

# Inquiry in Science Classrooms: A Cross National Examination of Inquiry and Its Relationship to Student Performance in Science

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# Inquiry: Definition

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- *...the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. (National Science Education Standards, 1996: 23)*

# Inquiry: Background & Context

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- From a pedagogical point of view, theories of constructivism and social development place emphasis and importance on using student-centered approaches, which can, in turn, lead to enhanced “deep learning”.
- However, it is not firmly established that inquiry necessarily leads to enhanced learning outcomes. In fact, some argue that inquiry can be counterproductive to learning. Known as *cognitive load theory*, some view inquiry approaches as requiring students to take on learning demands that they are unable to cognitively handle, which can actually be *detrimental* to learning (Kirschner et al., 2006)

# Inquiry: Background & Context

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- Empirical evidence is somewhat mixed (and largely US focused):
  - Schneider et al. (2002) found that 10th and 11th grade students who took part in a Project Based Science (PBS) curriculum scored significantly higher than a NAEP subsample on 44% of 34 NAEP items from the 1996 NAEP, with most of the higher scores concentrated among questions emphasizing scientific investigations.
  - Von Secker (2002) finds that five inquiry-based teaching practices<sup>[1]</sup>, individually and collectively, are positively associated with 10th grade student achievement as measured by performance on a standardized science examination.
  - Teacher-centered instruction *negatively* impacts student performance (the effect size is -0.47;  $p < 0.000$ ;  $\alpha = 0.05$ ), yet laboratory inquiry positively relates. Interestingly, though critical thinking (which is a core tenet of deeper learning) is positively related to achievement, it is not significantly different from zero (Von Secker & Lisztz, 1999: 1119).

<sup>[1]</sup> Practices included the extent to which teachers emphasized: (1) eliciting student interest and engagement, (2) using lab techniques, (3) problem solving, (4) conducting further study, and (5) scientific writing (Von Secker 2002: 152).

# Research Questions

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## □ Research Questions:

- (1) Do countries that rely more extensively on inquiry-based approaches have higher science achievement?
- (2) What particular inquiry-based approaches tend to be more effective at improving achievement in science?
- (3) How do the effects of inquiry-based practices on achievement vary by gender and class size?
- (4) Are there particular types of schools (based on school-level characteristics such as school-level funding, accountability and governance factors) that tend to rely more frequently on inquiry-based approaches?

# Data

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- 2006 Program for International Student Assessment (PISA).
  - PISA 2006 was conducted in 57 countries and assessed performance in math, reading and science among a sample that is representative of the over 20 million 15-year olds who are nearing the end of their compulsory education (OECD, 2007: 16). We selected PISA 2006 for its large-scale, international scope, rigorous design and, most importantly, its rich detailed information on inquiry based practices.
  
- Inquiry-Based Variables from PISA 2006:
  - SCAPPLY: use of applications and models
  - SCHANDS: hands-on activities
  - SCINTACT: interaction
  - SCINVEST: student investigations
  - Note: higher values of each index indicate a higher frequency with which students report such practices occurring during science lessons.

# Data

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- **School-Level Variables.** For our school level analyses, we focus on a set of 17 variables that are organized into four categories (PISA Data Analysis Manual: SPSS Second Edition Appendix 1 p. 326):

## **1. School Management and Funding**

Privately Managed Schools [XPRIVMAN]

Schools with Higher Percentage of Government Funding [XGOVFUND]

## **2. Parental Pressure and Choice**

Higher Levels of School Competition [XSCHLCOMP]

Higher Levels of Perceived Parental Pressure [XPRESSPA]

## **3. Accountability Practices**

Schools that inform parents of student's performance (relative to other students) [XACC1]

Schools that inform parents of student's performance (relative to other nat'l benchmarks) [XACC2]

Schools that inform parents of student's performance (relative to other schools) [XACC3]

Schools that publicly post achievement data [XACC4]

Schools that use achievement data to evaluate principals [XACC5]

Schools that use achievement data to evaluate teachers [XACC6]

Schools that use achievement data to allocate resources [XACC7]

Schools that track achievement data over time [XACC8]

## **4. School Autonomy**

Autonomy in Staffing [XFACS]

Autonomy in Budgeting [XFACB]

Autonomy in Educational Content [XFACC]

