International Comparative Studies in Mathematics:

Lessons for Improving Students' Learning

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International Comparative Studies in Mathematics

Lessons for Improving Students' Learning

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Session Outline

- Introduction
- Lesson 1: Examining the dispositions and experiences of mathematically literate students
- Lesson 2: Understanding students' thinking
- Lesson 3: Changing classroom instruction, and
- Lesson 4: Making global assessment research locally meaningful
- Looking into the future

What Is An International Comparative Study?

We use the phrase ‘international comparative studies’ to refer to all those involving at least two ‘countries’, with an intention to compare at the ‘country’ level

What Is An International Comparative Study?

- Small and large,
- Qualitative and quantitative, and
- Initiatives of government or individual researchers

International Comparative Studies are to:

- Compare different school systems and different traditions and cultures of schooling,

- Understand where we stand, both in relation to others as well as to our own past experiences (through comparing) , and

- Create awareness of different possibilities for teaching mathematics and improving students' learning of mathematics.

Improving Students' Learning

- Lesson 1: Examining the dispositions and experiences of mathematically literate students
- Lesson 2: Understanding students' thinking
- Lesson 3: Changing classroom instruction, and
- Lesson 4: Making global assessment research locally meaningful

Lesson 1
Examining the dispositions and experiences of mathematically literate students

Kaye Stacey

- Emeritus Professor and formerly Foundation Professor of Mathematics Education at the University of Melbourne
- BSc (Hons) (UNSW), MSc D Phil (Oxford, UK), Dip Ed (Monash), FAustMS
- Teacher educator, researcher, author, and government advisor
- Chair, international Mathematics Expert Group for OECD's PISA 2012 survey
- Currently Director of Curriculum Resources for the Australian Academy of Science *Mathematics by Inquiry* project.

Lesson 1
Examining the dispositions and experiences of mathematically literate students

Large international comparisons

- Projects of governments primarily for policy makers
  - Education for benefit of country and individual
  - Many research questions, huge size, strong statistics
  - Main aim is to deliver scores on achievement and dispositions for comparison between groups and trends
  - Strong processes to define the assessment, ensure good translation, eliminate identifiable cultural biases etc.
  - Procedures must be practical e.g. simple ‘scoring’
  - Mathematics is only part of the agenda
- Thousands of ‘results’ , that answer some questions, raise others and cannot address some.

A story from PISA 2012 : what curriculum, experiences and dispositions promote mathematical literacy?

Mathematical literacy: ability to use mathematical knowledge in situations that are likely to arise in the lives and work of citizens in the modern world. Hence PISA items set within a real world context

Main sources

OECD. (2013). *PISA 2012 Results: What Students Know and Can Do (Volume I).*

OECD. (2013). *PISA 2012 Results: Ready to Learn Students' Engagement, Drive and Self-Beliefs (Volume 3).*

PISA 2012 scores

613	Shanghai-China
573	Singapore
561	Hong Kong-China
560	Chinese Taipei
554	Korea
538	Macao-China
536	Japan
535	Liechtenstein
531	Switzerland
523	Netherlands
521	Estonia
519	Finland

504	Australia
501	Ireland

494 OECD AVERAGE

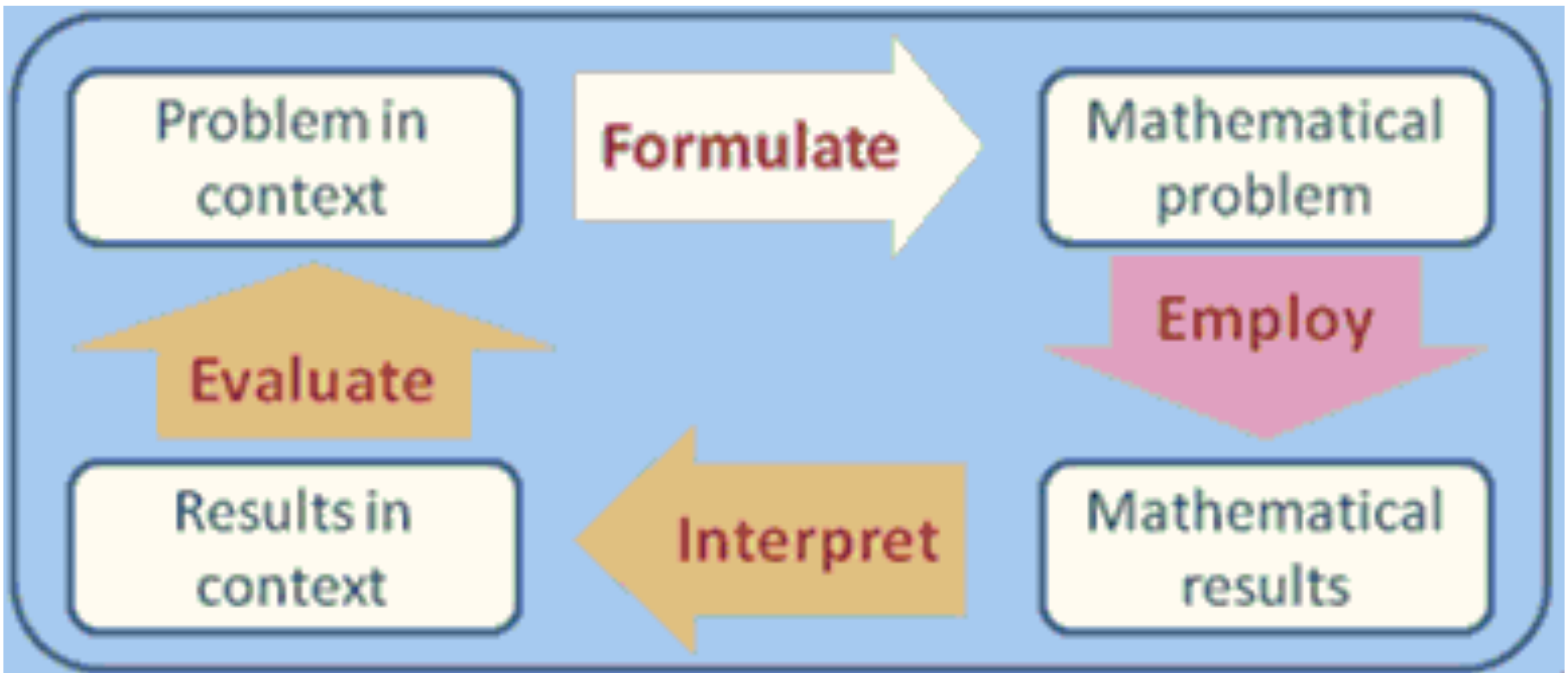
489	Norway
487	Portugal
485	Italy
484	Spain
482	Russian Federation
482	Slovak Republic
481	United States

