Two Approaches to Modeling Student Performance

John Anderson

Todd Milford

&

Shelley Ross

University of Victoria
Curriculum and Instruction (EDCD)

- ☞ **Secondary data analysis – SDA**

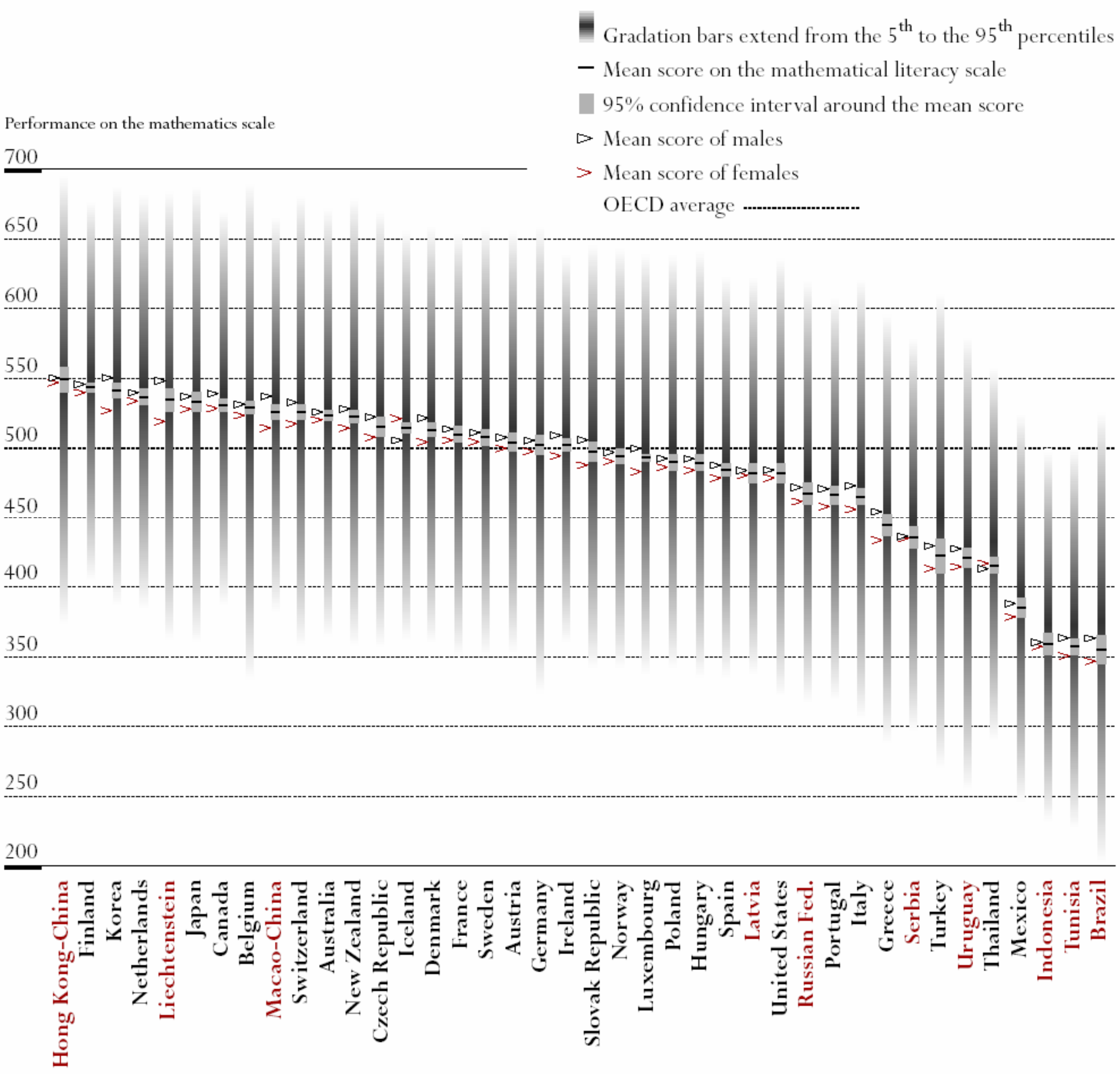
- ☞ **Multilevel Modeling - HLM**

SDA in CRYSTAL

- ✓ The PISA dataset
  - The student variables
  - The school variables
  - Items & indices
  - Plausible values, design weights & replicate weights
- ✓ The PISA performance measures – Mathematics & Science