# Methods

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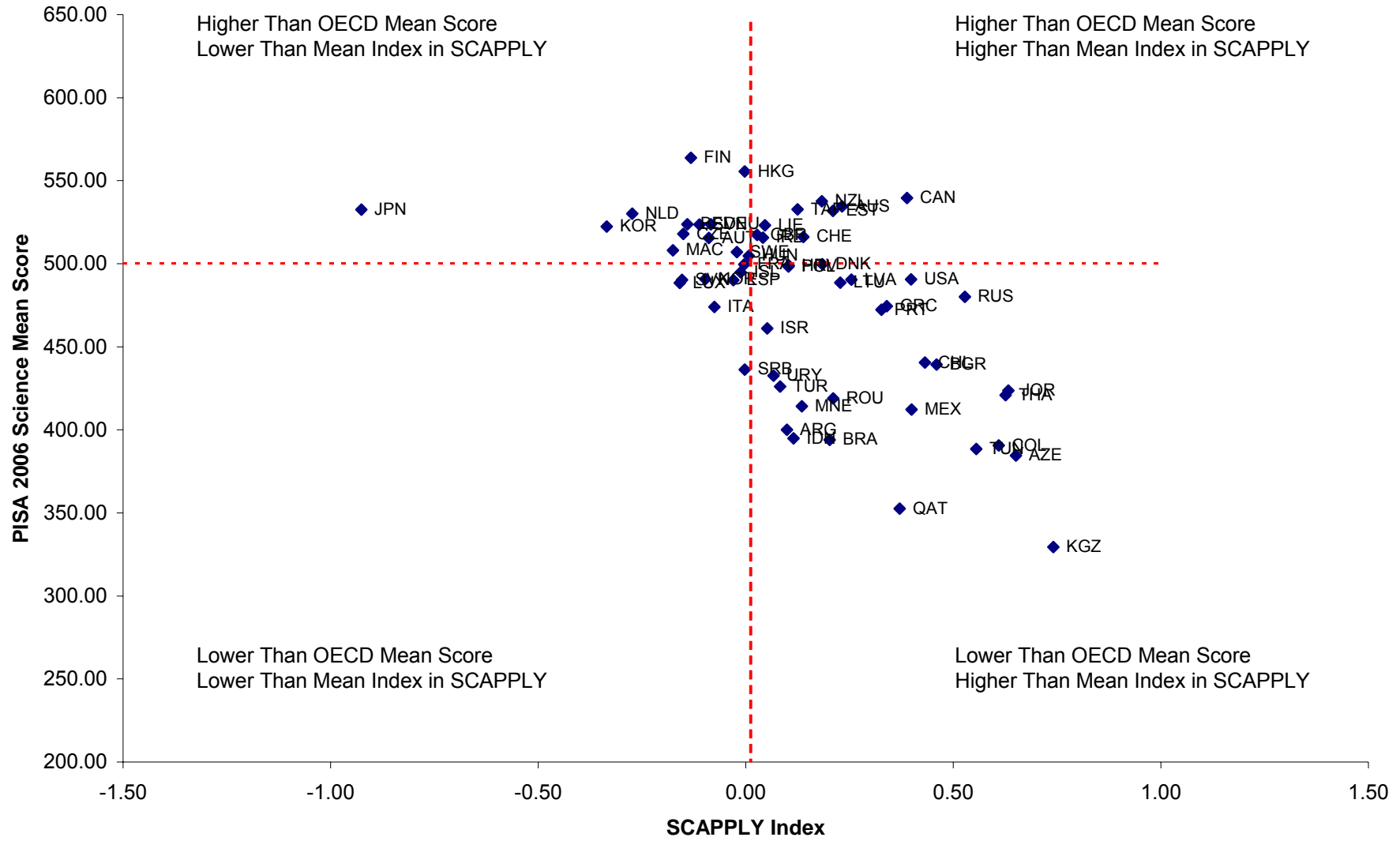
- Correlational Analysis (RQ1 and RQ4)
- Hierarchical Linear Modeling (HLM) to account for students clustered in schools (RQ2 and RQ3)

# Do countries that rely more extensively on inquiry-based approaches have higher science achievement?

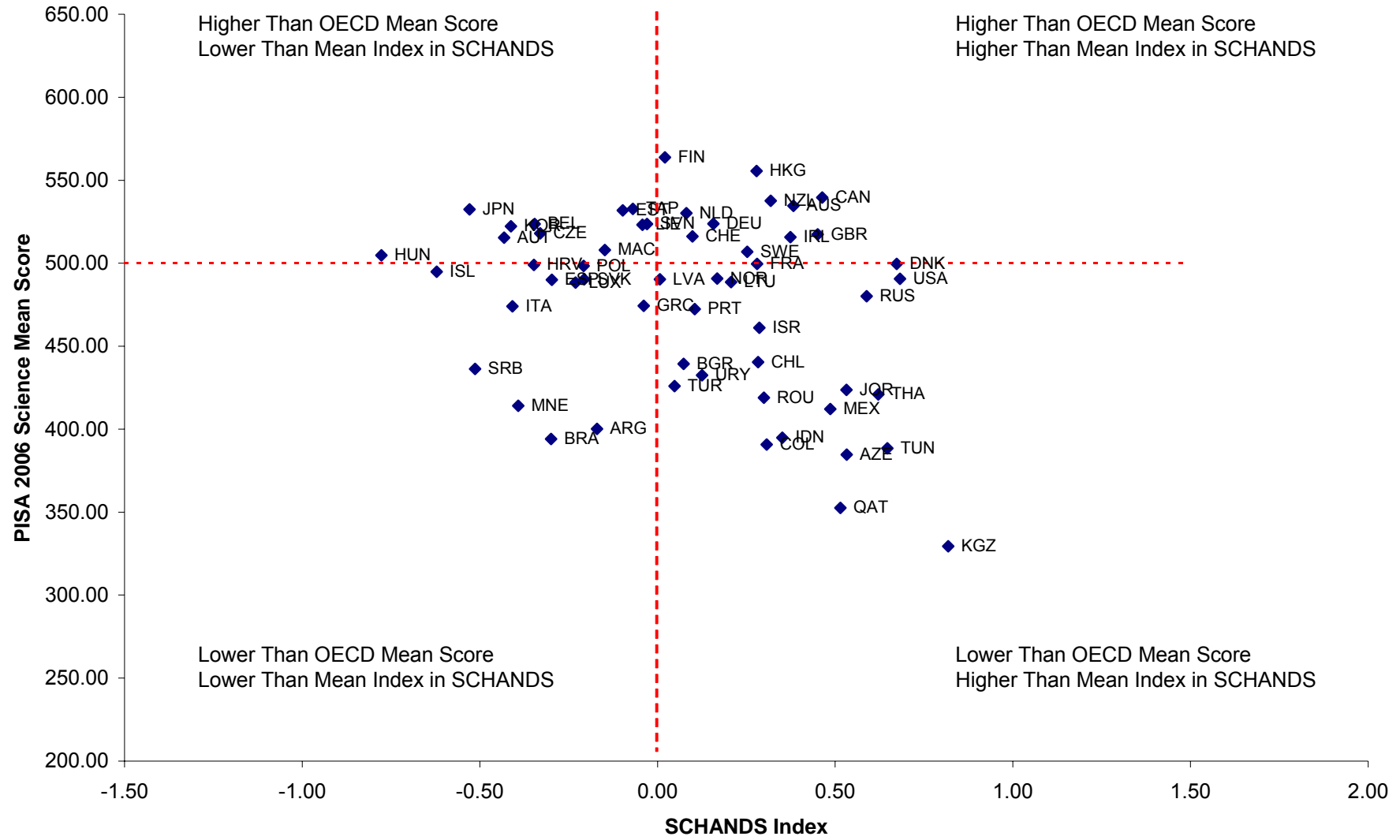
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- All of the indices (SCAPPLY, SCHANDS, SCINTACT and SCINVEST) have a strong negative relationship with student achievement. In other words, countries which have higher mean science scores actually have *lower* mean values on each of the indices representing inquiry-based teaching and learning approaches. There are two notable trends in how countries tend to cluster in these four quadrants:
- East Asian Countries (Korea, Japan, Macao, Hong Kong and Taiwan): These countries tend to cluster in the upper left quadrant representing *higher* than average OECD science scores and *lower* than mean reported values on the four indices.
- Latin American Countries (Mexico, Brazil, Argentina, Uruguay, Colombia and Chile): These countries tend to cluster in the lower right quadrant representing *lower* than average OECD science scores and *higher* than mean reported values on the four indices.