386	Jordan
376	Colombia
376	Qatar
375	Indonesia
368	Peru

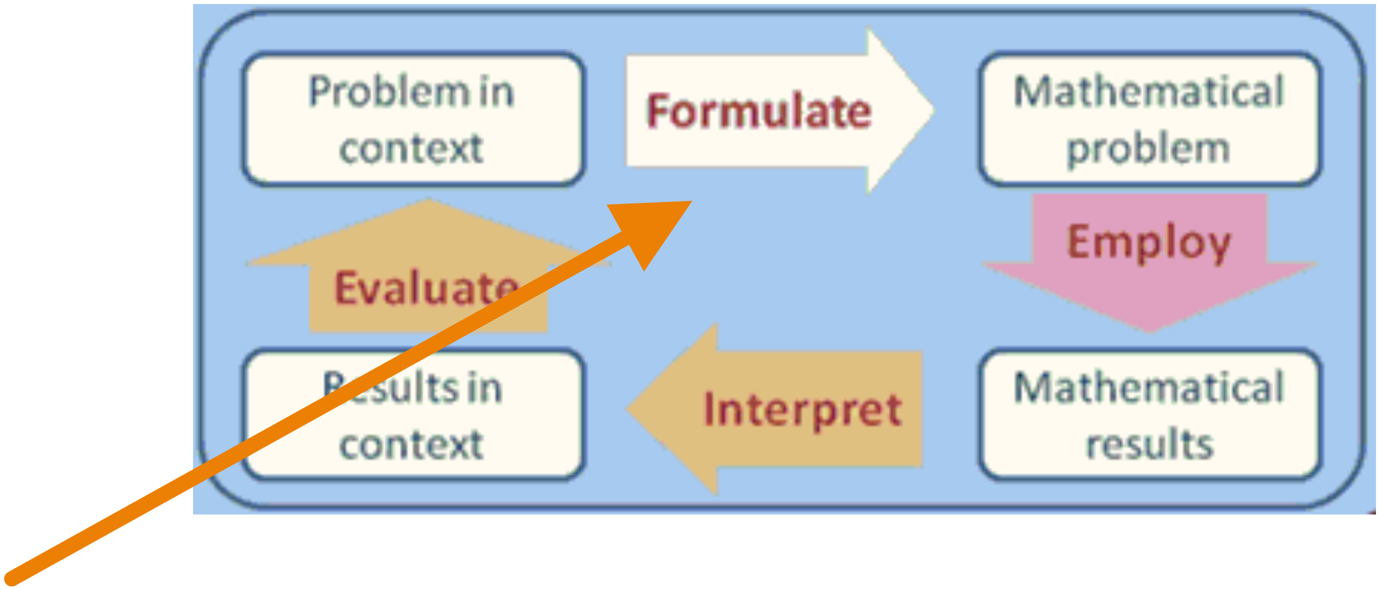
PISA's three processes

Thinking about real world ideas

Thinking about mathematical ideas



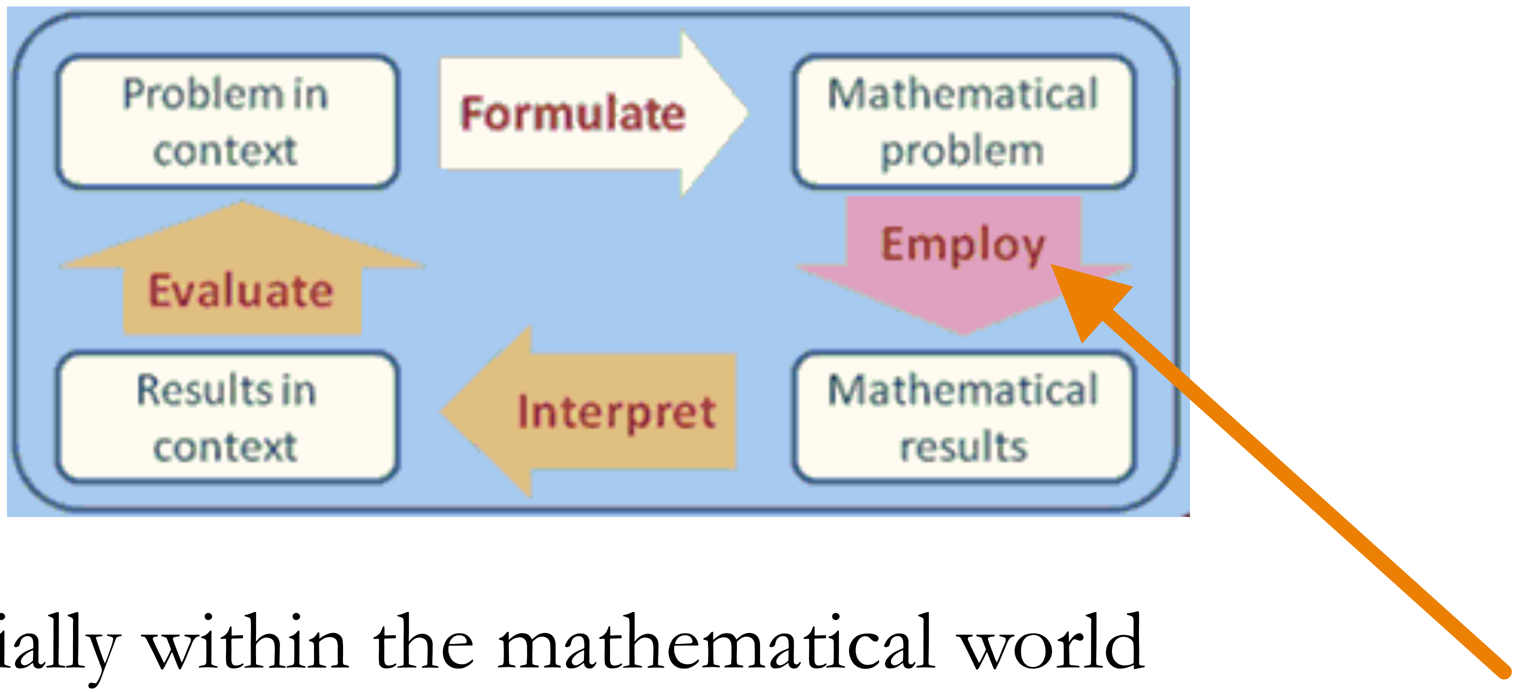
Formulating situations mathematically



PISA problems start in the real world and need to be translated into mathematical terms

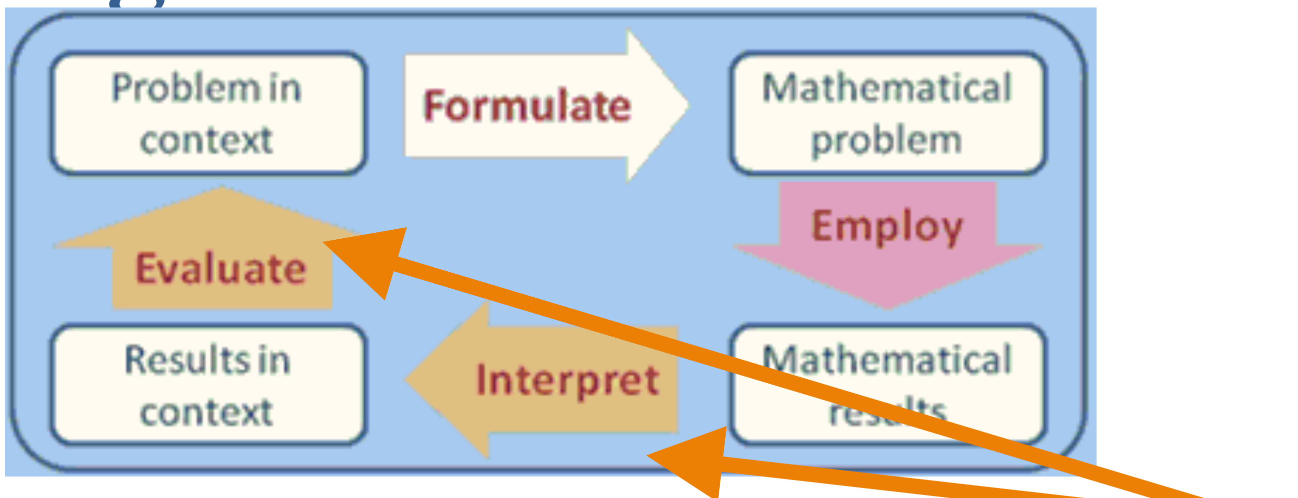
PISA ‘Formulate’ score derives from items where formulating presents the greatest cognitive demand.