The basic achievement measures

Figure 2.17 ■ **Distribution of student performance on the mathematics scale**



Measures on potential correlates of learning – the COLO's

Student Background

- Age
- Study programme
- Family Structure
- Highest Occupational Status of Parents
- Educational Level of Parents
- Immigration Background
- Language Use at Home

Learning and Instruction

- Relative Grade
- Expected Educational Level
- Expected Occupational Status
- Relative Time spent on Mathematics Homework
- Minutes of Mathematics Instruction
- Minutes of Overall School Instruction
- Relative Instructional Time on Mathematics

Student-Level Scale Indices

- Student Background
- Computer Facilities at Home
- Home Educational Resources
- Cultural Possessions

School Climate

- Attitudes Toward School
- Student-teacher Relations
- Sense of Belonging

Classroom Climate

- Teacher Support
- Disciplinary Climate

Self-Related Cognitions In Mathematics

- Interest and Enjoyment in Mathematics
- Instrumental Motivation in Mathematics
- Mathematics Self-Efficacy
- Mathematics Anxiety
- Mathematics Self-Concept

Learning Strategies and Preferences in Mathematics

- Learning Strategies: Memorisation/Rehearsal
- Learning Strategies: Elaboration
- Learning Strategies: Control Strategies
- Preference for Competitive Learning Situations
- Preference for Cooperative Learning Situations

School Characteristics

- School Size
- Proportion of Girls Enrolled at School
- School Type

Indicators of School Resources

- Availability of Computers
- Quantity of Teaching Staff at School
- Quantity of Teaching Staff for Mathematics at School

Admittance Policies and Instructional Context

- School Selectivity
- Use of Assessments
- Ability Grouping
- Mathematics Activity Index

School Resources

- Quality of the School’s Physical Infrastructure
- Quality of the School’s Educational Resources
- Teacher Shortage

School Climate

- Teacher Morale and Commitment
- Student Morale and Commitment
- Teacher-related Factors affecting School Climate
- Student-related Factors affecting School Climate
- Teacher Consensus on Mathematics Teaching

School Management

- School Autonomy
- Teacher Participation

PISA performance measures

Space & Shape

Change & Relationships

Quantity

Uncertainty

A total of 85 mathematics items

Table A6.1

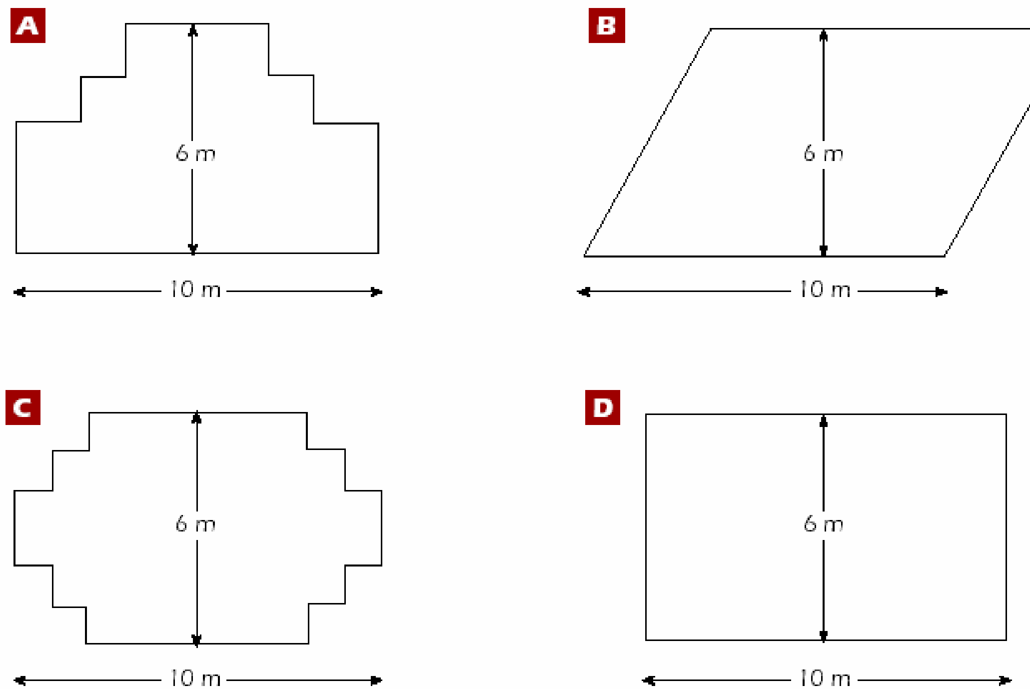
Distribution of items by the dimensions of the PISA framework for the assessment of mathematics