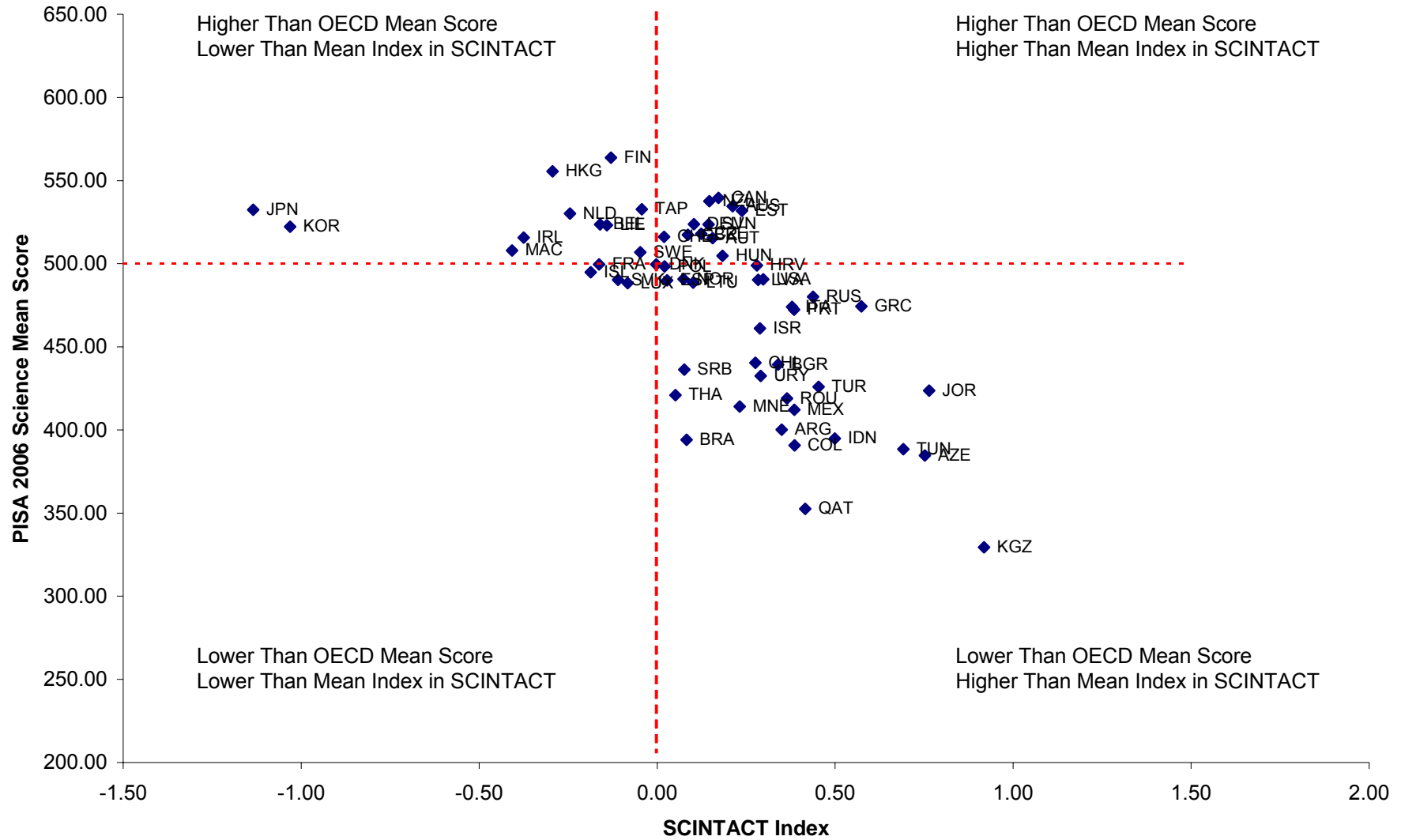
### SCAPPLY vs. PISA 2006 Science Score



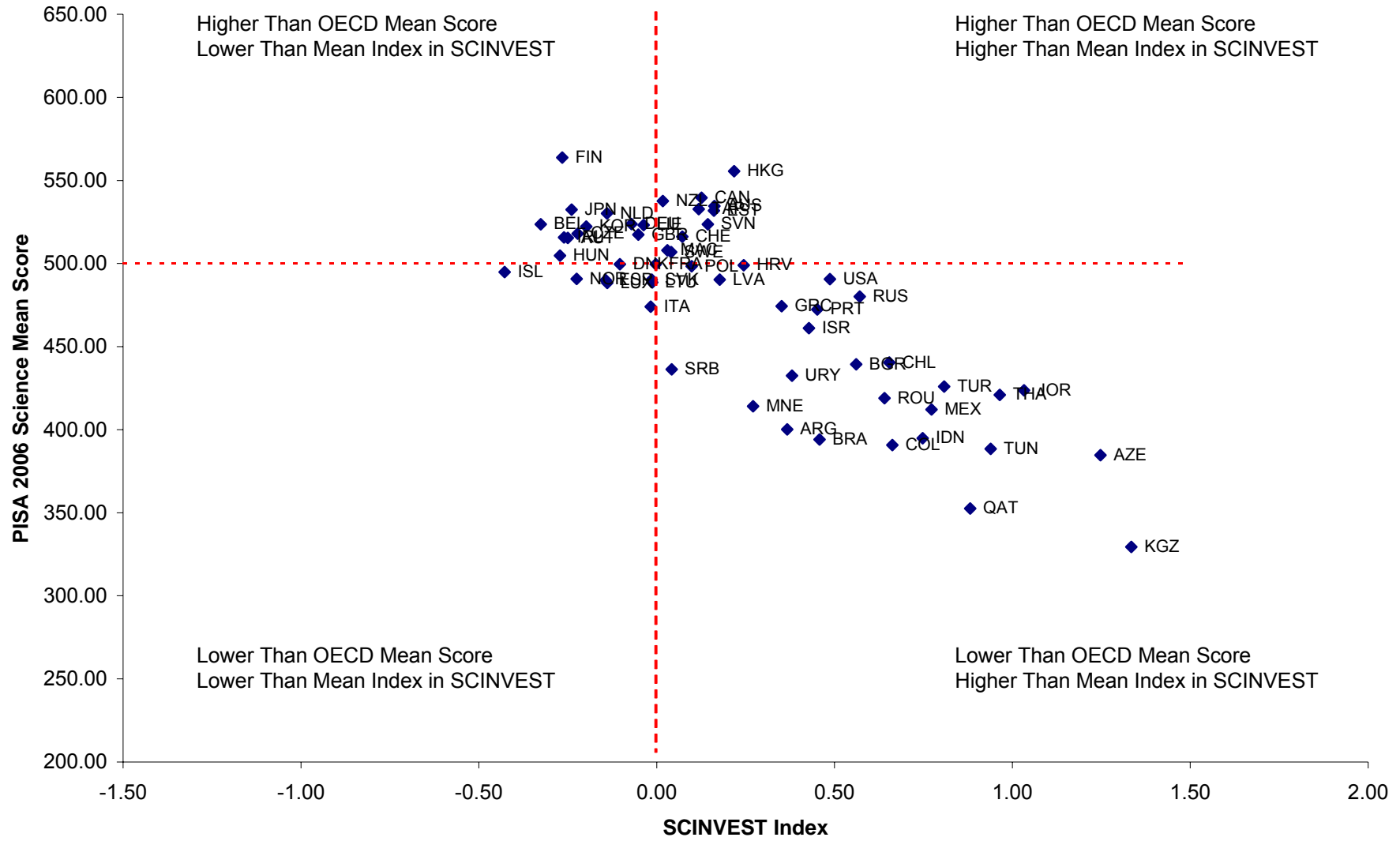
### SCHANDS vs. PISA 2006 Science Score



### SCINTACT vs. PISA 2006 Science Score



### SCINVEST vs. PISA 2006 Science Score



# What particular inquiry-based approaches tend to be more effective at improving achievement in science?

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- To further investigate the effect of inquiry based learning/teaching approaches *within* countries, we selected pairs of countries from each of the four quadrants shown in Figures 2a through 2d. We classified each pair into four distinct categories as summarized below.

Classification of selected countries

	<b>Above OECD Mean Score in Science</b>	<b>Below OECD Mean Score in Science</b>
<b>Above OECD Mean Score for Each Index</b>	Australia and Canada	US and Mexico
<b>Below OECD Mean Score for Each Index</b>	Japan and Finland	Spain and Italy