Employing mathematical concepts, facts, procedures and reasoning



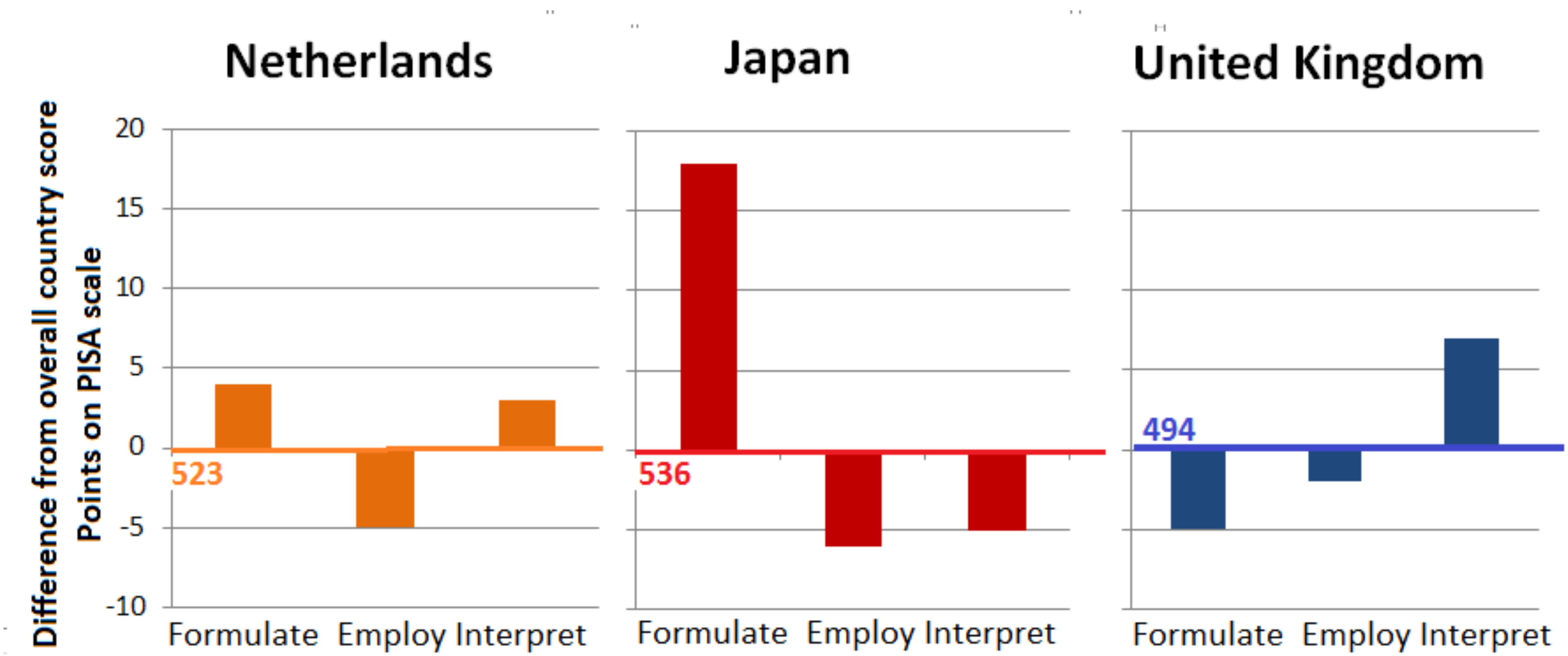
Essentially within the mathematical world

Interpreting, applying and evaluating mathematical outcomes



- putting mathematical outcomes into real world terms
- evaluating the adequacy of solutions
- Does NOT mean interpreting the problem statements or given information

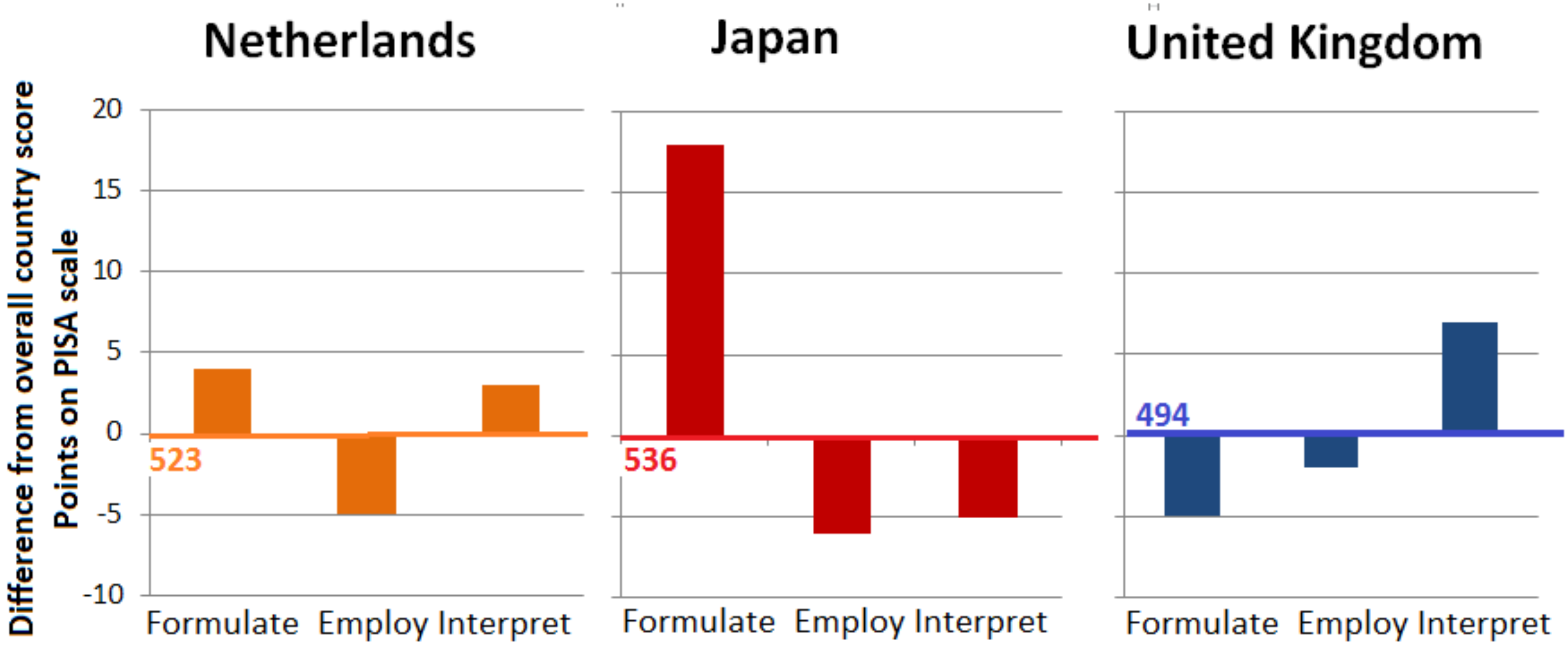
Country patterns in process scores



Students rating confidence and exposure to formal and applied tasks

- Students asked to rate
  - how **confident** they felt about solving a set of mathematics tasks, and
  - how **frequently they had met** similar tasks in class.
- Included two types of tasks
  - formal mathematics (no context) e.g. volume of box
  - applied mathematics
    - e.g. calculating times using a train timetable, calculating petrol consumption, and interpreting a misleading graph in a newspaper (a released PISA item).

