and regulation refers to control and manipulation of one's cognition. Knowledge of cognition is a prerequisite for regulation of cognition for many researchers, (e.g., Baker, 1989). Metacognitive strategies involve planning and self-evaluation during learning, and they facilitate mastery of complex skills, such as language (Oxford et al., 1989). Metacognitive strategies do so by helping students identify specific learning goals, filter new information, and retrieve relevant information to fill in the knowledge gaps (Pichert & Anderson, 1977). Identifying learning goals and recognizing the required information can enhance deeper processing of target information and facilitate transfer.

Past intervention studies have shown that metacognitive instruction and practice in reflection, planning, and evaluation promote performance (Kincannon, Gleber, & Kim, 1999; Teong, 2003). For example, Zemira and Kramarski (2003) found that 8th graders who received metacognitive training performed better on mathematical tasks than their counterparts exposed to examples of problem solutions. Furthermore, this metacognitive training advantage persisted one year after the intervention.

However, learners often fail to use their metacognitive skills, resulting in incorrect answers to problems. As metacognitive processing requires extra cognitive demands, it is effortful. Thus, if students perceive a task as unimportant, they often do not use their metacognitive skills (Gardner, 1990). Also, many students do not use them if the task instructions do not ask them to do so (Gardner, 1990).

Teaching metacognitive skills to students can also be difficult due to metacognition's covert nature and student reluctance to changing their learning routines (Conner & Gunstone, 2004). As learning of metacognition is relatively covert, objective evaluation of these learning processes is arduous. Teaching metacognition is further complicated by learners' automatization of their own strategy use and reluctance in changing their roles to become active learners who reflect on their knowledge and actions.

Though cognitive strategies and metacognitive strategies are distinctive, they are often used together and enhance each other (Kang, 1997). Because they are relatively important to different aspects in the learning process, we examined the links between students' academic achievement in difference countries and their reported uses of these three learning strategies: rote memorization, transfer through elaboration, and metacognition.

2. Economic and cultural contexts

Apart from these individual level associations of learning strategies, a country's economy and cultural values provide a broad context in which students learn. As such, differences in economies and cultural values might affect students' academic achievement. Countries with higher real gross domestic product (GDP) per capita tend to foster higher student achievement both directly through education spending (e.g., books, teacher training, better curricula) and indirectly through higher nutritional standards or better health care (Heyneman & Loxley, 1983; Baker, Goesling, and Letendre, 2002; UNICEF, 2001).

Students in countries with more equal distribution of resources (e.g., income, rich schoolmates, certified teachers) also scored higher on measures of achievement than students in less equal countries due to diminishing marginal returns or homophily (Chiu, in press; Chiu & Khoo, 2005). Consider a thirsty woman and two glasses of water. She greatly values the first glass of water and drinks it all. Her thirst quenched, she does not value the second glass of water as much and does not finish it. This relatively lower value of the additional resource is diminishing marginal returns (Mankiw, 2004, p. 273). Hence, poorer students typically benefit more from an extra book than richer students do. With greater equality, poorer students have more resources and benefit more from them, resulting in higher education outcomes overall (Chiu & Khoo, 2005). As people prefer to interact with others of similar socio-economic status (*homophily*; McPherson, Smith-Lovin, & Cook, 2001), greater equality within a country might encourage greater cooperation among students, which would also result in higher overall academic performance (Chiu, in press).

Countries differ not only by wealth and degree of equality but also by their cultural values. Cultural values vary mostly across countries, as cultural values are linked more strongly to one's nation than to religion, employer organization, or individual personality (Hofstede et al., 1990; Inglehart & Baker, 2000). People learn these values through both formal socialization, via direct teachings of parents, teachers, and religious leaders, and informally via everyday exposure to customs, laws, norms and practices shaped by and expressing cultural values (Bourdieu, 1993; Markus and Kitayama, 1994).

Table 1
Two common dimensions from four frameworks of cultural values

Theoretical Framework	2 Dimensions of cultural values					
	Responsible societal behavior			Individual vs. group interests		
Hofstede	High power distance	↔	Low power distance	Collectivism	↔	Individual
Schwartz and Ros	Hierarchy	↔	Egalitarian	Embedded /conservative	↔	Autonomy
Smith, Dugan and Trompenaars	Loyal	↔	Utilitarian	Embedded /conservative	↔	Autonomy
Inglehart and Baker	Defer to authority	↔	Secular-rational	Survival	↔	Self-expression

All societies face two central issues: (a) how to induce responsible individual behavior to preserve the fabric of a society and (b) how to prioritize the interests of individuals and groups (Schwartz & Ros, 1995). A society might encourage responsible behavior by assigning clear, fixed hierarchical roles and by teaching its citizens to obey authority (hierarchy). Alternatively, a society may teach its members to view, value, and act towards one another as equals based on their common humanity (egalitarian). Not surprisingly, people in countries with more equal distributions of income tend to have egalitarian values (Inglehart & Baker, 2000). Likewise, society may prioritize group interest over individual interest (collectivist) or vice-versa (individualist).

Cross-country, quantitative studies based on different frameworks with various methods, participants, and at many time periods all yielded similar results. Although their terminologies differ, researchers created conceptually similar frameworks, and placed most countries in similar locations on a grid defined by these two dimensions: (a) hierarchy ↔ egalitarian and (b) collective ↔ individual (see Table 1; Hofstede, 1980, 2003; Schwartz & Ros, 1995; Smith & Bond, 1998; Smith, Dugan & Trompenaars, 1996; Inglehart & Baker, 2000). Factor analyses of questionnaire responses showed that these two dimensions accounted for 84% of the differences among nations and that other factors accounted for little variance (Smith et al., 1996). Therefore, we measure cultural values along these two dimensions in this study.

These economic properties and cultural values might account for country differences in students' reported use of learning strategies and in the links among learning strategies and academic achievement. For instance, metacognitive skills might be particularly prominent in less equal and more hierarchical countries. In these countries, students' access to educational resources (e.g., books, teacher support) varies substantially (Chiu & Khoo, 2005). Thus, underprivileged students who can use their metacognitive skills to identify and implement ways to obtain these resources might substantially improve their academic achievement. As resource differences among students are smaller in more equal or more egalitarian countries (Chiu & Khoo, 2005), metacognitive skills might be less beneficial to students in these countries (*lower-impact egalitarian metacognition* hypothesis).

Meanwhile, students in collectivist societies might cooperate, support, and learn from one another more than those in individualist societies (Hofstede, 2003). Thus, schoolmates' learning strategies, especially metacognitive strategies directed at schoolmates during group activities, might have a larger effect in collective societies (*collectivist schoolmate metacognition* hypothesis). At the same time, collectivist societies often discourage individuals from standing out (Hofstede, 2003), which might discourage individual student initiative and individual use of learning strategies (*individualistic metacognition* hypothesis).

3. The present study

In this study, we examined the links between academic achievement (mathematics, reading, science) and three learning strategies (memorization, transfer through elaboration, and metacognition) across various economic and cultural contexts (see Fig. 1). In particular, we addressed five major research questions. First, how do students' learning strategies affect their academic achievement? Second, how do schoolmates' learning strategies influence student performance on academic tasks? Third, at the country level, are country resources and equality of resource distribution linked to student achievement? Fourth, are cultural values linked to student achievement? Lastly, how do cultural values influence the links among student achievement, learning strategies and schoolmates' learning strategies?