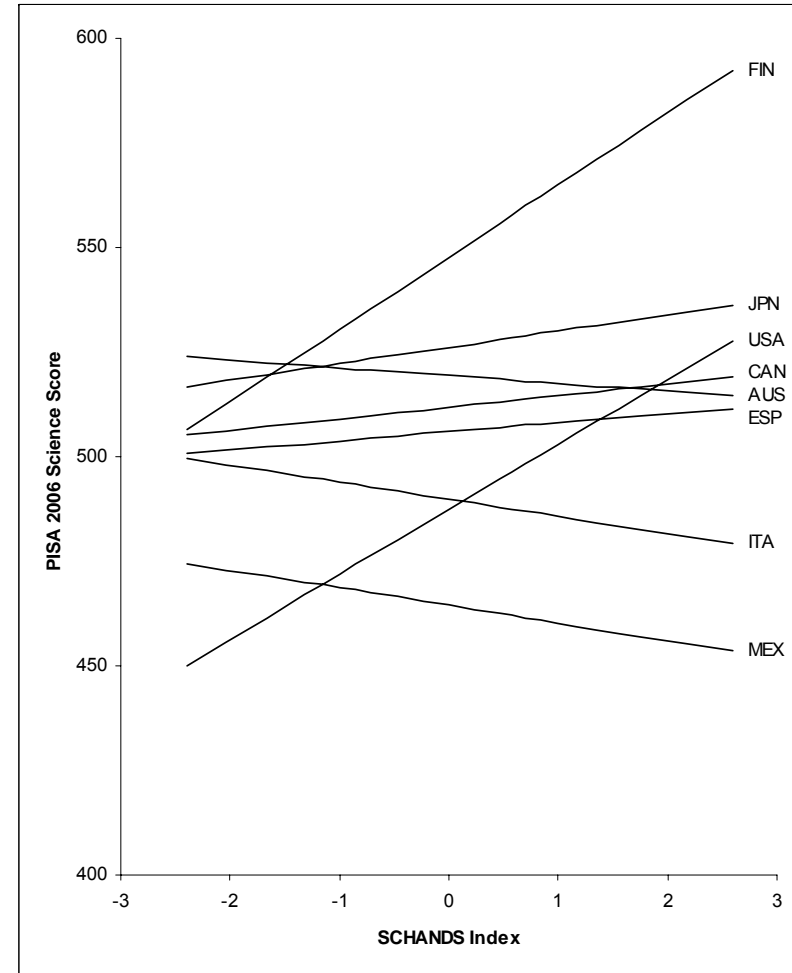
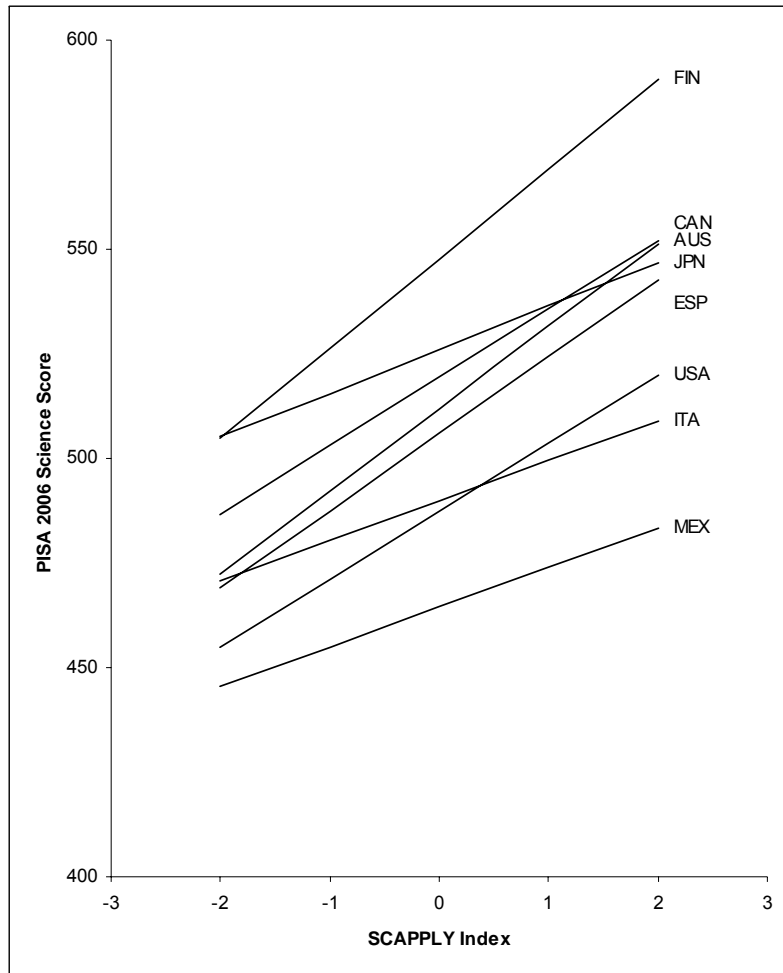
# Results from Hierarchical Linear Models

**Table 4.** The change in PISA 2006 science scores associated with a one point positive change in each index describing inquiry-based approaches. Reported estimates are calculated based upon fitted HLM models for each country. Estimates are for prototypical students within that country of average SES, gender, reporting mean levels of all other indices, attending schools with average SES and a class size equal to the mean of the country as a whole.