	Number of items[1]	Number of multiple-choice items	Number of complex multiple-choice items	Number of closed-constructed response items	Number of open-constructed response items	Number of short response items
Distribution of mathematics items by "overarching ideas"						
Space and shape	20	4	4	6	4	2
Change and relationships	22	1	2	4	11	4
Quantity	23	4	2	2	1	14
Uncertainty	20	8	3	1	5	3
Total	*85*	*17*	*11*	*13*	*21*	*23*
Distribution of mathematics items by competency cluster						
Reproduction	26	7	0	7	3	9
Connections	40	5	9	4	9	13
Reflection	19	5	2	2	9	1
Total	*85*	*17*	*11*	*13*	*21*	*23*
Distribution of mathematics items by situations or contexts						
Personal	18	5	3	1	3	6
Educational/Occupational	20	2	4	6	2	6
Public	29	8	2	4	8	7
Scientific	18	2	2	2	8	4
Total	*85*	*17*	*11*	*13*	*21*	*23*

Space & shape

CARPENTER

A carpenter has 32 metres of timber and wants to make a border around a garden bed. He is considering the following designs for the garden bed.



The prompt →

QUESTION 1

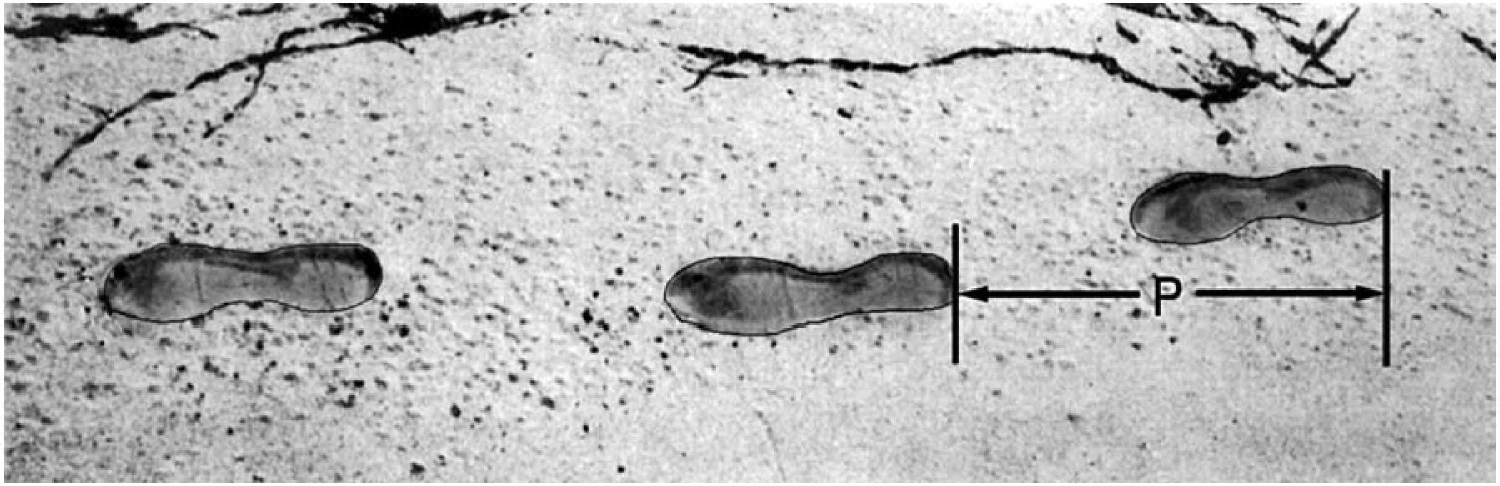
Circle either "Yes" or "No" for each design to indicate whether the garden bed can be made with 32 metres of timber.

Garden bed design	Using this design, can the garden bed be made with 32 metres of timber?
Design A	*Yes / No*
Design B	*Yes / No*
Design C	*Yes / No*
Design D	*Yes / No*

Score 1 (687)
Answers which indicate Yes, No, Yes, Yes, in that order.