To examine these research questions, we statistically controlled several variables: past achievement, self-efficacy, self-concept, and locus of control, percentage of GDP spent on public schools, immigrant status, language spoken at home, family SES, schoolmate SES, and gender. Past achievement was entered first in all regression analyses as a control variable to explain improvement between past and present achievement, namely learning (Goldstein &

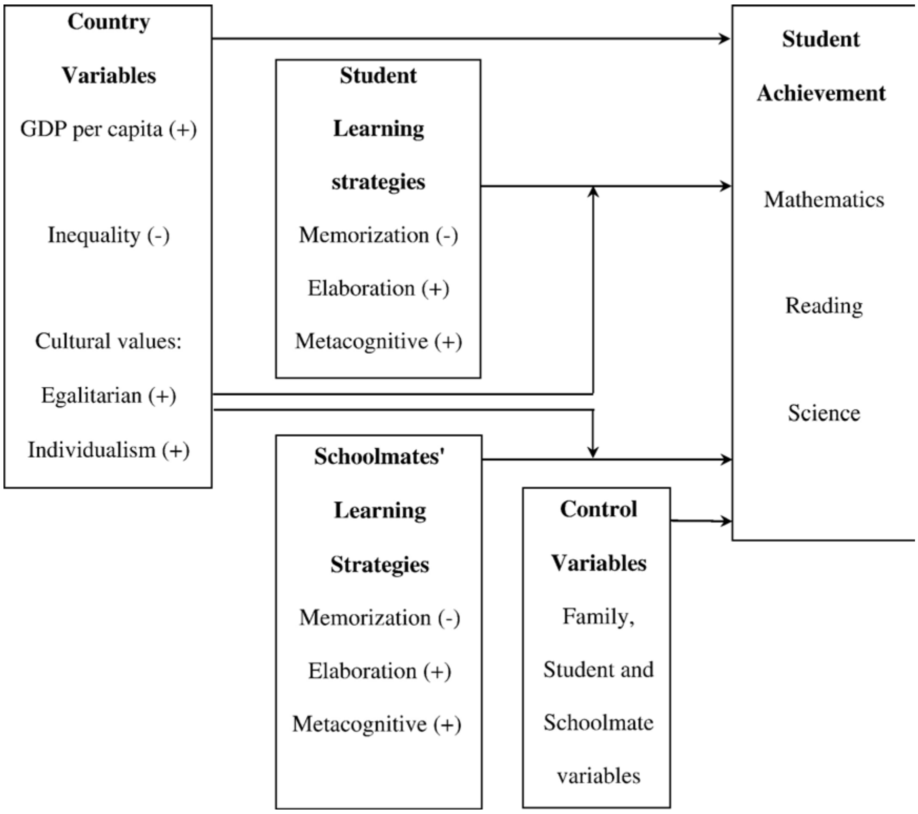

Fig. 1. Model of how country variables, learning strategies, their interactions and other family, student schoolmate, and variables might affect mathematics, reading and science achievement.

Thomas, 1996). This approach also reduces the problems of estimating the effects of variables that might change over time (e.g. parents' jobs might change year to year; Hanushek, Kain, Markman & Rivkin, 2003).

Students' beliefs in their achievement abilities are linked to academic achievement, particularly in adolescence when such self-beliefs become increasingly accurate (Bracken & Lamprecht, 2003). Specifically, academic self-efficacy, self-concept, and locus of control refer to beliefs in one's capability to succeed academically, one's academic competence relative to one's counterparts, and one's sense of personal control over academic events, respectively (Findley & Cooper, 1983; Marsh, 1993; Valentine et al., 2004). Students with stronger academic self-efficacy, self-concept, and locus of control show more effort, persistence, and resilience on academic tasks, resulting in more learning and achievement (Guay, Larose, & Boivin, 2004; Robbins et al., 2004; Stipek & Weisz, 1981; Valentine et al., 2004).

In addition, countries that spend proportionately more on schooling might have higher academic achievement (Benabou, 1996). Furthermore, students with less cultural or linguistic capital (e.g. immigrants or students who speak a foreign language at home) often have lower academic achievement (Collier, 1995; Fuligni, 1997; Portes & MacLeod, 1996). In contrast, students with higher family SES often have more educational resources, which serve as extra learning opportunities on which they often capitalize to learn more (Bradley & Corwyn, 2002). Likewise, students with richer schoolmates might interact with them to obtain and capitalize on extra learning opportunities to learn more (Pong, 1998). Finally, past research has shown that girls often outscore boys on standardized reading exams, while boys outscore girls on standardized mathematics and science exams (Halpern, 1998, 2000).

4. Method

4.1. Data

The Organization for Economic Cooperation and Development (OECD) assessed 15-year-olds' mathematics, reading and science (MRS) literacy and asked students to fill out questionnaires through its Program for

International Student Assessment (PISA) in 2000 (OECD, 2002). In total, 158,848 15-year-olds completed a reading literacy test and a questionnaire. Of these students, 88,401 completed a science test, and 88,590 completed a mathematics test. OECD countries share the principles of the market economy, pluralist democracy and respect for human rights. The participating countries used this study to evaluate their school systems and consider ways to improve them.

Participating OECD countries' education experts defined mathematics, reading, and science literacy; built assessment frameworks; created test items, forward- and backward-translated these items; and pilot tested these items (for details, including reliability and validity checks, see OECD, 2002). (Within 2 years, fifteen non-OECD countries joined the study. See Table 6 below for a list of participating countries.) These OECD experts defined MRS literacy as the ability to understand, use, and reflect on mathematical concepts, written texts, and scientific ideas to achieve one's goals, develop one's knowledge and potential, and participate effectively in society. PISA test items represent the kinds of MRS literacy that 15-year-olds might require in the future. Sample assessment items are available at the PISA Web site (www.pisa.oecd.org). Each student completed a 2-hour assessment test and then, a 30–40-min questionnaire. We also used two additional data sets: economic data from OECD (2000), and cultural values data from Hofstede (2003). See Table 2 for variable descriptions and statistics.

5. Variables

We modeled students' MRS achievement using measures of past achievement, country level variables, family variables, schoolmate family variables, students' self-beliefs, learning strategies, schoolmate learning strategies, and their interactions. See Table 2 for summary statistics and descriptions of variables.

Past achievement is entered first as a control variable to predict improvement between past and present achievement, namely learning. By focusing on the smaller time period between past achievement and current achievement rather than a student's entire life, this approach reduces the problems of estimating the effects of variables that might change over time (e.g. parents' jobs might change year to year; Hanushek et al., 2003). However, remedial courses are coarse proxies for past achievement due to possible school or country variation in placement of students into remedial courses and in the curricula of these remedial courses. Furthermore, remedial courses do not distinguish between high-achieving and middle-achieving students. Hence, readers should cautiously interpret results involving remedial courses.

Country level variables were log GDP per capita, GDP GINI, percentage of GDP spent on public education, and two cultural values, degree of egalitarianism and degree of individualism. Family variables were first generation immigrant, second generation immigrant, foreign language spoken at home, mother's years of schooling, and highest parent job status. We created *school means* of the above family variables to examine how schoolmates' families affected a student's MRS scores. Students' self-beliefs variables were self-efficacy, self-concept, and locus of control. Strategy variables were memorization, transfer through elaboration, and metacognition. We also tested the effects of school means of each learning strategy to test the effects of schoolmate use of these strategies. As each student reported his or her own metacognitive strategy use, "school mean metacognitive strategy use" was computed from the mean of each school sample's students' metacognitive strategy use. After "student metacognitive use" had been entered and controlled, entering "school mean metacognitive strategy use" had the effective meaning of schoolmates' metacognitive use (as the specific student's metacognitive use is statistically controlled). Lastly, we tested the effects of interactions among these variables.

6. Methodological design

To address these research questions across many countries and schools, researchers must sample representative 15-year-olds, create precise tests and questionnaire items for data collection, and model the data's relationships with appropriate statistical tools (Chiu & McBride-Chang, 2006). Random sampling does not necessarily yield a sample that is representative of the country's 15-year-olds. Thus, OECD (2002) sampled first at the school level, and then at the student level (stratified sampling). Using stratified sampling with respect to neighborhood SES and student intake, OECD selected about 150 schools to represent a broad