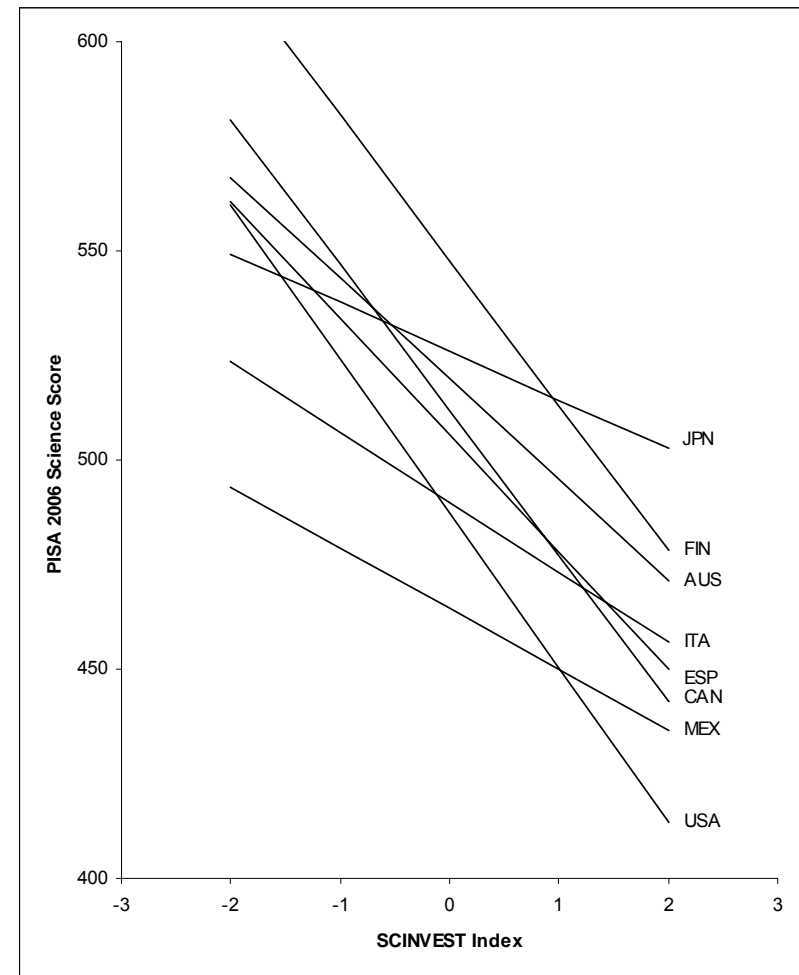
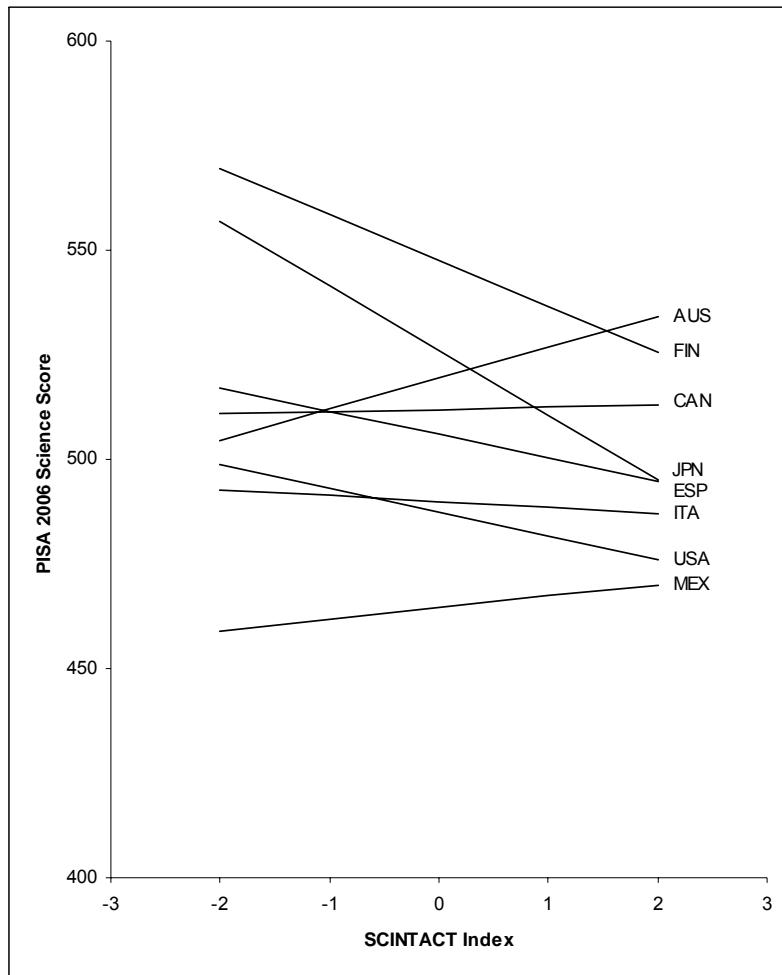
	Country							
	USA	MEX	JPN	FIN	AUS	CAN	ESP	ITA
SCAPPLY	16.30	9.50	10.40	21.45	16.35	19.75	18.35	9.50
SCHANDS	21.77	-5.88	5.39	24.01	-2.66*	3.92	2.94*	-5.67
SCINTACT	-5.70	2.80	-15.45	-10.95	7.40	0.55*	-5.55	-1.45*
SCINVEST	-36.85	-14.55	-11.65	-34.65	-24.05	-34.80	-27.95	-16.75