This complex multiple-choice item is situated in an educational context, since it is the kind of quasi-realistic problem that would typically be seen in a mathematics class, rather than being a genuine problem likely to be met in an occupational setting. While not regarded as typical, a small number of such problems have been included in the PISA assessment. However, the competencies needed for this problem are certainly relevant and part of mathematical literacy. This item illustrates Level 6 with a difficulty of 687 score points. The item belongs to the space and shape content area, and it fits the connections competency cluster – as the problem is non-routine. The students need the competence to recognise that for the purpose of solving the question the two-dimensional shapes A, C and D have the same perimeter, therefore they need to decode the visual information and see similarities and differences. The students need to see whether or not a certain border-shape can be made with 32 metres of timber. In three cases this is rather evident because of the rectangular shapes. But the fourth is a parallelogram, requiring more than 32 metres. This use of geometrical insight and argumentation skills and some technical geometrical knowledge makes this item illustrate the Level 6.

WALKING



The picture shows the footprints of a man walking. The pacelength P is the distance between the rear of two consecutive footprints.

For men, the formula, $\frac{n}{P} = 140$*, gives an approximate relationship between n and P where:*

n = *number of steps per minute, and*
P = *pacelength in metres.*

The prompt →

QUESTION 5

Bernard knows his pacelength is 0.80 metres. The formula applies to Bernard's walking.

Calculate Bernard's walking speed in metres per minute and in kilometres per hour. Show your working out.

Score 3 (723)

Answers which indicate correctly metres/minute (89.6) and km/hour (5.4). Errors due to rounding are acceptable.

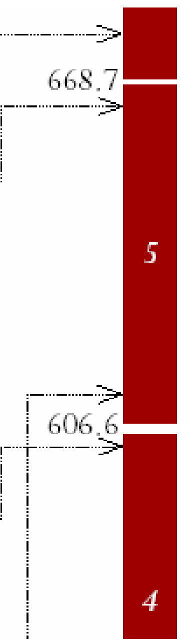
Score 2 (666)

Answers which are incorrect or incomplete because:

- They were not multiplied by 0.80 to convert from steps per minute to metres per minute.
- They correctly showed the speed in metres per minute (89.6 metres per minute) but the conversion to kilometres per hour was incorrect or missing.
- They were based on the correct method (explicitly shown) but with other minor calculation error(s).
- They indicated only 5.4 km/hr, but not 89.6 metres per minute (intermediate calculations not shown).

Score 1 (605)

Answers which give $n = 140 \times .80 = 112$ but no further working out is shown or incorrect working out from this point.