Table 2
Summary statistics of variables

Variable	Mean	S.D.	Description
Mathematics score	480	112	Mathematics test scores. Min = 109, Max = 864. The student MRS scores estimated by the Rasch models were calibrated to a mean of 500 and a standard deviation of 100 (based on data from only the OECD countries; OECD, 2002). (Many non-OECD countries scored below the mean)
Reading score	479	107	Reading test scores. Min = 48, Max = 855. See above mathematics test description for details.
Science score	480	106	Science test scores. Min = 28, Max = 845. See above mathematics test description for details.
Remedial course variables at the student level			
Some remediation	0.161	0.367	1 = Some reading remedial courses in school. Rough proxy of past achievement.
Much remediation	0.039	0.194	1 = Much reading remedial courses in school. Rough proxy of past achievement.
Country level variables			
Log GDP per capita	9.167	0.559	Min = 7.627, Max = 9.881. World Bank, 2004.
GDP Gini	35.101	8.853	Gini scores range from 0 (perfect equality with the same income for all) to 1 (one person has all the income). Min = 24.4, Max = 59.1. World Bank, 2004.
% GDP on schools	0.050	0.012	Percentage of a country's GDP spent on public schools. Min = 0.029. Max = 0.082 OECD, 2000.
Egalitarian	53.590	22.729	Min = 11, Max = 93. Inverted Power-distance scale, Hofstede, 2003. Hofstede created these two cultural values indices from factors analyses of questionnaire responses in each country.
Individualism	54.391	23.170	Min = 18, Max = 91. Hofstede, 2003. See "egalitarian" regarding index construction.
Family variables at the student level			
1st gen immigrant	0.044	0.205	1 = First generation immigrant (The student, mother, and father were all born outside the country)
2nd gen immigrant	0.039	0.194	1 = Second generation immigrant (Same as 1st gen. immig. but student was born in the country)
Foreign language	0.098	0.297	1 = Foreign language spoken at home
Mother's schooling	11.403	3.505	Mother's years of schooling. Min = 0, Max = 18.
Father's schooling	11.652	3.459	Father's years of schooling. Min = 0, Max = 18.
Highest job status	47.659	16.348	Min = 16, Max = 90. Students listed their parents' job which OECD converted to a number using Ganzeboom, de Graaf, and Treiman's (1992) index (ranging from 16–90).
Schoolmate family variables at the school level			
Mother's schooling — school mean	11.403	2.073	School mean of mother's years of schooling. Min = 0, Max = 16.667.
Highest job status — school mean	47.659	8.374	School mean of highest parent job status. Min = 16, Max = 79.
Girl	0.508	0.500	1 = Girl.
Students' self-beliefs variables at the student level			
Self-efficacy	0.028	0.949	Index of "I am certain I can understand the most difficult material presented in readings," "I am confident I can do an excellent job on assignments and tests," and "I am certain I can master the skills being taught." Reliability = 0.70. Min = −2.90, Max = 2.28.
Self-concept in mathematics	0.023	0.937	Index of "I get good marks in mathematics," "mathematics is one of my best subjects," and "I have always done well in mathematics." Reliability = 0.88. Min = −1.62, Max = 1.74.
Self-concept in reading	0.031	0.947	Index of "I'm hopeless in <language of assessment classes>," "I learn things quickly in <language of assessment classes>," and "I get good marks in the <language of assessment classes>." Reliability = 0.75. Min = −2.62, Max = 1.81.
Academic self-concept	0.024	0.951	Index of "I learn things quickly in most school subjects," "I am good at most school subjects," and "I can do well in most school subjects." Reliability = 0.79. Min = −2.51, Max = 1.85.
Locus of control	0.054	0.948	Index of "When I sit myself down to learn something really hard, I can learn it," "If I decide not to get any bad grades, I can really do it," "If I decide not to get any problems wrong, I can really do it," "If I want to learn something well, I can." Choices = almost never, sometimes, often, and almost always. Reliability = 0.75. Min = −3.38, Max = 2.24.
Student strategy variables			Choices for questions in this section were: almost never, sometimes, often, and almost always
Memorization strategy	0.075	0.939	Index of "I try to memorize everything that might be covered," "I memorize as much as possible," "I memorize all new material so that I can recite it," "I practice by saying the material to myself over and over." Choices = almost never, sometimes, often, and almost always. Reliability = 0.72. Min = −2.80, Max = 2.49.

Table 2 (*continued*)

Variable	Mean	S.D.	Description
Student Strategy Variables			
Elaboration strategy	0.100	0.955	Index of "I try to relate new material to things I have learned in other subjects," "I figure out how the information might be useful in the real world," "I try to understand the material better by relating it to things I already know," "I figure out how the material fits in with what I have learned." Choices = almost never, sometimes, often, and almost always. Reliability = 0.77. Min = −2.82, Max = 2.61.
Metacognitive strategy	0.055	0.942	Index of "I start by figuring out what exactly I need to learn," "I force myself to check to see if I remember what I have learned," "I try to figure out, as I read, which concepts I still haven't really understood," "I make sure that I remember the most important things," "When I study and I don't understand something, I look for additional information to clarify the point." Choices = almost never, sometimes, often, and almost always. Reliability = 0.76. Min = −3.56, Max = 2.61.
Metacognitive — school mean	0.055	0.367	Schoolmates' use of metacognitive strategies. Min = −2.64, Max = 1.77.

Note: All data are from PISA, unless otherwise specified. OECD (2002) created Warm (1989) indices and tested them for reliability. PISA indices were initially standardized ($m=0$; SD = 1) for OECD countries. Non-OECD countries were added later, so negative means indicate lower values for non-OECD countries. Unless otherwise noted, choices were: disagree, disagree somewhat, agree somewhat, and agree.

spectrum of schools. Within each of these schools, 35 students were randomly selected from the school's 15-year olds.

Each country sample included at least 4500 students. By weighting the participant test scores and variables accordingly, OECD created a representative sample of each country's schools and the 15-year-old students. See OECD (2002) for sampling details.

OECD (2002) tested this representative sample of students and asked them to fill out questionnaires. When students take long, traditional tests that seek to cover a lot of MRS content, they might suffer from fatigue or learn content during the exam, both of which reduce test accuracy. OECD used a balanced incomplete block (BIB) test to reduce these effects and to maximize evaluative precision. Compared to the overall test, a student only answers a subset of its questions on a BIB test (subtest, Lord, 1980). As pairs of subtests share overlapping questions, OECD (2002) could analyze the test scores with a graded response Rasch model. A Rasch model estimates the difficulty of each item and each student's achievement score based on the subtest responses (adjusting for the difficulty of each test item and calibrating all test items, Lord, 1980). The test included both multiple choice and open-ended questions. Hence, the Rasch model's graded response component captures the partial credit of student responses to open-ended questions (Samejima, 1969).

The questionnaire, like the tests, should also maximize precision. Measuring a construct with a single question and a finite number of possible responses (e.g., Likert scale, yes vs. no) typically yields substantial measurement error. OECD (2002) minimized this measurement error by including multiple measures for each theoretical construct and computed a single value from these measures with a Rasch model (Warm, 1989 estimates). Compared to the traditional method of summing unweighted response values of multiple measures, this method is more precise (Rowe & Rowe, 1997).

Multilevel analyses are likely needed to model the complex relationships in this data precisely. As traditional ordinary least squares regressions tend to overestimate predictor effects in clustered data (students within schools within countries), we modeled school and country level effects with multi-level analyses, which yield more precise estimates (Goldstein, 1995; also called hierarchical linear modeling or HLM [Bryk & Raudenbush, 1992]). (Variance decomposition models, such as multilevel analyses, require that the sum of the weights be equal to the number of observations. Thus, the data were weighted to represent the students in each school and country. Then each country's data were divided by the country population and multiplied by the country sample size, so that the total weight would equal the total sample size.)

Students did not answer all questions, so there were missing data (5%) that could reduce estimation efficiency, complicate data analyses, and bias results (Peugh & Enders, 2004). Using Markov Chain Monte Carlo multiple

Table 3
Summary of variables in multilevel regression model for mathematics, reading and science achievement

Vector	Variables	Level
S: Past achievement coarse proxy	Some remedial courses in school (+)	Student
	Many remedial courses in school (+)	
T: Country differences	log GDP per capita (+)	Country
	GDP Gini (−)	
	% of GDP spent on public schools (+)	
	Egalitarianism (+)	
	Individualism (−)	
U: Family	First generation immigrant (−)	Student
	Second generation immigrant (−)	
	Foreign language spoken at home (−)	
	Mother's years of schooling (+)	
	Highest parent job status (+)	
V: Schoolmate family	School means of	School
	First generation immigrant (−)	
	Second generation immigrant (−)	
	Foreign language spoken at home (−)	
	Mother's years of schooling (+)	
	Highest parent job status (+)	
W: Self-beliefs	Self-efficacy (+)	Student
	Self-concept (+)	
	Locus of control (+)	
X: Learning strategies	Memorization (−)	Student
	Elaboration (+)	
	Metacognitive (+)	
Z: Schoolmate learning strategies	School means of	School
	Memorization (−)	
	Elaboration (+)	
	Metacognitive (+)	

imputation, we addressed these problems more effectively than other approaches (such as deletion, mean substitution, simple imputation, Peugh & Enders, 2004; Rubin, 1996).