	Overall Math'l literacy	Exposure to formal maths	Exposure to applied maths
Japan	536	high	low
Netherlands	523	low	high
UK	494	average	average



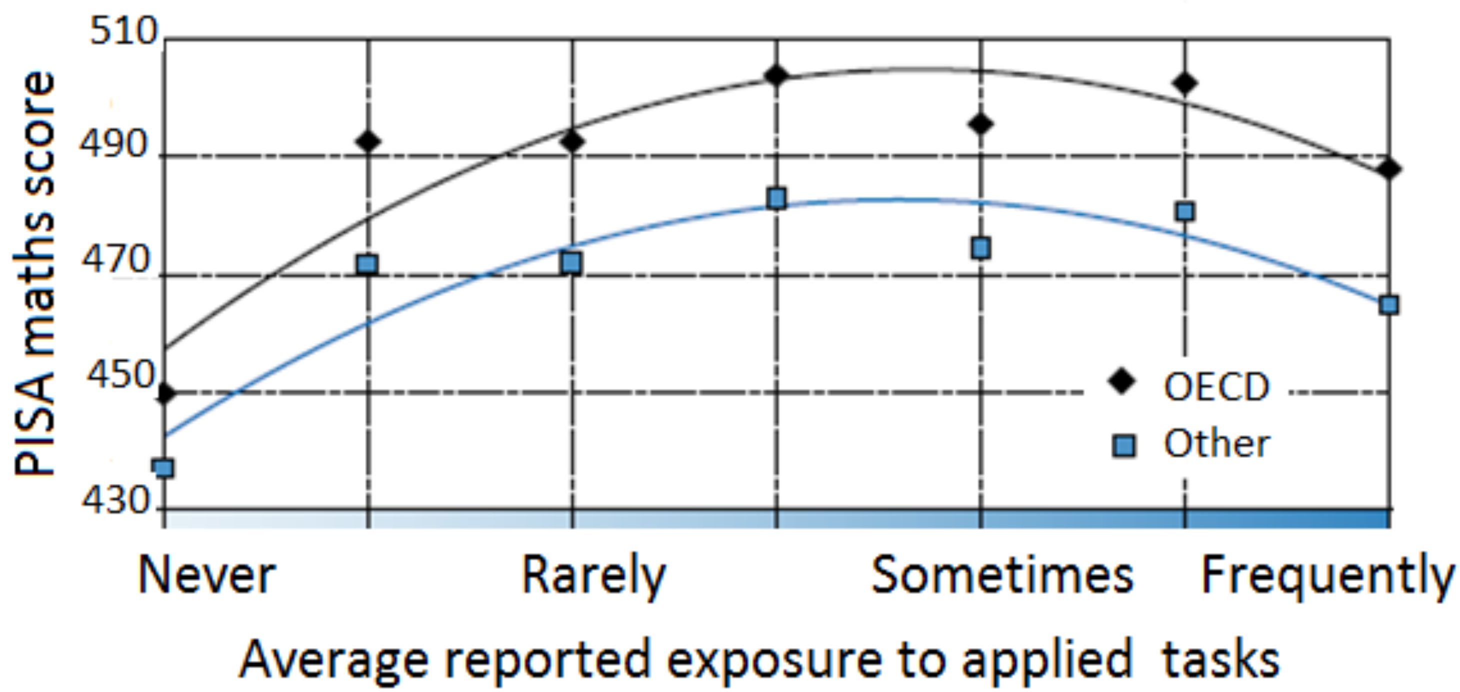
Students' reports of frequency for doing these problem types

	Top 3	At OECD average	Bottom 3
Formal	Shanghai, Singapore Macao	Chile, Australia	Iceland, Sweden
Applied	Thailand Indonesia	Bulgaria Slovenia	Shanghai, Macao, Czech Republic

N.B. Many countries cluster around the average

What curriculum for math'l literacy?

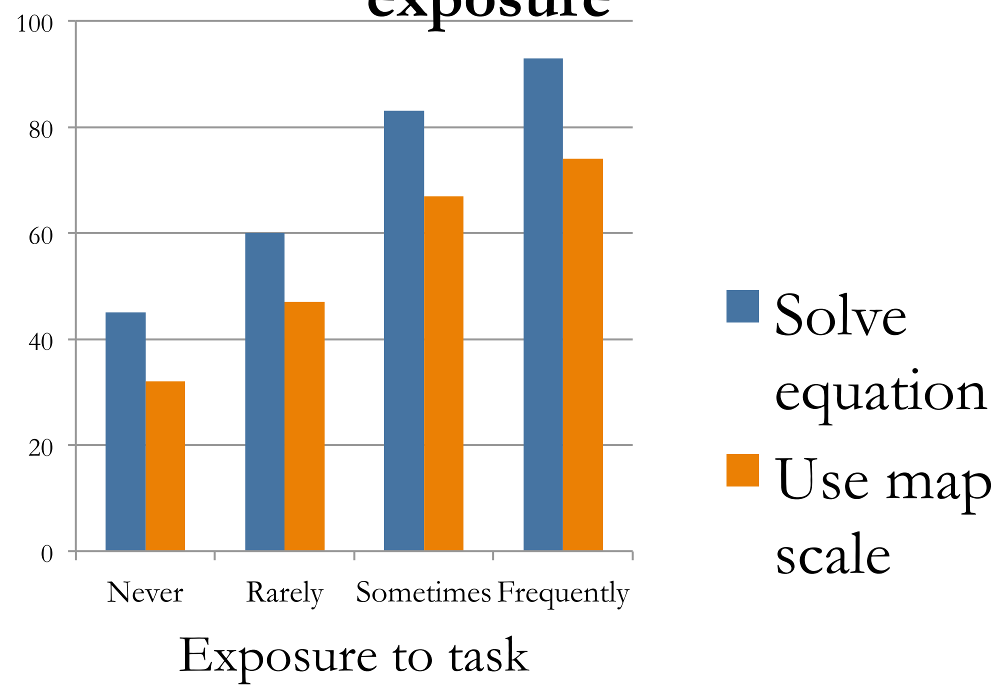
- Relationship of exposure with achievement scores
  - formal mathematics: strong and positive
  - applied mathematics: 'quadratic' relationship