\*relationship is not statistically significant

# Fitted relationships between inquiry indices (SCAPPLY and SCHANDS) and 2006 PISA science score

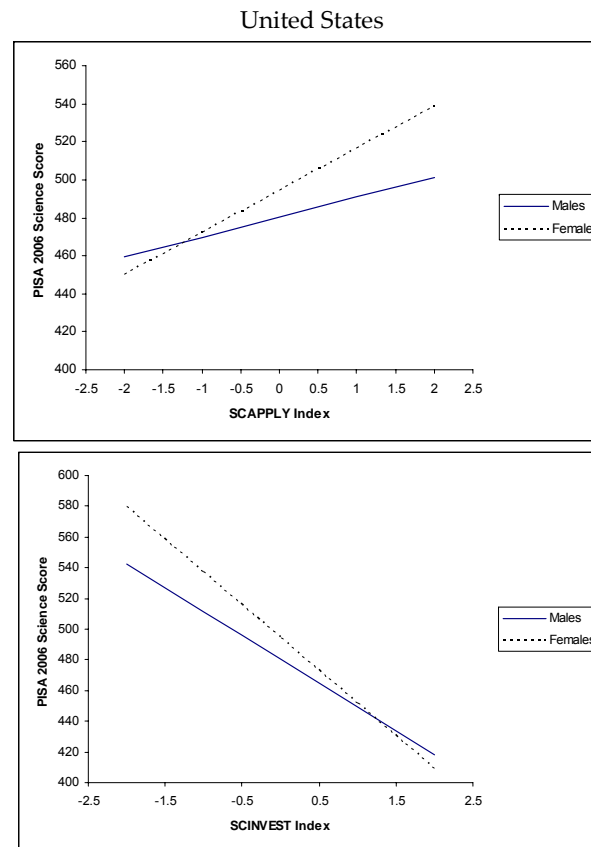


# Fitted relationships between inquiry indices (SCAPPLY and SCHANDS) and 2006 PISA science score



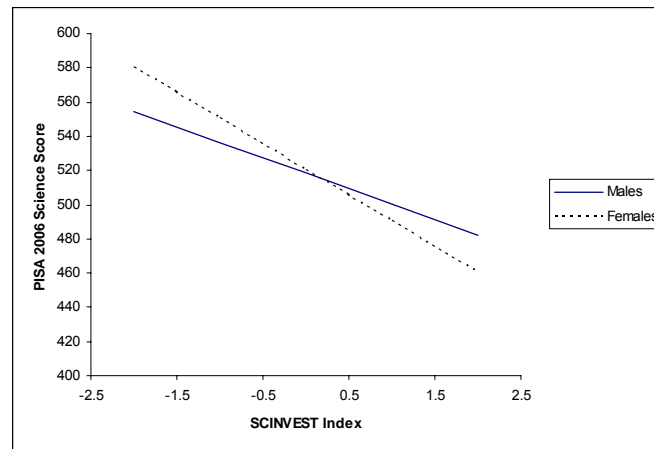
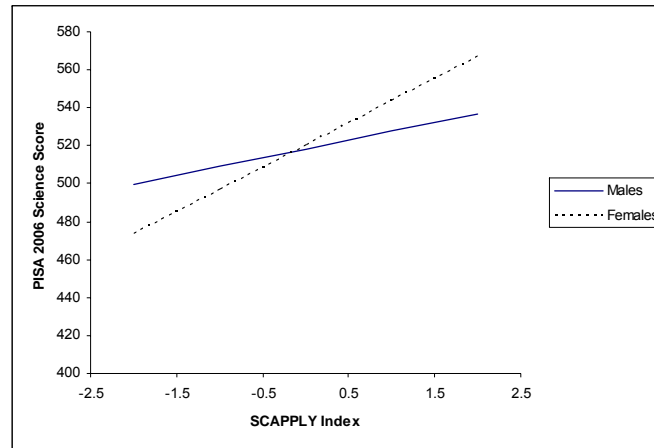
# How do the effects of inquiry-based practices on achievement vary by gender and class size?

Figure 4a. Fitted relationships between inquiry indices and 2006 PISA science score by gender.



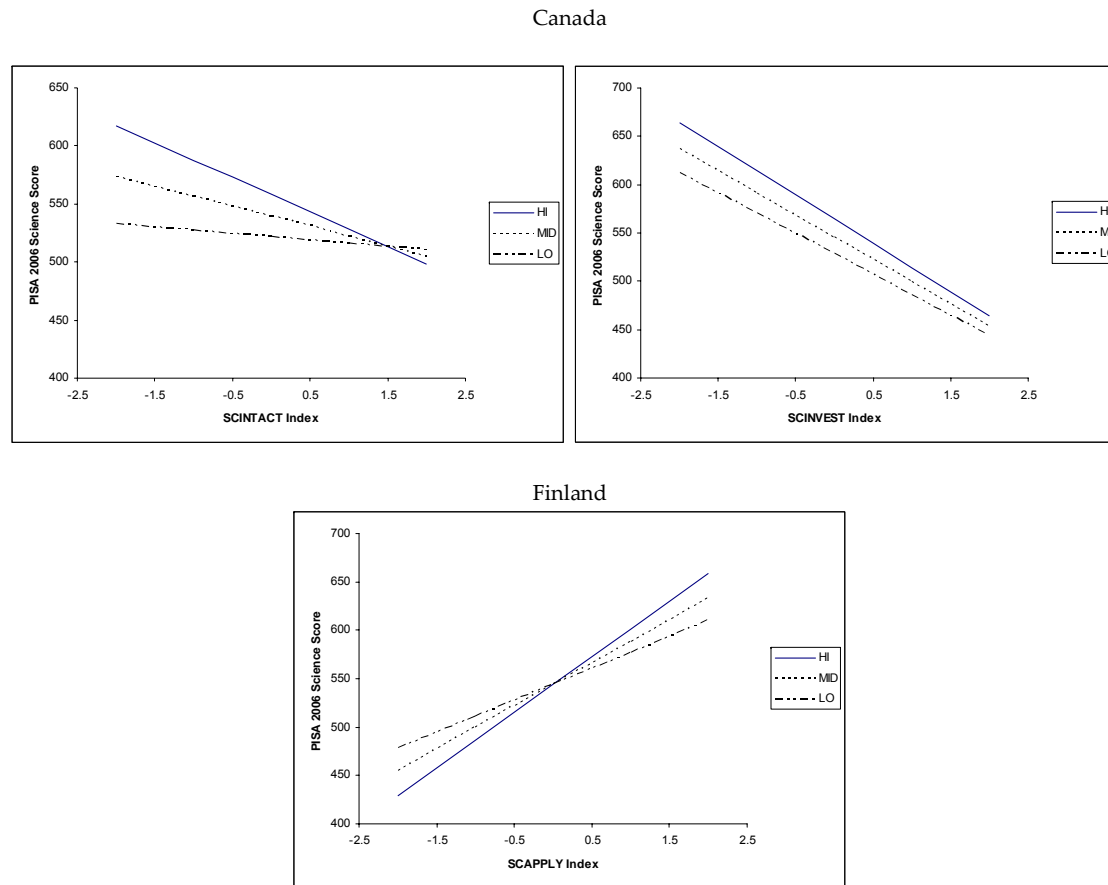
# How do the effects of inquiry-based practices on achievement vary by gender and class size?