7. Analysis

We analyzed the data with multi-level analyses using MLn software (Rasbash & Woodhouse, 1995). We tested the following models for students' MRS scores one at a time, first mathematics, then reading, then science. (Because of the different student samples for each test score, a multi-level system of equations model is not appropriate.) The multi-level model separates unexplained error into student (level 1), school (level 2), and country (level 3) components, thereby removing the correlation among error terms resulting from students nested within schools within countries. We began with a variance components model to test if the variances were significant at each level.

$$Y_{ijk} = \beta_{000} + e_{ijk} + f_{0jk} + g_{00k} \tag{1}$$

Y_{ijk} is the students' mathematics scores for student i in school j in country k. β_{000} is the grand mean intercept. The error terms (residuals) at the student-, school-, and country-levels are e_{ijk}, f_{0jk}, and g_{00k}, respectively.

We modeled students' mathematics scores with sequential sets of variables (also known as hierarchical sets, Cohen, West, Aiken, & Cohen, 2003) to estimate the variance explained by each set. We aimed to measure learning rather than simply achievement, so we included coarse past achievement variables, some or many remedial courses. Country variables might affect family variables. A student's family variables and schoolmate family variables might influence choice of schools. All of these might affect student properties. Hence, we entered the variables in this order: remedial courses variables, country variables, family variables, schoolmates' family variables, students' beliefs variables, and learning strategies variables.

We began by entering a vector of t remedial course variables at the student level as a proxy for past student achievement: some remedial courses in school, and much remedial courses in school (**S**, see Table 3).

$$Y_{ijk} = \beta_{000} + e_{ijk} + f_{0jk} + g_{00k} + \beta_{sjk}\mathbf{S}_{ijk} \tag{2}$$

Next, we entered a vector of t variables at the country level: log GDP per capita, GDP GINI, percent of GDP spent on public schools, egalitarianism, and individualism (**T**, see Table 3). (Note that log GDP per capita fits the data better than linear GDP per capita, as in other cross-country studies such as Baker et al., 2002)

$$Y_{ijk} = \beta_{000} + e_{ijk} + f_{0jk} + g_{00k} + \beta_{sjk}\mathbf{S}_{ijk} + \beta_{00t}\mathbf{T}_{00k} \tag{3}$$

We tested whether this set of predictors was significant with a nested hypothesis test (χ^2 log likelihood, Cohen et al., 2003). Then, we tested for interaction effects among pairs of significant variables in **T**. Non-significant variables and interactions were removed from the specification.

Next, we added u family variables at the student level: first generation immigrant, second generation immigrant, foreign language spoken at home, mother's years of schooling, and highest parent job status (**U**, see Table 3).

$$Y_{ijk} = \beta_{000} + e_{ijk} + f_{0jk} + g_{00k} + \beta_{sjk}\mathbf{S}_{ijk} + \beta_{00t}\mathbf{T}_{00k} + \beta_{ujk}\mathbf{U}_{ijk} \tag{4}$$

As with **T**, we did a nested hypothesis test for **U**, modeled interaction effects of significant variables, and removed non-significant variables. Next, we tested if the u student-level regression coefficients ($\beta_{ujk}=\beta_{u00}+g_{u0k}$) differed significantly at the country-level ($g_{u0k}\neq 0$?). If so, we tested whether they depended on the above country characteristics (**T**).

$$\beta_{ujk} = \beta_{u00} + g_{u0k} + \beta_{u0t}\mathbf{T}_{00k} \tag{5}$$

Then, we added v schoolmate variables at the school level (**V**, see Table 3): the school means of each of the student-level family variables.

$$Y_{ijk} = \beta_{000} + e_{ijk} + f_{0jk} + g_{00k} + \beta_{sjk}\mathbf{S}_{ijk} + \beta_{00t}\mathbf{T}_{00k} + \beta_{ujk}\mathbf{U}_{ijk} + \beta_{0vk}\mathbf{V}_{0jk} \tag{6}$$

As with **U**, we tested for and modeled significant variation of the v schoolmate variable regression coefficients.

$$\beta_{0vk} = \beta_{0v0} + g_{0vk} + \beta_{0vt}\mathbf{T}_{00k} \tag{7}$$

Then we repeated the above procedures for **U** on the w student belief variables (self-efficacy, self-concept, locus of control, **W**, see Table 3) and the x student learning strategy variables (memorization, elaboration, and metacognitive strategy, **X**, see Table 3). Lastly, we repeated the above procedures for **V** on the schoolmate learning strategy variables at the school-level (**Z**, see Table 3).

$$Y_{ijk} = \beta_{000} + e_{ijk} + f_{0jk} + g_{00k} + \beta_{sjk}\mathbf{S}_{ijk} + \beta_{00t}\mathbf{T}_{00k} + \beta_{ujk}\mathbf{U}_{ijk} + \beta_{0vk}\mathbf{V}_{0jk} + \beta_{wjk}\mathbf{W}_{ijk} + \beta_{xjk}\mathbf{X}_{ijk} + \beta_{0zk}\mathbf{Z}_{0jk} \tag{8}$$

To facilitate interpretation of the results, we reported the models with country-level predictors only (Eq. (3)) and with all significant predictors (Eq. (8)). Also, we reported how a ten percent increase in each continuous predictor above its mean affected students' MRS scores (10% effect $= b * \mathrm{SD} * [10\%/34\%]$; 1 SD $\approx$ 34%). (10% is a common reference number in our base-10 system.)

Table 4
Summaries of 6 regression models predicting students' mathematics, reading, science scores, with unstandardized coefficients, standard errors (in parentheses), and standardized coefficients

	Mathematics		Reading		Science	
Predictor	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Some remedial courses in school	−32.460***	−28.250***	−38.161***	−30.920***	−33.080***	−26.610***
	(0.771)	(0.727)	(0.551)	(0.517)	(0.775)	(0.735)
	−0.290	−0.253	−0.357	−0.290	−0.312	−0.251
Much remedial courses in school	−33.630***	−31.350***	−41.710***	−35.530***	−35.550***	−29.240***
	(1.416)	(1.333)	(1.019)	(0.953)	(1.430)	(1.353)
	−0.301	−0.280	−0.391	−0.333	−0.335	−0.276
Log GDP per capita	64.180**	72.910**	55.990**	62.500**	52.490**	61.670**
	(20.130)	(26.100)	(17.020)	(22.770)	(17.730)	(22.550)
	0.325	0.369	0.293	0.327	0.280	0.329
GDP Gini	−1.974*	−1.104				
	(0.814)	(1.058)				
	−0.156	−0.087				
Individual	−0.145	−0.916	0.234	−0.625	0.004	−0.873
	(0.500)	(0.648)	(0.416)	(0.558)	(0.439)	(0.559)
	−0.030	−0.190	0.051	−0.136	0.001	−0.191
1st generation immigrant		−19.590***		−21.560***		−21.810***
		(1.440)		(1.024)		(1.453)
		−0.175		−0.202		−0.206
2nd generation immigrant		−4.918**		−5.950***		−9.823***
		(1.460)		(1.035)		(1.478)
		−0.044		−0.056		−0.093
Foreign language spoken at home		−14.250***		−16.831***		−19.780***
		(1.037)		(0.745)		(1.052)
		−0.127		−0.158		−0.187
Mother's years of schooling		1.119***		1.092***		1.193***
		(0.094)		(0.066)		(0.096)
		0.035		0.036		0.039
Highest parent job status		0.685***		0.708***		0.620***
		(0.019)		(0.013)		(0.019)
		0.100		0.108		0.096
Mother's years of schooling — school mean		6.657***		6.587***		5.076***
		(0.528)		(0.544)		(0.523)
		0.127		0.128		0.102
Highest parent job status — school mean		2.609***		3.003***		2.731***
		(0.102)		(0.106)		(0.100)
		0.205		0.235		0.225
Girl		−11.050 ***		22.880***		−4.226***
		(0.552)		(0.396)		(0.556)
		−0.099		0.214		−0.040
Self-efficacy		6.077***		8.257***		6.210***
		(0.391)		(0.275)		(0.407)
		0.051		0.073		0.056
Self-concept in relevant subject[a]		14.870***		10.130***		14.880***
		(0.299)		(0.211)		(0.345)
		0.125		0.090		0.133
Locus of control		6.283***		6.973***		4.019***
		(0.390)		(0.275)		(0.397)
		0.053		0.062		0.036
Memorization strategy		−8.436***		−8.994***		−9.229***
		(0.346)		(0.244)		(0.347)
		−0.071		−0.079		−0.082
Metacognitive strategy		2.814***		4.499***		2.968***
		(0.394)		(0.279)		(0.402)
		0.024		0.040		0.026