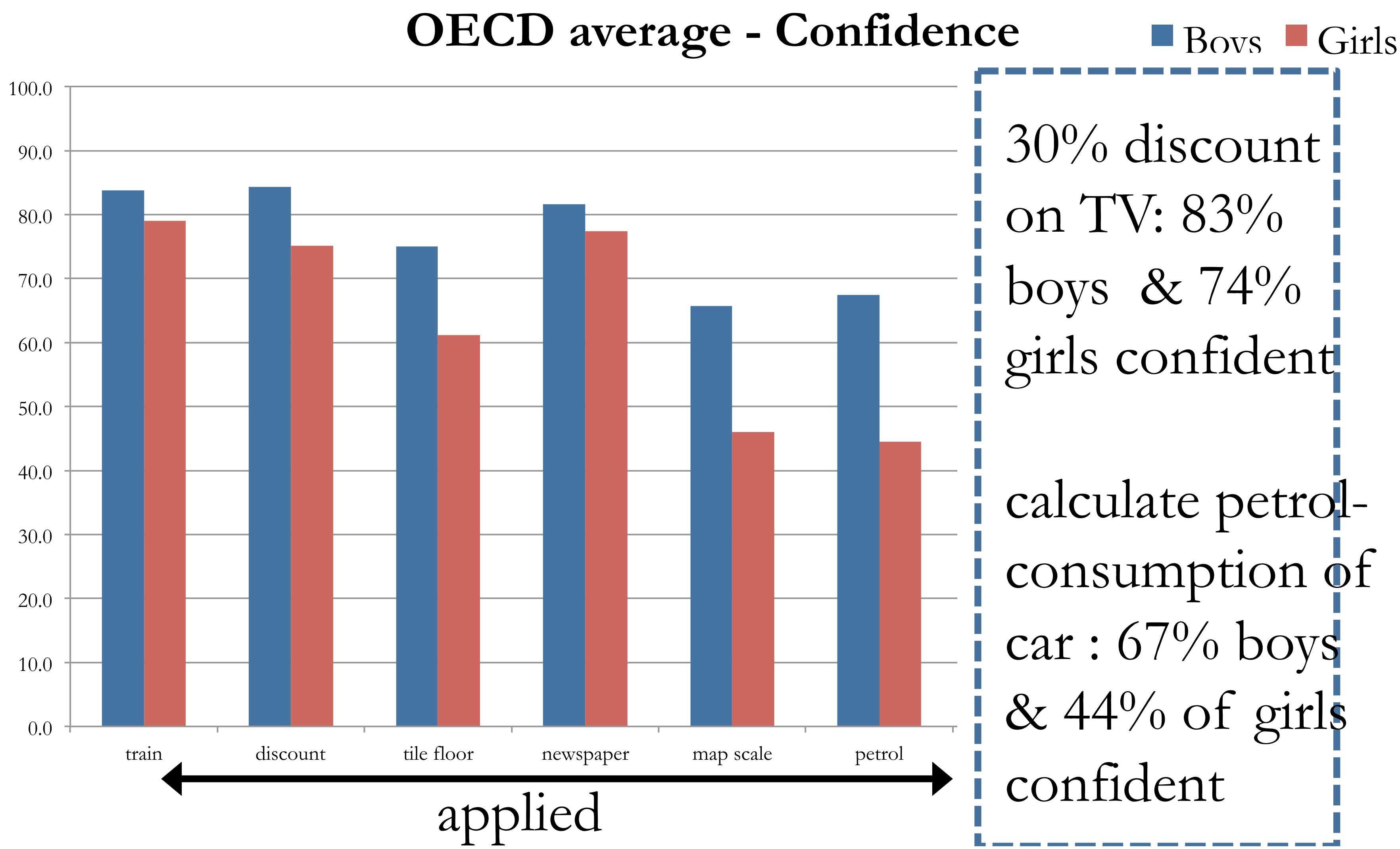
Exposure to and confidence in formal and applied mathematics

- Exposure to task strongly linked to confidence to do it.
- Relationship ‘narrow’: quite specific to items
- Confidence for formal tasks higher than for applied tasks.
- WHY? Applied tasks involve 3 processes.

% OECD students confident to solve task by level of exposure



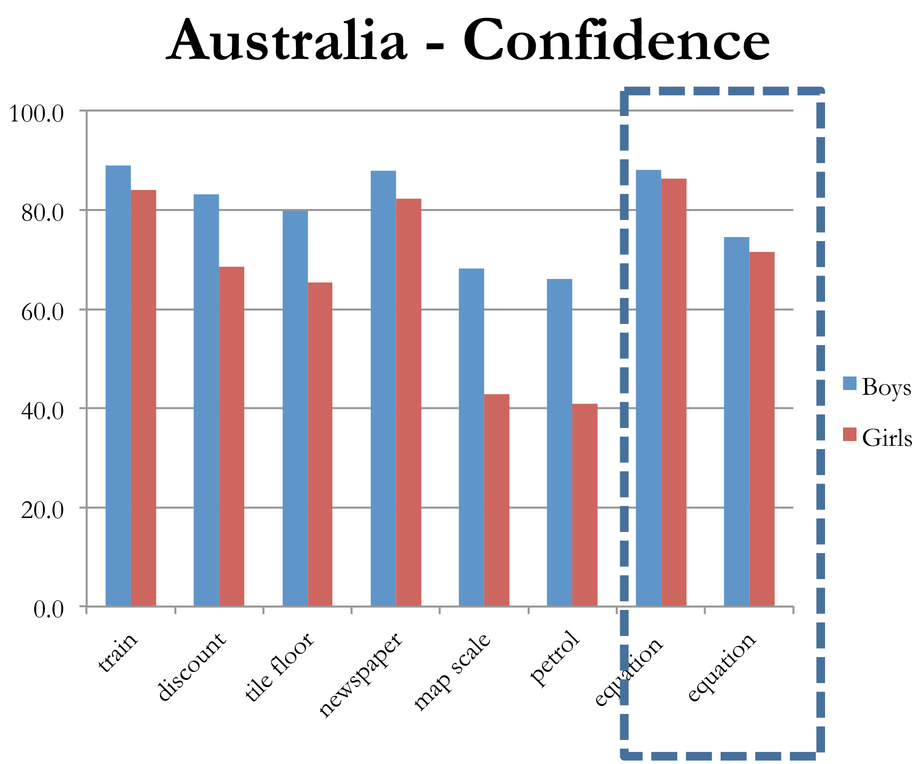
Gender differences in confidence in ‘applied’ and ‘formal’ items

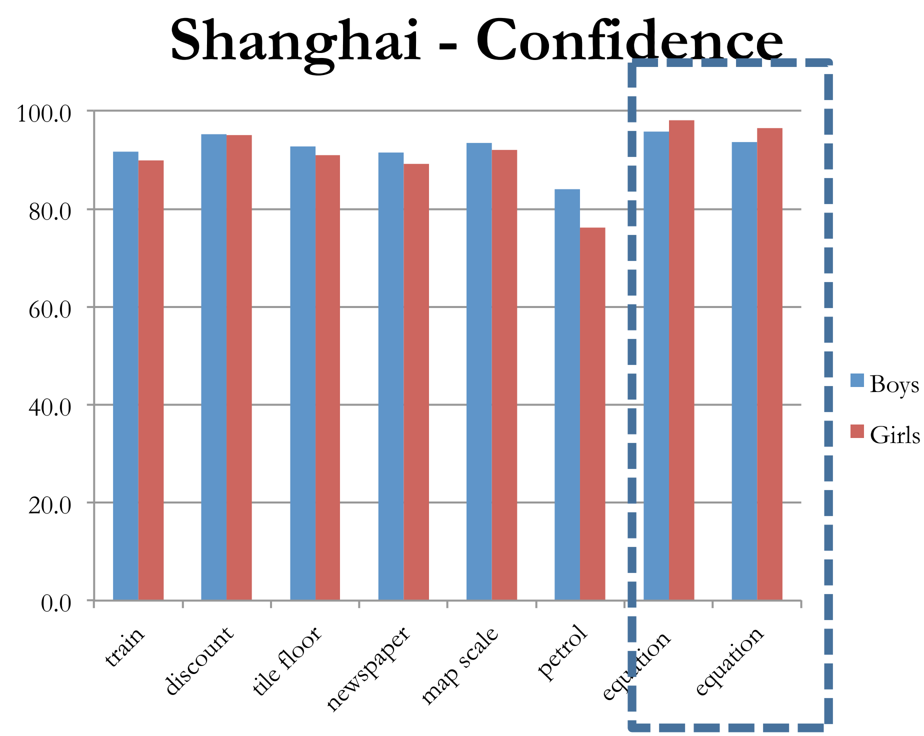


30% discount on TV: 83% boys & 74% girls confident

calculate petrol-consumption of car : 67% boys & 44% of girls confident

Gender differences in confidence in 'applied' and 'formal' items





Differences might affect choice of STEM career

Relationships of dispositions to exposure to formal and applied mathematics
(mathematics engagement, motivation, self-beliefs)

	Formal	Applied
All students	+	+

Mathematics educators can assist in using outcomes from these studies better

- Contributing to better understanding of the results both within and between countries
- Drawing together evidence from multiple sources to inform policy
- Drawing on underlying framework and items to inform local directions for mathematics education
- Research of all methodologies can contribute to this endeavour
- Important because of status of large studies