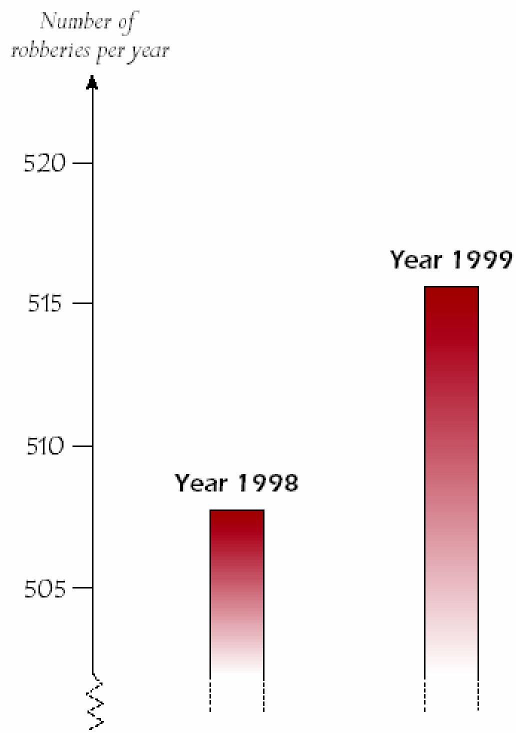


This open-constructed response item is situated in a personal context. The coding guide for this item provides for full credit, and two levels of partial credit. The item is about the relationship between the number of steps per minute and pacelength. It follows that it fits the change and relationships content area. The mathematical routine needed to solve the problem successfully is substitution in a simple formula (algebra), and carrying out a non-routine calculation. To solve the problem, students first calculate the number of steps per minute when the pace-length is given (0.8 m). This requires substitution into and manipulation of the expression: n/0.8 = 140 leading to: n = 140 x 0.8 which is 112 steps per minute. The next question asks for the speed in m/minute which involves converting the number of steps to a distance in metres: 112 x 0.80 = 89.6 metres; so his speed is 89.6 m/minute. The final step is to transform this speed into km/h - a more commonly used unit of speed. This involves relationships among units for conversions which is part of the measurement domain. Solving the problem also requires decoding and interpreting basic symbolic language, and handling expressions containing symbols and formulae. The problem, therefore, is rather a complex one involving formal algebraic expression and performing a sequence of different but connected calculations that need understanding of transforming formulas and units of measures. The lower level partial credit part of this item belongs to the connections competency cluster and with a difficulty of 605 score points it illustrates the top part of Level 4. The higher level of partial credit illustrates the upper part of Level 5, with a difficulty of 666 score points. Students who score the higher level of partial credit are able to go beyond finding the number of steps per minute, making progress towards converting this into the more standard units of speed asked for. However, their responses are either not entirely complete or not fully correct. Full credit for this item illustrates the upper part of Level 6, as it has a difficulty of 723 score points. Students who score full credit are able to complete the conversions and provide a correct answer in both of the requested units.

ROBBERIES

A TV reporter showed this graph and said:

"The graph shows that there is a huge increase in the number of robberies from 1998 to 1999."



QUESTION 15

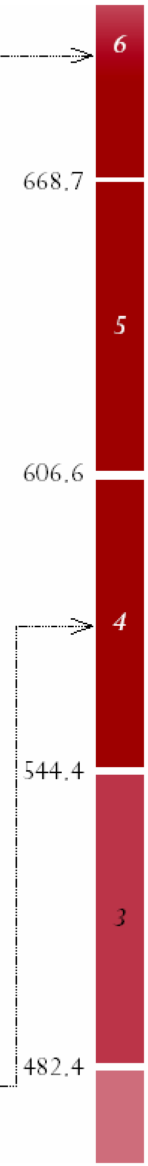
Do you consider the reporter's statement to be a reasonable interpretation of the graph? Give an explanation to support your answer.

Score 2 (694)

Answers which indicate "No, not reasonable" and focus on the fact that only a small part of the graph is shown, or contain correct arguments in terms of ratio or percentage increase, or refer to requirement of trend data before a judgement can be made.

Score 1 (577)

Answers which indicate "No, not reasonable" but explanation lacks detail (focuses ONLY on an increase given by the exact number of robberies, but does not compare with the total) or with correct method but with minor computational errors.



This open-constructed response item is situated in a public context. The graph as presented in the stimulus of this item actually was derived from a real graph with a similarly misleading message as the one here. The graph seems to indicate, as the TV reporter said: "a huge increase in the number of robberies". The students are asked if the statement fits the data. It is very important to look through data and graphs as they are frequently presented in the media in order to participate effectively in society. This constitutes an essential skill in mathematical literacy. Quite often designers of graphics use their skills (or lack thereof) to let the data support a pre-determined message, often with a political context. This is an example. The item involves the analysis of a graph and data interpretation, placing it in the uncertainty area. The reasoning and interpretation competencies required, together with the communication skills needed, are clearly belonging to the connections competency cluster. The competencies that are essential for solving this problem are understanding and decoding of a graphical representation in a critical way, making judgments and finding appropriate argumentation based on mathematical thinking and reasoning (although the graph seems to indicate quite a big jump in the number of robberies, the absolute number of increase in robberies is far from dramatic; the reason for this paradox lies is the inappropriate cut in the y-axis) and proper communication of this reasoning process.

A partial credit response illustrates Level 4 with a difficulty of 577 points. In this case students typically indicate that the statement is not reasonable, but fail to explain their judgment in appropriate detail. This means here that the reasoning only focuses on an increase given by an exact number of robberies in absolute terms, but not in relative terms. Communication is critical here, since one will always have answers that are difficult to interpret in detail. An example: "an increase from 508 to 515 is not large" might have a different meaning from "an increase of around 10 is not large". The first statement shows the actual numbers, and thus the intended meaning of the answer might be that the increase is small because of the large numbers involved, while this line of reasoning does not apply to the second answer. In this kind of response, students use and communicate argumentation based on interpretation of data; therefore it illustrates Level 4.

A full credit response illustrates Level 6 with a difficulty score of 694 score points. In the case of full credit the students indicate that the statement is not reasonable, and explain their judgment in appropriate detail. This means here that the reasoning not only focuses on an increase given by an exact number of robberies in absolute terms, but also in relative terms. The question requires students to use and communicate argumentation based on interpretation of data, using some proportional reasoning in a statistical context, and in a not-too-familiar situation. Therefore it illustrates Level 6.