Australia



# How do the effects of inquiry-based practices on achievement vary by gender and class size?

Figure 5. Fitted relationships between inquiry indices and 2006 PISA science score by class size.



Are there particular types of schools (based on school-level characteristics such as school-level funding, accountability and governance factors) that tend to rely more frequently on inquiry-based approaches?

- For the US: Accountability positively linked to SCINVEST; Autonomy negatively linked to SCINVEST

School Level Variables	Inquiry Based Approaches			
	SCAPPLY	SCHANDS	SCINVEST	SCINTACT
<b>School Management and Funding</b>				
Privately Managed Schools [XPRIVMAN]	n/s	n/s	-	n/s
Schools with Higher Percentage of Government Funding [XGOVFUND]	n/s	n/s	+	n/s
<b>Parental Pressure and Choice</b>				
Higher Levels of School Competition [XSCHLCOMP]	n/s	+	n/s	n/s
Higher Levels of Perceived Parental Pressure [XPRESSPA]	n/s	n/s	-	n/s
<b>Accountability Practices</b>				
Schools that inform parents of student's performance (relative to other students) [XACC1]	n/s	n/s	+	n/s
Schools that inform parents of student's performance (relative to other nat'l benchmarks) [XACC2]	n/s	n/s	n/s	n/s
Schools that inform parents of student's performance (relative to other schools) [XACC3]	n/s	n/s	+	+
Schools that publicly post achievement data [XACC4]	n/s	+	+	n/s
Schools that use achievement data to evaluate principals [XACC5]	n/s	n/s	+	n/s
Schools that use achievement data to evaluate teachers [XACC6]	n/s	-	+	n/s
Schools that use achievement data to allocate resources [XACC7]	n/s	n/s	n/s	n/s
Schools that track achievement data over time [XACC8]	n/s	+	+	n/s
<b>School Autonomy</b>				
Autonomy in Staffing [XFACS]	n/s	+	-	n/s
Autonomy in Budgeting [XFACB]	n/s	n/s	-	n/s
Autonomy in Educational Content [XFACC]	n/s	+	-	-

+ = positive correlation - = negative correlation n/s = correlation is not significant

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- ❑ **Overall Pattern: Government funding linked to higher SCINVEST**
- ❑ Overall, the correlations seem to suggest that schools with higher percentages of government funding tend to favor students conducting independent investigations during lessons.
  - This is true for six of the eight countries: Spain, Italy, Japan, Australia, Canada and the United States. Again, this is interesting given the negative relationship between SCINVEST and achievement for each of these countries. In fact, for Italy, all four indices have positive associations with schools that have higher percentages of government funding.

# Are there particular types of schools (based on school-level characteristics such as school-level funding, accountability and governance factors) that tend to rely more frequently on inquiry-based approaches?

School Level Variables	Inquiry Based Approaches			
	SCAPPLY	SCHANDS	SCINVEST	SCINTACT
<b>School Management and Funding</b>				
Privately Managed Schools [XPRIVMAN]	n/s	n/s	n/s	n/s
Schools with Higher Percentage of Government Funding [XGOVFUND]	+	+	+	+
<b>Parental Pressure and Choice</b>				
Higher Levels of School Competition [XSCHLCOMP]	n/s	n/s	-	-
Higher Levels of Perceived Parental Pressure [XPRESSPA]	n/s	-	-	n/s
<b>Accountability Practices</b>				
Schools that inform parents of student's performance (relative to other students) [XACC1]	+	+	+	n/s
Schools that inform parents of student's performance (relative to other nat'l benchmarks) [XACC2]	n/s	+	-	-
Schools that inform parents of student's performance (relative to other schools) [XACC3]	n/s	n/s	-	n/s
Schools that publicly post achievement data [XACC4]	-	-	-	-
Schools that use achievement data to evaluate principals [XACC5]	n/s	+	n/s	n/s
Schools that use achievement data to evaluate teachers [XACC6]	n/s	-	n/s	+
Schools that use achievement data to allocate resources [XACC7]	n/s	-	n/s	+
Schools that track achievement data over time [XACC8]	n/s	+	n/s	-
<b>School Autonomy</b>				
Autonomy in Staffing [XFACS]	n/s	n/s	+	+
Autonomy in Budgeting [XFACB]	n/s	n/s	n/s	+
Autonomy in Educational Content [XFACC]	+	n/s	+	+

+ = positive correlation - = negative correlation n/s = correlation is not significant

# Key Take Aways

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- Within eight countries (USA, Mexico, Japan, Finland, Australia, Canada, Spain and Italy) students reporting higher frequency on an index capturing investigations in science teaching and learning tend, on average, to have lowered achievement in science. Moreover, for several of these countries (USA, Australia, Canada and Finland), the effect of student investigations in science teaching and learning differentially affects the achievement of female versus male students, lowering the achievement more for females relative to their male counterparts.
- Within these same countries, students who report higher frequencies on an index of focus on model of applications in science teaching and learning tend to have higher PISA 2006 science scores, on average. For two countries, the US and Australia, females have larger gains in achievement due to an emphasis on models/applications in science teaching and learning versus their male counterparts.
- For Canada, a larger class size differentially affects the impact that investigations and interaction in the sciences has on science achievement. Students in larger class sizes tend to have lower achievement due to science investigations and interaction versus their peers in smaller class sizes.
- In the United States, schools that demonstrate more accountability tend to have students reporting higher frequency in conducting student investigations during their lessons while more autonomous schools have students reporting less of such practices during lessons.

# Conclusion

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- ❑ Students should conduct investigations with appropriate guidance and instructional scaffolding.
- ❑ Making science relevant seems important for student's achievement, as captured by the positive link between models and applications in science (SCAPPLY) and science achievement.