Lesson 2
Understanding Students' Thinking

Jinfa Cai

- Professor of Mathematics and Education, University of Delaware
- Born and raised in Hangzhou, China
- Graduated from Hangzhou Normal University (BS), Beijing Normal University (M.Ed), and University of Pittsburgh (Ph.D.)
- Editor, *Compendium for Research in Mathematics Education*
- Editor, *Journal for Research in Mathematics Education (JRME)*
- Fellow, American Educational Research Association (AERA)

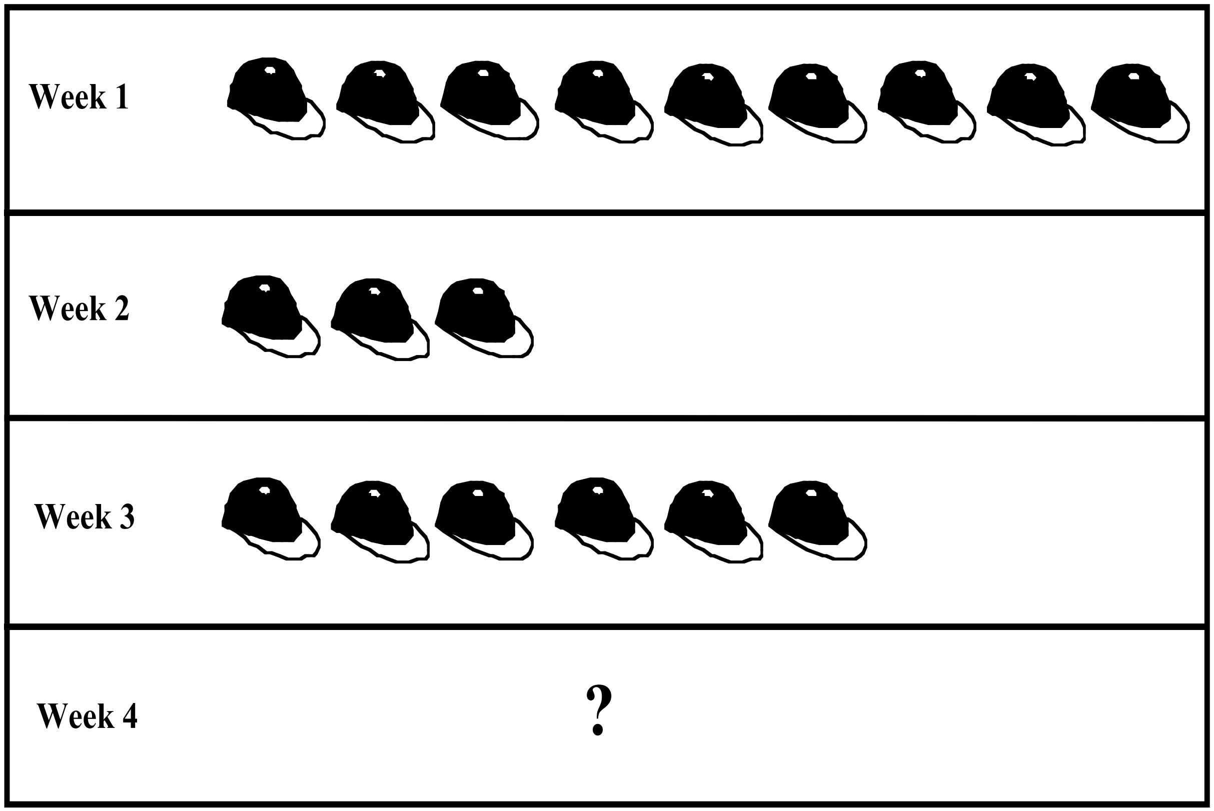
Lesson 2
Understanding Students' Thinking

The Can Averaging Problem (Task 1)

For their club's food drive, Tasha has 11 cans, David has 6 cans, Jeffrey has 5 cans, and Dwayne has 2 cans. What is the average number of cans for those four people? Explain how you found your answer.

Hats Average Problem (Task 2)

Angela is selling hats for the Mathematics Club. This picture shows the number of hats Angela sold during the first three weeks.



How many hats must Angela sell in Week 4 so that the <u>average</u> number of hats sold is 7? Show how you found your answer.

Correctness of Numerical Answers for Both Averaging Problems

		TASK 2			
		CORRECT		INCORRECT	
		U.S.	CHINA	U.S.	CHINA
TASK 1	CORRECT	42%	67%	24%	23%
	INCORRECT	3%	4%	31%	6%

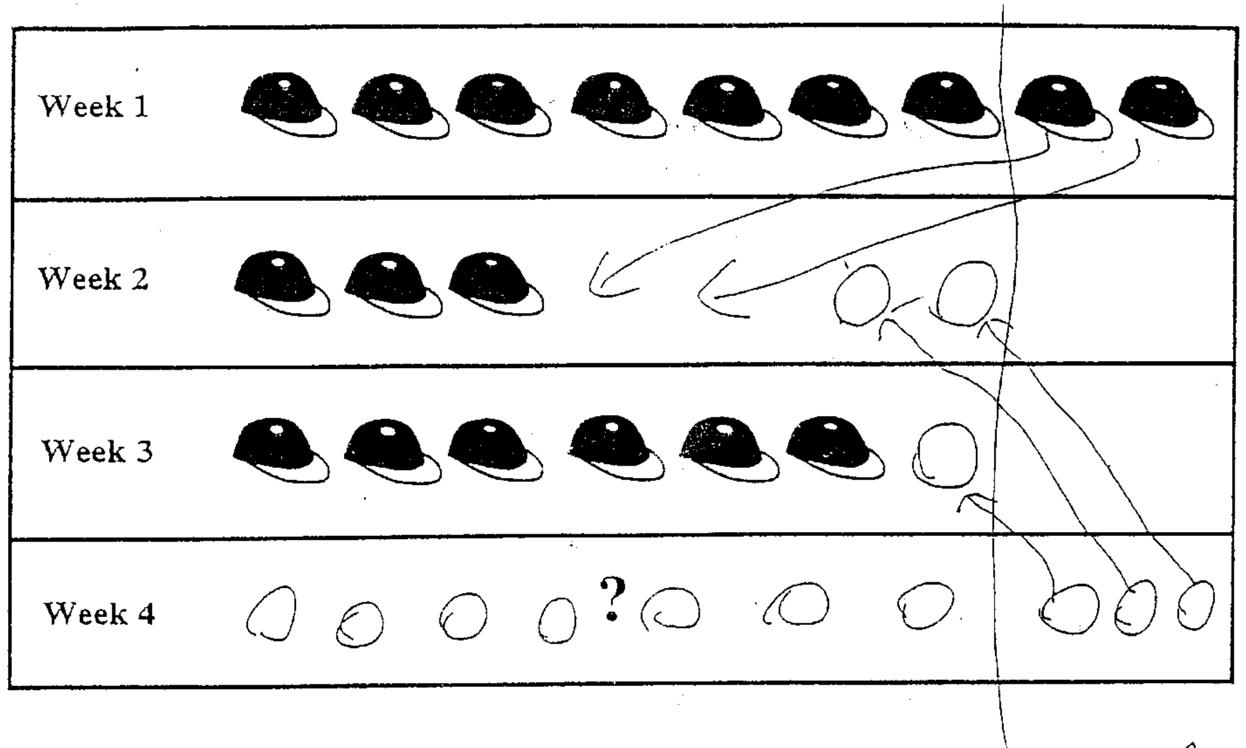
Solutions

Using Average Formula: The student correctly used the average formula to solve the problem

- arithmetically (e.g., 7 x 4 - (9 + 3 + 6) = 10

or

- algebraically (e.g., 9 + 3 + 6 + x = 7 x 4, then solve for x).