Table 4 (*continued*)

Predictor	Mathematics		Reading		Science	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Metacognitive strategy		0.085 **				
* GDP Gini		(0.031)				
		0.007				
Metacognitive strategy				0.060 ***		0.095 ***
* Individual				(0.008)		(0.013)
				0.012		0.019
Metacognitive strategy — school mean		19.120 ***		21.230 ***		15.480 ***
		(1.786)		(1.880)		(1.748)
		0.068		0.073		0.058
Metacognitive strategy — school mean		−0.301 ***				−0.259 **
* Individual		(0.076)				(0.076)
		−0.025				−0.022
Explained variance at each level						
Country	0.577	0.279	0.594	0.249	0.475	0.138
School	0.053	0.587	0.066	0.651	0.060	0.589
Student	0.021	0.128	0.034	0.153	0.022	0.121
Total	0.177	0.286	0.160	0.326	0.118	0.250

Note. Each regression included a constant term.

*p<.05, **p<.01, ***p<.001.

[a] “Relevant” refers the subject tested, so mathematics for regression of mathematics test scores, and reading or language arts for the reading test. Academic self-concept was used for regression of the science test scores as OECD-PISA did not collect data on science self-concept.

We used an alpha level of .05 for all statistical tests. Doing many tests on one set of data increases the likelihood of a spurious correlation. We reduced this likelihood by adjusting the alpha level based on the number of predictors via Hochberg’s (1988) variation on Holm’s (1979) method. As readers might have interest in specific countries, we did separate sets of two-level regressions (school and student levels) for each of the 34 countries with all variables except the country-level variables (Goldstein, 1995).

8. Results

8.1. Summary statistics

This sample included a variety of countries. They ranged from poor, very unequal, hierarchical, collectivist nations (e.g., Albania) to rich, relatively equal, egalitarian, individualistic ones (e.g., Switzerland). See Table 2 for summary statistics (see Appendix A for correlation–variance–covariance matrices and ancillary tables). Overall, the percentage of students in each country reporting use of learning strategies varied widely (see Table A2); reported memorization use ranged from 25% (Italy) to 81% (Hungary); elaboration 41% (Iceland) to 72% (Macedonia); metacognition 38% (Norway) to 67% (Macedonia). Notably, students in Asian countries did not report higher memorization rates than those in other countries (Korea: 44%; Thailand: 48%; Hong Kong: 53%).

8.2. Explanatory model

Past achievement, country, family, schoolmate family, self-beliefs, and learning strategy variables all helped explain differences in students’ MRS scores (see Table 4; as mediation tests showed no significant results, sets of predictors were combined to save space, yielding a country level model and a full model). About half of the variances in students’ MRS scores occurred at the student level (48%, 49%, and 54% for MRS respectively), a quarter at the school level (26%, 31%, and 27%), and another quarter at the country level (27%, 21%, and 19%). All results discussed below describe first entry into the regression, controlling for the effects of all previously included variables. Ancillary regressions and statistical tests are available upon request from the authors.

8.2.1. Past achievement

Students who never attended remedial courses in school (a proxy for past achievement) averaged 32, 38, and 33 points higher in MRS than those who attended some remedial courses in school and 34, 42, and 36 points than those attending many remedial courses in school (Table 4, models 1, 3, and 5). These variables accounted for 4%, 5%, and 4% of the variance in MRS scores.

8.2.2. Countries' economic conditions and cultural values

MRS scores were linked to economic conditions, but not cultural values. Students in richer countries scored higher. When a country's GDP per capita was 10% higher than that of another country, students in the richer country averaged 6, 5, and 5 points higher in MRS than those in the poorer country (the 10% effect of a log variable $=\ln[1+10\%]*b$; $6=\ln[1+10\%]*64.18$; $5=\ln[1+10\%]*55.99$; $5=\ln[1+10\%]*52.49$), (Table 4, models 1, 3, and 5). Regressions with linear GDP per capita did not fit the data as well, explaining less of the variance in MRS scores.

Students in countries with greater inequality of incomes scored lower. When a country's Gini was 1 point higher (more unequal) than another country's, students from the more unequal country averaged 2 points lower in mathematics (Table 4, models 1, 3, and 5). Individualism, egalitarianism, and percentage of GDP spent on public schools showed no significant effects on students' MRS scores. Country variables accounted for 58%, 59%, and 48% of the differences between countries for MRS, respectively. Together, country variables accounted for an extra 14%, 11%, and 8% of the variance in students' MRS scores.

As expected, family properties were linked to student achievement. Native students and those speaking the same language at home and at school had higher MRS scores than other students. These results are consistent with past studies showing that students achieve more if they have more cultural and linguistic capital (Table 4, models 2, 4, and 6; Collier, 1995; Fuligni, 1997; Portes & MacLeod, 1996). Family SES and schoolmates' family SES was also linked to MRS scores. Students whose mothers had more years of schooling or whose parents had higher job status, scored higher, consistent with past studies showing strong links between family SES and academic achievement (Bradley & Corwyn, 2002). Together, family variables accounted for 7%, 8%, and 8% of the variance in students' MRS scores.

Students also scored higher with schoolmates whose mothers had more schooling or whose families had higher job status. The positive link between academic achievement and schoolmates with higher family SES is consistent with the view that higher SES schoolmates have more educational resources, skills and experiences to share, resulting in more learning opportunities and higher academic achievement (Chiu &

Table 5
Summary of two-level metacognitive strategy parameter estimates predicting students' mathematics, reading and science scores for each country (upon first entry)

	Predictor effect on student's scores					% of Countries	
Predictor	Mean	S.D.	Min	Median	Max	Signif -	Signif+
Memorization strategy							
Math	−6.979	4.504	−16.610	−6.798	3.177	68%	0%
Reading	−7.522	5.574	−18.380	−8.156	3.103	79%	0%
Science	−7.886	5.007	−14.990	−9.043	5.318	76%	0%
Metacognitive strategy							
Math	−1.069	5.495	−13.780	−0.984	10.430	29%	12%
Reading	2.368	6.306	−14.830	2.463	13.510	15%	47%
Science	−0.361	5.992	−13.250	−0.522	10.900	24%	24%
Metacognitive strategy–school mean							
Math	21.733	22.657	−8.516	20.430	84.120	0%	38%
Reading	29.236	27.435	−5.455	28.145	111.800	0%	56%
Science	18.751	23.430	−35.010	19.110	77.630	3%	41%

Table 6
Signs of significant metacognitive strategy coefficients upon first entry into 2-level regressions predicting students' mathematics, reading, and science scores for each country

Predictor	Alb	Aus	Aut	Bel	Brz	Bul	Chl	Cze	Dnk	Fin	Ger	H K	Hun	Ice	Ire	Isr	Ita	Kor	Ltv	Lie	Lux	Mex	Hol	N Z	Nor	Prt	Rom	Rus	Swe	Swz	Tha	Mac	UK	USA
Memorization strategy																																		
Mathematics		−	−	−	−	−	−	−	−	−	−			−	−	−	−					−			−	−		−	−	−		−	−	−
Reading		−	−	−	−	−	−	−	−	−	−			−	−	−	−	−			−	−	−	−	−	−		−	−	−		−	−	−
Science		−	−	−		−	−	−	−	−	−			−	−	−	−	−	−			−	−	−	−	−		−	−	−		−	−	−
Metacognitive strategy																																		
Mathematics	+		−	−					−	−	−	+	−	−		−									−	+					+			−
Reading	+	+			+			+	−	−		+		−	+		+	+			+	+		+	−	+		+	−	+	+		+	
Science		+						+	−	−		+	−	−		−						+		+	−	+			−		+		+	−
Metacognitive strategy−scholl mean																																		
Mathematics			+		+		+	+			+	+		+		+		+				+				+		+		+		+		
Reading			+		+	+	+	+			+	+	+		+	+		+	+	+		+				+	+	+		+		+		
Science			+		+	+	+	+			+	+	+					+		+		+				+		+		+			−	

Note. Participating countries included Albania (Alb), Australia (Aus), Austria (Aut), Belgium (Bel), Bulgaria (Bul), Brazil (Brz), Chile (Chl), Czech Republic (Cze), Denmark (Dnk), Finland (Fin), Germany (Ger), Holland (Hol), Hong Kong (H K), Hungary (Hun), Iceland (Ice), Ireland (Ire), Israel (Isr), Italy (Ita), Korea (Kor), Latvia (Ltv), Liechtenstein (Lie), Luxembourg (Lux), FYR Macedonia (Mac), Mexico (Mex), Norway (Nor), New Zealand (N Z), Portugal (Prt), Romania (Rom), Russian Federation (Rus), Sweden (Swe), Switzerland (Swz), Thailand (Tha), United Kingdom (U K), and United States (USA). The symbols indicate a significant positive effect (+), a significant negative effect (−), and no significant effect (" " ; a blank).