Modeling Approach

Multilevel modeling

or

Hierarchical linear modeling (HLM)

HLM

Intercept — Slopes

Math achievement ← Average Math + Student gender + Academic focus + . . .

Level 1 model

$$Y_{ij} = \beta_{0j} + \beta_{1j}(\text{Gender}) + \beta_{2j}(\text{Focus}) + r_{ij}$$

HLM

Math achievement ← Average Math + Student Gender + Academic Focus + . . .

Level 2 models

Average Math ← Mean math + School trait 1 + School trait 2

$$\beta_{0j} = \gamma_{00} + \gamma_{01}\,(\text{Trait 1})_j + \gamma_{02}\,(\text{Trait 2})_j + U_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}\,(\text{Trait 1})_j + \gamma_{12}\,(\text{Trait 2})_j + U_{1j}$$

$$\beta_{2j} = \gamma_{20} + \gamma_{21}\,(\text{Trait x})_j + \gamma_{22}\,(\text{Trait y})_j + U_{2j}$$

An example using Canadian data from SAIP

Our research questions

- How do students' attitudes, and beliefs influence their science achievement?
- How is achievement further influenced by school environments, specifically teacher attitudes towards science, and classroom attitudes, and beliefs?

Level 1

$$\text{Science (16 year olds)}_{ij} = \beta_{0j} + \beta_{1j}(\text{Gender}) + \beta_{2j}(\text{Mot\_1}) + \beta_{3j}(\text{Mot\_2}) + \beta_{4j}(\text{Mot\_3}) + \beta_{5j}(\text{Att\_3}) + \beta_{6j}(\text{Att\_4}) + \beta_{7j}(\text{Bel\_1}) + \beta_{8j}(\text{Bel\_2}) + r_{ij}$$

Level 2

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{TAttSc\_2}) + \gamma_{02}(\text{TAtt\_St\_2}) + u_{0j}$$

$$\beta_{1j} = \gamma_{10}$$

$$\beta_{2j} = \gamma_{20} + \gamma_{21}(\text{AggBel\_1})$$

$$\beta_{3j} = \gamma_{30} + \gamma_{31}(\text{TAttSt\_3}) + \gamma_{32}(\text{AggAtt\_3}) + \gamma_{33}(\text{AggAtt\_4})$$

$$\beta_{4j} = \gamma_{40} + \gamma_{41}(\text{TAttSt\_1})$$

$$\beta_{5j} = \gamma_{50}$$

$$\beta_{6j} = \gamma_{60}$$

$$\beta_{7j} = \gamma_{70} + \gamma_{71}(\text{AggAtt\_4})$$

$$\beta_{8j} = \gamma_{80} + \gamma_{81}(\text{AggAtt\_3})$$

SAIP Science – 16 year olds

Level 1 Model

Gender	.12
Help-seeking	-.09
Luck attributions	-.17
Teacher attributions	.04
Coping attitude	.09
Positive academic attitude	.05
Positive science beliefs	.27
Negative science beliefs	-.12

Conclusions

- For science achievement, these findings supported previous research:
  - Being male, having good coping attitudes, a positive academic attitude, and positive beliefs about the value of science all predicted increased scores
    - As did being in a classroom where teachers held a practical attitude about science
  - Attributing outcomes to luck, needing to seek help often, and having negative beliefs about science all predicted decreased scores
    - As did a classroom where teachers believed that students are responsible for their own outcomes.

PISA findings

- Gu, 2006
- Modeled math self-concept and math performance
- Compared Hong Kong and Canada
- Found that for both countries, math self-concept is positively related to math achievement
  - Mean math self-concept lower for Hong Kong students than Canadian students
  - Even though Hong Kong students had higher mean performance in math

PISA findings

- Goh, 2006
- Modeled relationships between student intrinsic motivation, teacher support and student-teacher relations, and math performance for Canadian students
- Found that motivation is positively related to math achievement
  - When student perception of teacher support is added to the model, level of teacher support is negatively related to math achievement.

PISA findings

- Ross (in progress)
- Modeling student level motivation factors and science, reading, and math achievement
- Compares Canada, the United States, Hong Kong, United Kingdom, Japan, and Korea
- This comparison allows for evaluation of generalizability of the relationships, and perhaps the generalizability of theories of motivation

Questions
Comments
&
Discussion