How many hats must Angela sell in Week 4 so that the <u>average</u> number of hats sold is 7?

Show how you found your answer.

Look at the figure

Answer: 10

Error 1

The student added the number of hats sold in week 1 (9), week 2 (3), and week 3 (6), then divided the sum by 3, and got 6. However, the average was 7. Therefore, the student added 3 to the sum of the numbers of hats sold in the first three weeks, then divided it by 3, and got 7, and then gave the answer 3.

Error 2

The student added the number of hats sold in week 1 (9), week 2 (3), and week 3 (6), then divided the sum by 3, and got 6, 6 + 1 = 7. So the student gave the answer 1

Error 3

The student added the number of hats sold in week 1 (9), week 2 (3), and week 3 (6), then divided the sum by 3. The student then gave the quotient (6) as the answer

Error 4

The student added the number of hats sold in week 1 (9), week 2 (3), week 3 (6), and the average (7), then divided the sum by 4. The student then gave the whole number quotient (6) as the answer.

Error 5

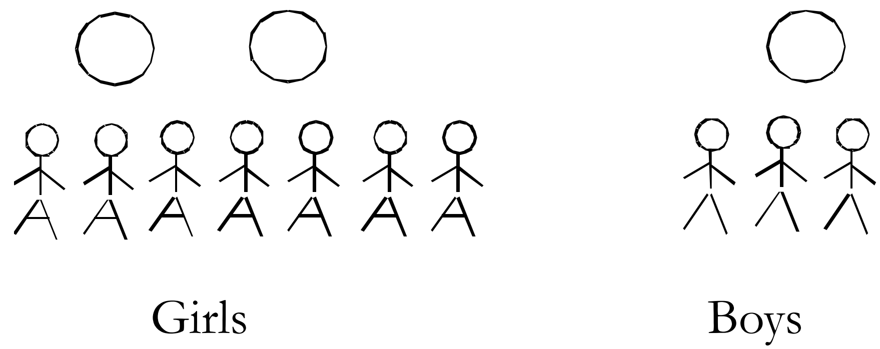
The student added the number of hats sold in week 1 (9), week 2 (3), and week 3 (6), then divided the sum by 4. The student then gave the quotient (4.5) as the answer.

Error 6

The student added the number of hats sold in week 1 (9), week 2 (3), and week 3 (6), then divided the sum by 7. The student then gave the whole number quotient (2) as the answer.

The Pizza Ratio Problem

Here are some children and pizzas. 7 girls share 2 pizzas equally and 3 boys share 1 pizza equally.



A. Does each girl get the same amount as each boy? Explain or show how you found your answer.

B. If each girl does not get the same amount as each boy, who gets more? Explain or show how you found your answer.

Convincing Argument

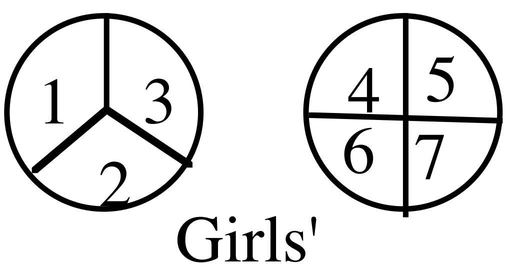
- Each boy will get 1/3 of a pizza and each girl will get 2/7 of a pizza. If you compared 1/3 with 2/7, you would know that 1/3 is bigger than 2/7 by transforming them into common fractions (1/3 = 7/21 and 2/7 = 6/21. 7/21 - 6/21 = 1/21) or decimals (1/3 = .33 and 2/7 = .29. .33 - .29 = .04).

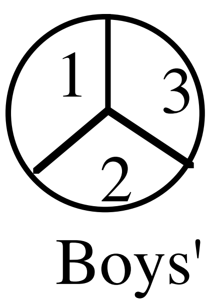
Convincing Argument

- Three girls share one pizza, and another three girls share another pizza. Each of these six girls will get the same amount of the pizza as each of the three boys. But one of the girls has no pizza. So, each boy will get more.

Convincing Argument

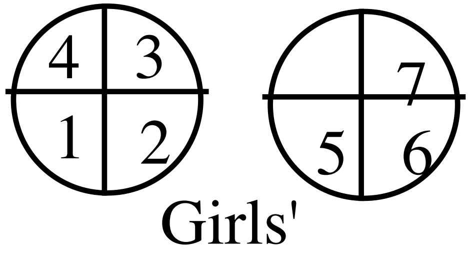
- Three girls share one pizza and remaining four share one pizza. Each piece that each of the remaining four girls get are smaller than those boys get. So boys get more.

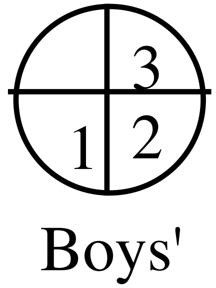




Convincing Argument

- Each pizza was cut into 4 pieces. Each girl gets 1 piece and 1 piece left over. Each boy gets piece and 1 piece left over. 1 piece left over must be shared by the 7 girls, but the 1 piece left over will be shared by three boys. So boys get more.





Lesson 3
Changing Classroom Instruction

Ida Ah Chee MOK

- Associate Dean and Associate Professor in the Faculty of Education at the University of Hong Kong
- Director, Centre for Research on Education, China Victory Theological Seminary
- Graduated from the University of Hong Kong (B.Sc. and M.Ed.) and King's College, the University of London (Ph.D.)
- Awarded the Diamond Jubilee International Visiting Fellowship (2013-2016), the University of Southampton
- Co-editor, *Making Connections: Comparing Mathematics Classrooms Around the World*

Lesson 3
Changing Classroom Instruction

Complementary roles of TIMSS Video Study and Learner's Perspective Study

- The first **TIMSS Video Study** took place in 1995 (Stigler and Hiebert 1999) and studied *national samples of eighth grade* mathematics lessons from Germany, Japan, and the USA
- The TIMSS 1999 Video Study (Mathematics) : Australia, the Czech Republic, Japan, the Netherlands, Switzerland, Hong Kong, and the USA.
- **Learner's Perspective Study LPS**: Started with Australia, Germany, Japan, and the USA (2000), now has expanded to become a research community consisting of researchers in 18 countries: Australia, China, the Czech Republic, Finland, Germany, Israel, Japan, Korea, New Zealand, Norway, the Philippines, Portugal, Singapore, Slovakia, South Africa, Sweden, the United Kingdom, and the USA

The TIMSS Video Study

- Teaching was a cultural activity
- To find pictures of what average teaching looked like in different countries.
- To study lessons from different cultures would give researchers and teachers the opportunity to discover alternative ideas about how we might teach mathematics.

The Learner's Perspective Study (LPS)

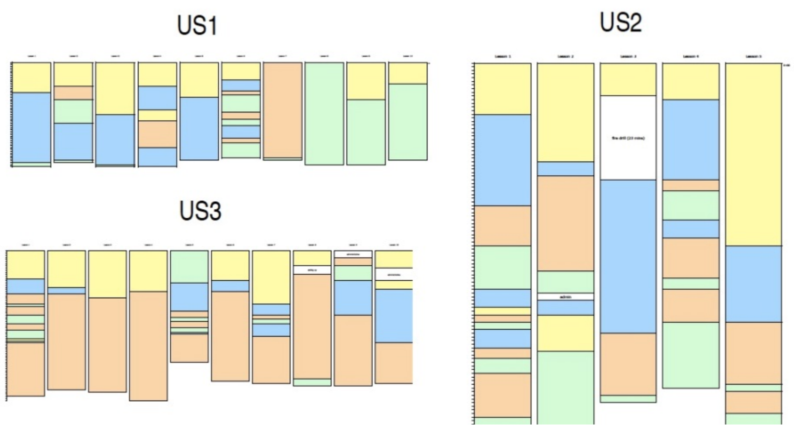
- LPS (Clarke et al. 2006a) was designed to complement other international studies that reported national norms of student achievement and teaching practices.
- To juxtapose the observable practices of the classroom and meanings attributed to those practices by the teachers and the students.
- to understand what competent teachers, recognized locally in different cultural settings, might make possible.
- Started with Australia, Germany, Japan, and the USA, now has expanded to become a research community consisting of researchers in 18 countries.