Khoo, 2005). School means of immigrant status and foreign language spoken at home were not significant. Together, schoolmate family variables accounted for 4%, 7%, and 6% of the variance in students' MRS scores.

Self-beliefs and gender were also linked to MRS scores. Students with higher self-efficacy, higher academic self-concept, or higher locus of control had higher MRS scores (Table 4, models 2, 4, and 6). Together, self-beliefs accounted for an extra 1% of the variance in students MRS scores. Likewise, girls outscored boys in reading, but boys outscored girls in mathematics and science (Table 4, models 2, 4, and 6), accounting for an extra 1% of the variance in MRS scores.

8.2.3. Learning strategies

Learning strategies were also linked to students' MRS scores (Table 4, models 2, 4, and 6). Students averaged 2, 2, and 3 points lower in MRS with an extra 10% of self-reported use of memorization strategies. (For example, the −2 point effect on mathematics score is computed as follows $= b * \mathrm{SD} * [10\%/34\%] = -8.436 * .0869 * 10\%/34\% = -2.156$). Students averaged 1 point higher in MRS with an extra 10% of self-reported use of metacognitive strategies. Meanwhile, self-reported elaboration strategy use was not significant.

The link between achievement and self-reported metacognitive strategy use varied across economic and cultural contexts. A 10% increase in both self-reported metacognitive strategy use and GDP Gini yielded an extra 0.5 points increase in mathematics scores above the increase due to the effect of self-reported metacognitive strategy use alone, supporting the lower-impact egalitarian metacognition hypothesis (see Table 4, models 2, 4, 6). Increasing both metacognitive strategy and individualism by 10% also yielded an extra 0.8 and 1.2 points increase in reading and science scores above the increases due to the effect of self-reported metacognitive strategy use, supporting the individualistic metacognition hypothesis (see Table 4, models 2, 4, 6).

Student's MRS scores were linked to schoolmates' reported use of metacognitive strategies. Students averaged 2 points higher in MRS with an extra 10% of schoolmates' reported use of metacognitive strategies (Table 4, models 2, 4, and 6). Increasing both school mean metacognitive strategy use and individualism by 10% yielded smaller positive effects in mathematics and science scores. As predicted, this result supports the view that the effect of schoolmate's reported use of metacognitive strategies on student achievement is higher in collective societies (collectivist schoolmate metacognition hypothesis). No other variables were significant (including school means of memorization or elaboration strategies, as well as all other interaction terms). Together, learning strategies of a student and his or her schoolmates accounted for less than 1% of the variance in MRS scores.

Although the correlation matrix in Table A1 shows that self-beliefs (columns 19–23) are moderately correlated with learning strategies (rows 24–27), learning strategies did not mediate any of the links between student beliefs and achievement after controlling for the above variables. Hence, these results do not support the claim that students' self-beliefs shape their learning strategies in ways that affect their academic achievement.

9. Differences in effects of learning strategies across countries and schools

Remedial courses, family, schoolmate families, and students' self-beliefs showed similar effects in most countries and schools. However, the effects of some learning strategies varied widely across countries (see Tables 5 and 6).

Students self-reporting more memorization strategies did not score higher in any country. They scored lower in most countries (in 68%, 79%, and 76% of the countries for MRS, see Table 6). However, the link between self-reported use of metacognitive strategies and MRS scores varied substantially across countries. As shown above in the 3-level regressions, the link between self-reported use of metacognitive strategies and mathematics score was more positive in countries with a less equal distribution of income (higher Gini), supporting the lower-impact egalitarian metacognition hypothesis. Likewise, the links between self-reported use of metacognitive strategies and reading and science scores were more positive in countries with greater individualism, supporting the individualistic metacognition hypothesis. Lastly, schoolmates' reported uses of metacognitive strategies were more positively linked to the cultural value of collectivism, supporting the collectivist schoolmate metacognition hypothesis. Schoolmates' reported uses of metacognitive strategies were positively linked to MRS scores in several countries (38%, 56%, and 41% for MRS, see Table 6). The link was not significant in others and was negative for science scores in the individualist United Kingdom (see Table 6).

These effects did not vary much across schools within a country. Only the effect of mother's years of schooling varied across schools in 24% of the countries. None of these schools showed significant predictor effects opposite to that of the overall predictor effect in its country. The remaining predictors showed no significant differences across schools within a country.

10. Discussion

The present study confirmed a variety of associations found in earlier studies. For example, students from richer nations typically showed higher academic achievement. Perhaps more interesting, countries with more equally distributed incomes also tended to show higher mathematics achievement, underscoring the importance of equality. Controlling for these economic factors, cultural values were not directly linked to mathematics, reading, or science achievement. At the individual level, students often showed higher achievement if they had higher past achievement, were native born, spoke the national language at home, had higher SES families or had schoolmates with higher SES families, all consistent with past studies (e.g., Bradley & Corwyn, 2002; Collier, 1995; Fuligni, 1997; Pong, 1998). Students also typically showed higher achievement if they had greater self-efficacy, self concept, or locus of control (Chapman, 1988, 1997; Chemers, Hu, & Garcia, 2001; Guay et al., 2004; Peetsma, Hascher, van der Veen, & Roede 2005; Robbins et al., 2004; Zimmerman, Bandura, & Martinez-Pons, 1992). Overall, girls tended to outperform boys in overall reading comprehension, whereas boys outperformed girls in mathematics and science (e.g., Halpern, 2000).

Apart from these correlates, our study primarily examined the potential importance of three learning strategies, memorization, transfer through elaboration, and metacognition for achievement in reading, mathematics and science across cultures. We found that students reporting greater use of memorization strategies often showed lower achievement across academic domains and cultures. Meanwhile, elaboration strategies were not linked to achievement in any domains or culture. In contrast, cultural values seemed to influence the link between metacognition and achievement. Lastly, schoolmates' reported use of metacognition was linked to individual student achievement across cultures.

The finding that memorization was negatively associated with achievement across domains was not surprising, as researchers have argued that memorization is an inefficient strategy for learning new material (e.g., Czuchry & Dansereau, 1998). Although memorization might be useful in the early stages of knowledge acquisition, its usefulness diminishes when higher level cognitive operations are required (e.g., Bloom, 1956). Given that the students in this study were relatively sophisticated adolescent learners, and that correctly answering these test questions often required integrating different aspects of background knowledge, previously learned strategies, and domain concepts, the finding of a negative association between students' reported use of memorization strategies and performance was expected. In addition, students in Asian cultures did not report using memorization strategies more often than did those in other cultures, in contrast to some stereotypes. Likewise, students in Asian cultures who reported greater use of memorization strategies did not score higher in any subject.

The result that transfer through elaboration was not linked to achievement was disappointing but not surprising. First, the measure of elaboration might not be sufficiently distinguished from that of memorization as the two measures were substantially correlated ($r = .62$). Second, a substantial literature shows that promoting transfer from one aspect of learning to another, even within a domain, is extremely difficult (e.g., Bransford et al., 1986; Halpern, 1998). Although several studies (e.g., Czuchry & Dansereau, 1998) have indicated that relating material to one's own past experiences tends to facilitate learning, the results from this study suggest that questionnaire responses might not adequately measure student ability to transfer through elaboration. For example, students may not have had an objective sense of the extent to which they could make connections between previously learned and new materials. How to transfer knowledge across situations or domains remains one of the greatest challenges faced by educators today (Halpern, 1998).

The metacognition results were the most interesting. The reported metacognitive strategy uses of both a student and his or her schoolmates were positively linked to student achievement in several countries, particularly in reading. This result suggests that a student's metacognitive strategies can regulate both one's own cognition (Baker, 1989) and those of one's schoolmates, thereby highlighting the importance of students' social environments to their learning (e.g., Vygotsky's zone of proximal development, 1997).

Furthermore, a student's achievement in all domains was more strongly linked to reported metacognitive strategy uses of schoolmates than those of the student. If schoolmates' metacognitive strategies only served as models from which a student learned, students with stronger metacognitive skills would not benefit much from those with weaker skills, and achievement would be more strongly linked to self-reported metacognitive strategy use than to those of schoolmates. However, this is not the case. Instead, this result supports the view that schoolmates actively take up some of the metacognitive load of academic or non-academic tasks to support a student's learning (e.g., students can help one another plan, evaluate, or remember [distributed memory]; Hinsz, Tindale, & Vollrath, 1997; Webb & Palincsar, 1996). Indeed, this result is consistent with Vygotsky's (1997) view that higher order cognitive skills such as metacognition appear first on the social plane between individuals working together before appearing in a person's intrapsychological plane.

The strength of these links between metacognition and achievement varied substantially across economic and cultural contexts. The link between self-reported metacognition use and achievement was stronger in less equal or more individualistic countries. The former result is consistent with the lower-impact egalitarian metacognition hypothesis: in less equal countries, students (especially underprivileged ones) with greater metacognitive skills can use them to obtain more educational resources and use to learn more than other students. As more equal countries often give students more equal access to educational resources (Chiu & Khoo, 2005), metacognitive skills might be less beneficial to students in these countries.

The link between self-reported use of metacognitive strategies and achievement was stronger in more individualistic societies, supporting the individualistic metacognition hypothesis. In contrast, the link between schoolmates' reported use of metacognitive strategies was stronger in more collective societies, supporting the collectivist schoolmate metacognition hypothesis. These results suggest that students in individualistic cultures rely more on individual learning strategies while students in collective cultures rely more on group learning strategies.

Consider students in the individualistic culture of the United Kingdom (UK) and those in the collective culture of Korea for example. In the UK, a high school student often has different classmates across subjects and does classwork and homework individually. In Korea however, high school students often sit with one set of classmates during the entire school day, working closely with one another on both classwork and homework. Not surprisingly, self-reported metacognitive strategy use is positively linked to science achievement in the UK, but not in Korea. In contrast, schoolmates' self-reported metacognitive strategy uses are positively linked to MRS scores in Korea, but not in the UK. Indeed, schoolmates' metacognitive strategy uses are negatively linked to science scores in the competitive UK, possibly because social comparison with more metacognitively-skilled and higher achieving schoolmates reduces a competitive student's academic self-concept and hence lowers their academic achievement (Marsh, Hau, & Kong, 2002; Marsh, Kong, & Hau, 2000). These findings partially replicate previous research that has emphasized the value of metacognition for learning and achievement (Kincannon et al., 1999). In many collective cultures however, self-reported metacognition effects were not significant. Furthermore, these results suggest that schoolmates' metacognitive strategies can explain adolescents' academic achievement beyond the individual level.

The primary limitation of this research is the little information on these students' actual learning strategies and their teachers' actual teaching strategies. Many previous studies have shown causal associations between learning strategies and learning outcomes (e.g., Kincannon et al., 1999). In this study however, we can only assume that student responses to our questionnaire about learning strategies relate in specific ways to their actual use of learning strategies and to the instructional practices of their school's teachers. Future studies might use lesson videotaping to capture the role of educators in fostering particular learning strategies among students. For example, the null association of transfer through elaboration could be better understood with more information about the ways in which teachers tried to teach students to transfer knowledge, formulas, and theories from one area of learning to another (Bransford et al., 1986; Halpern, 1998). Furthermore, the reliabilities of some measures such as self-beliefs and learning strategies were less than 0.85 in the present study. Thus, readers should interpret the results with caution. Lastly, a student's academic achievement is more likely to be influenced by friends or classmates rather than schoolmates.

Nevertheless, despite these limitations, the present study has expanded our understanding of learning strategies in relation to achievement in three ways. First, we have shown that memorization strategies are often negatively associated with adolescent achievement across the domains of mathematics, science, and reading achievement. Second, we have shown that the strength of the link between students' self-reported metacognition and academic achievement varies along specific economic and cultural dimensions across countries. Third, we have shown that schoolmates' self-reported metacognition is linked to achievement, especially in collective cultures. These findings contribute to the growing literature on the importance of cultural sensitivity to learning strategies and learning outcomes (e.g., Feinberg, 1998; Pedersen & Carey, 2002).

Appendix A. Ancillary results

Table A1
Correlation–variance–covariance matrix of outcome variables and significant predictors. The correlations, variances, and covariances are along the lower left triangle, diagonal, and upper right triangle respectively

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	**13427**			−9.05	−2.46	29.74	−250	0.18	716	997	−0.32	0.47	−4.94	113	606	89.06	422	−2.74	9.24	12.50			7.50	−1.59	1.58	4.08	−1.20
2		**11407**		−8.78	−1.94	20.55	−167	0.20	671	746	−1.30	−0.23	−4.03	106	601	81.79	411	7.64	12.52		17.04		12.41	−4.08	2.72	9.89	0.51
3			**11242**	−7.76	−1.69	17.80	−185	0.11	564	605	−1.32	−0.40	−4.20	101	558	76.31	380	−0.05	12.88			15.44	11.09	−4.32		8.04	0.47
4	−0.21	−0.22	−0.20	**0.13**	−0.01	−0.03	0.24	−0.0003	−1.19	−1.13	0.002	0.0005	0.01	−0.10	−0.56	−0.08	−0.39	−0.01	−0.01	−0.001	−0.02	−0.02	−0.01	0.01	0.01	−0.01	−0.002
5	−0.10	−0.09	−0.08	−0.09	**0.04**	−0.003	0.003	−0.0001	−0.23	−0.15	0.001	0.0003	0.001	−0.01	−0.06	0.0001	−0.03	−0.001	0.001	0.003	−0.003	−0.002	0.002	0.008	0.01	0.005	0.001
6	0.42	0.34	0.30	−0.15	−0.03	**0.31**	−1.71	0.003	8.94	10.57	0.01	0.01	0.001	0.37	1.43	0.37	1.43	−0.01	−0.02	0.002	−0.02	0.00	−0.04	−0.06	−0.079	−0.03	−0.03
7	−0.26	−0.18	−0.20	0.07	0.002	−0.35	**78.37**	−0.04	−69.27	−71.89	−0.02	0.005	−0.09	−7.57	−18.99	−7.57	−18.99	0.07	0.36	0.20	−0.01	−0.08	0.28	0.08	0.63	0.40	0.40
8	0.13	0.16	0.09	−0.06	−0.02	0.40	−0.33	**0.0001**	0.17	0.12	0.0001	−0.00001	0.0002	0.005	0.02	0.005	0.02	0.00001	0.0001	0.0004	−0.0001	0.0004	−0.0002	−0.001	−0.001	−0.001	−0.001
9	0.29	0.28	0.23	−0.14	−0.05	0.70	−0.34	0.63	**517**	364	0.44	0.29	0.11	11.29	47.36	11.29	47.36	−0.08	−0.28	0.16	−0.40	0.48	−1.57	−1.93	−2.729	−1.40	−1.40
10	0.37	0.30	0.25	−0.13	−0.03	0.82	−0.35	0.42	0.69	**537**	0.34	0.26	0.15	20.26	66.14	20.26	66.14	−0.13	−0.05	0.74	0.56	2.05	−0.67	−1.27	−2.43	−0.59	−0.58
11	−0.01	−0.06	−0.06	0.03	0.02	0.11	−0.01	0.03	0.09	0.07	**0.04**	−0.002	0.02	−0.03	−0.12	−0.01	−0.01	−0.001	−0.001	0.004	−0.004	−0.001	−0.0001	0.004	−0.001	0.001	−0.001
12	0.02	−0.01	−0.02	0.01	0.01	0.13	0.003	−0.005	0.07	0.06	−0.04	**0.04**	0.01	−0.06	−0.14	−0.03	−0.03	−0.0002	−0.001	0.001	−0.01	−0.003	−0.003	0.003	−0.003	0.0003	−0.001
13	−0.13	−0.13	−0.13	0.06	0.03	0.01	−0.04	0.04	0.02	0.02	0.29	0.18	**0.09**	−0.15	−0.54	−0.09	−0.31	−0.002	−0.01	0.004	−0.01	−0.01	−0.01	0.001	−0.005	−0.01	−0.01
14	0.29	0.28	0.27	−0.08	−0.01	0.19	−0.24	0.11	0.14	0.25	−0.04	−0.10	−0.15	**12.28**	26.45	4.30	13.09	−0.04	0.36	0.19	0.29	0.40	0.35	0.07	0.17	0.26	0.15
15	0.33	0.34	0.32	−0.09	−0.02	0.16	−0.13	0.10	0.13	0.17	−0.04	−0.04	−0.11	0.46	**267.26**	13.09	70.13	−0.08	1.98	1.15	1.54	1.93	1.78	−0.19	0.87	1.29	0.69
16	0.37	0.37	0.34	−0.11	0.00	0.32	−0.41	0.18	0.24	0.42	−0.02	−0.06	−0.15	0.59	0.39	**4.30**	13.09	0.01	0.16	0.07	0.17	0.23	0.19	0.06	0.04	0.15	0.15
17	0.43	0.46	0.41	−0.13	−0.02	0.31	−0.26	0.19	0.25	0.34	−0.01	−0.02	−0.12	0.45	0.51	0.75	**70.13**	0.13	0.81	0.41	0.71	0.84	0.81	−0.12	0.18	0.69	0.69
18	−0.05	0.14	0.00	−0.03	−0.01	−0.02	0.02	0.00	−0.01	−0.01	−0.01	−0.002	−0.01	−0.02	−0.01	0.01	0.03	**0.25**	−0.03	−0.04	0.07	0.01	0.01	0.03	−0.01	0.04	0.01
19	0.09	0.12	0.13	−0.03	0.004	−0.03	0.04	0.01	−0.01	−0.002	−0.003	−0.01	−0.03	0.11	0.13	0.08	0.10	−0.07	**0.90**	0.26	0.28	0.49	0.60	0.29	0.49	0.50	0.08
20	0.13			−0.004	0.02	0.004	0.03	0.04	0.01	0.04	0.02	0.01	0.02	0.06	0.07	0.04	0.05	−0.09	0.35	**0.74**			0.23	0.07	0.21	0.17	0.03
21		0.17		−0.07	−0.02	−0.03	−0.001	−0.01	−0.02	0.03	−0.02	−0.03	−0.04	0.09	0.10	0.08	0.09	0.15	0.31		**0.90**		0.27	0.11	0.20	0.24	0.04
22			0.15	0.15	−0.05	−0.01	0.01	0.03	−0.01	0.02	0.09	−0.01	−0.02	0.12	0.12	0.11	0.10	0.11	0.02			**0.90**	0.44	0.19	0.34	0.37	0.08
23	0.07	0.12	0.11	−0.03	0.01	−0.07	0.03	−0.017	−0.07	−0.03	−0.001	−0.01	−0.03	0.11	0.11	0.10	0.10	0.01	0.66	0.66	0.30	0.48	**0.90**	0.31	0.46	0.50	0.07
24	−0.02	−0.04	−0.04	0.03	0.04	−0.11	0.01	−0.06	−0.09	−0.06	0.02	0.01	0.003	0.02	−0.01	0.03	−0.01	0.05	0.33	0.33	0.13	0.22	0.35	**0.88**	0.34	0.46	0.06
25	0.01	0.03	0.04	0.02	0.03	−0.15	0.07	−0.09	−0.13	−0.11	−0.01	−0.02	−0.02	0.05	0.06	0.02	0.02	−0.01	0.54	0.23	0.22	0.37	0.51	0.38	**0.91**	0.56	0.08
26	0.04	0.10	0.08	−0.02	0.02	−0.05	0.05	−0.07	−0.07	−0.03	0.004	0.002	−0.02	0.08	0.08	0.08	0.09	0.09	0.56	0.56	0.27	0.41	0.56	0.52	0.62	**0.89**	0.13
27	−0.03	0.01	0.01	−0.01	0.01	−0.14	0.12	−0.18	−0.17	−0.07	−0.02	−0.02	−0.06	0.12	0.11	0.20	0.22	0.07	0.23	0.24	0.13	0.20	0.21	0.17	0.23	0.39	**0.13**

1) Mathematics score, 2) Reading score, 3) Science score, 4) Some remedial school courses , 5) Many remedial school courses, 6) Log GDP per capita, 7) GDP GINI, 8) % GDP spent on public education, 9) Egalitarian, 10) Individual, 11) 1st generation immigrant, 12) 2nd generation immigrant, 13) Foreign language spoken at home, 14) Mother's years of schooling, 15) Highest parent job status, 16) Mother's years of schooling–school mean, 17) Highest parent job status–school mean, 18) Girl, 19) Self-efficacy, 20) Self-concept in mathematics, 21) Self-concept in reading, 22) Academic self-concept, 23) Locus of control, 24) Memorization strategy, 25) Elaboration strategy, 26) Metacognitive strategy, 27) Metacognitive strategy-school mean.

Table A2
Each country's individualism (vs. collectivism) cultural value score and mean percentiles of self-reported frequency of use of each learning strategy as a percentage of the entire weighted sample

Country	Indiv.	Country	Memorize	Country	Elab.	Country	Metacog.
USA	91	Hungary	81%	Macedonia	72%	Albania	67%
Australia	90	Albania	79%	Romania	69%	Chile	66%
UK	89	Romania	67%	Albania	68%	Austria	65%
Netherlands	80	Russia	64%	Chile	67%	Macedonia	63%
New Zealand	79	Ireland	61%	Brazil	66%	Czech	61%
Italy	76	Brazil	59%	Bulgaria	65%	Israel	60%
Belgium	75	New Zealand	59%	Mexico	63%	Italy	60%
Denmark	74	Bulgaria	58%	Portugal	57%	Germany	60%
Sweden	71	Latvia	57%	Austria	57%	Romania	58%
Ireland	70	Sweden	56%	Hungary	56%	Portugal	58%
Norway	69	Australia	55%	Russia	56%	Hungary	58%
Switzerland	68	Israel	54%	UK	54%	Brazil	57%
Liechtenstein	68	Belgium	54%	Czech	54%	Bulgaria	57%
Germany	67	USA	54%	New Zealand	54%	Mexico	57%
Finland	63	UK	53%	Australia	53%	Belgium	56%
Iceland	60	Hong Kong	53%	Switzerland	53%	Liechtenstein	56%
Latvia	60	Mexico	52%	Germany	52%	Switzerland	54%
Luxembourg	60	Denmark	52%	Latvia	52%	Russia	53%
Czech	58	Germany	52%	Thailand	52%	Ireland	53%
Austria	55	Portugal	51%	USA	52%	New Zealand	52%
Hungary	55	Austria	50%	Israel	50%	UK	52%
Israel	54	Switzerland	49%	Sweden	50%	Luxembourg	52%
Russia	39	Chile	49%	Liechtenstein	50%	Sweden	51%
Brazil	38	Netherlands	49%	Belgium	48%	Australia	51%
Bulgaria	30	Czech	48%	Korea	47%	USA	48%
Mexico	30	Thailand	48%	Ireland	47%	Netherlands	47%
Romania	30	Luxembourg	47%	Italy	46%	Latvia	46%
Portugal	27	Liechtenstein	46%	Denmark	46%	Denmark	41%
Macedonia	26	Finland	46%	Luxembourg	46%	Hong Kong	39%
Hong Kong	25	Korea	44%	Finland	44%	Iceland	36%
Chile	23	Macedonia	40%	Netherlands	43%	Thailand	36%
Thailand	20	Iceland	39%	Hong Kong	42%	Finland	32%
Albania	20	Norway	28%	Norway	42%	Korea	32%
Korea	18	Italy	25%	Iceland	41%	Norway	29%

Note: "Indiv" refers to degree of individualism in a country. "Elab" refers to elaboration strategies. "Metacog" refers to metacognitive strategies.

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