What to compare

LESSON STRUCTURES AND LESSON EVENTS

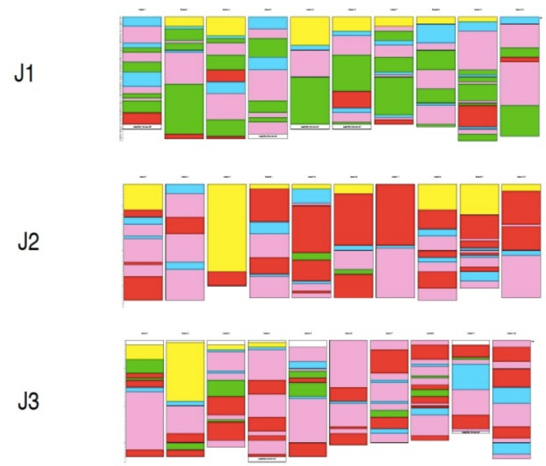
Lesson Structure

The US Schools



The German Schools

The Japanese Schools



The teachers appeared to vary the structure of their lessons purposefully across a topic sequence.

Clarke, LPS Project overview, available at http://www.lps.iccr.edu.au/images/LPS%20Project%20Overview.pdf

Lesson events

- A viable unit for comparison, characterized by a combination of form (visual features and social participants) and function, such as intention, action, inferred meaning, and outcome (Clarke et al. 2006a; Clarke et al. 2006b).
- E.g. Kikan-Shido (between desk instruction)
  - Shanghai lessons: correcting errors, encouraging students to think further, (Lopez-Real et al. 2004).
  - German lessons: questioning to stimulate student mathematical thought (Clarke et al. 2006a).
  - Japanese lessons: eliciting their mistakes, eliciting their puzzlement, eliciting opposing solutions, pointing out different solutions and giving explanations, pointing out difficulties and giving explanations, making their way of thinking visible to the group (Hino 2006).

Multiple accounts of a teacher's practice

- The LPS data set is to allow researchers to reconstruct multiple accounts of the classroom scenarios by putting together the data from all the lesson materials, including *videos, student interviews, and teacher interviews*, hence providing the opportunity for an in-depth study of the practice of a particular teacher in a specific cultural system.

Seeking an explanation for the "Asian Learner's Paradox"

- The "Asian Learner's Paradox" refers to the apparently contradictory phenomenon of outstanding student performances in Asian regions and the reported classroom environment being non-conducive to learning with characteristics of directive teaching, large classes, etc. (Watkins and Biggs 2001).
- Mok's (2006) analysis of the LPS data of a Shanghai teacher:
  – Despite the strong teacher guidance in the lesson, the teacher showed an interpretation of student-centeredness that was different from that in the Western education community.
  – The teacher saw himself as non-traditional and he had made use of his deep understanding of his students in order to create a lesson experience so that the students might follow his intended plan with little side-tracking.

The episode of the train-ticket problem in a Shanghai Lesson

"Xiu-min and his family went to Beijing for a holiday. They booked 3 adult tickets and 1 student ticket, costing a total of 560 dollars. His classmate Xiu-wang, learning this, decided to join Xiu-ming's family for the trip. Consequently, they bought 3 adult tickets and 2 student tickets, costing a total of 640 dollars. Please calculate the cost of 1 adult ticket and the cost of 1 student ticket."

- *Dora: Intuitive answer, compare two cases, one more student ticket*
- *Teacher's paraphrase: subtraction 640-560*
- The teacher continued to request for a second way: $3x + y = 560$ and $3x + 2y = 640$

A planned experience for the students

- Three levels of contrast:
  - 1st level: Dora's answer & the teacher's paraphrase
  - 2nd level: the arithmetic method & the equation method
  - 3rd level: elimination by subtracting equation & elimination by substitution
- The lesson is by no means spontaneous, but rather represents a synthesis based on the effort of a very experienced teacher and his understanding of a pedagogical framework of variation (Experimenting Group of Teaching Reform in Mathematics in Qingpu County, Shanghai, 1991).

Lessons for the implementation of mathematical tasks

Two key results of TIMSS Video Study:

- Teachers in all countries studied spent the majority of lesson time solving problems;
- Teachers in higher-achieving countries implemented making connections problems differently from teachers in the USA" (Stigler and Hiebert 2004).

Two types of problems:

- "Using procedure" problems, that is, problems requiring students to use only a memorized procedure or algorithm,
- "Making connections" problems, that is, problems requiring students to establish relationships between ideas, facts, and procedures and to engage in mathematical reasoning.

TIMSS Video Study: What or where was the difference?

- With the exception of Japan, all six countries used more "using procedure" problems than "making connections" problems.
- As far as seeing teaching as a cultural activity was concerned, the videos of each country revealed some unique features.
  - Netherlands lessons frequently used calculators and real-world problem scenarios.
  - The Japanese students spent on average a longer time working to develop their own solution procedures for problems that they had not seen before.
  - In the high-performing countries except Australia the teachers made use of the rich potential in the problem statements and did not simplify the problem, i.e., they implemented a higher percentage of "making connections" problems as "making connections" problems.
  - In contrast, the U.S. teachers changed "making connections" problems to "using procedure" problems, hence lowering the cognitive demand of the problems.

LPS: The implementation of the tasks matters

- Huang and Cai (2010): the sampled teachers of the LPS data for both USA and China were willing to present cognitively demanding tasks in their lessons and implement them by soliciting students' answers and organizing exploratory activities, yet the Chinese teacher was more frequently able to sustain the cognitive demand of the mathematical tasks during implementation.
- Mesiti and Clarke (2010) made a functional analysis of the mathematical tasks in the LPS data from China, Japan, and Sweden. They selected "distinctive" tasks suggesting instructional effectiveness, which might mean either typical or unusual. The classroom performance of a task was ultimately a unique synthesis of task, teacher, students, and situation.

Lessons for changing classroom instruction

- The TIMSS Video Study: large-scale survey of a national sample, suggested seeing teaching as a cultural activity.
- LPS: provided comparisons of mathematics lessons via analysis of lesson events during a sequence of lessons and multiple accounts, including the perspectives of the teacher and the learners.
- Although teachers in different cultural systems spend time on the same lesson event, they might be in fact carrying out activities with different meanings and functions.

Lessons cont'd

- The Asian Learner's Paradox: the investigation of an effective case might take into account the many constraints (such as examination-orientation, content coverage, teaching pace, and large class size in a specific cultural system) and culturally rooted clues (such as the teacher's conceptions and beliefs, the norm of the students' expectation, the locally implemented pedagogical framework).
- Different kinds of tasks play different roles in the agenda of effective classroom instruction. How the teacher sustaining the intended roles of the tasks during implementation is important.

Lesson 4: Making Global Research Locally Meaningful: TIMSS in South Africa

Vijay Reddy

- Executive Director of the Education and Skills Development Research Programme at the Human Sciences Research Council in South Africa.
- Committed to 'social science that makes a difference'. Conducted research related to large-scale surveys, life histories, national policy and planning.
- Work experiences include high school science and mathematics teaching, university chemistry lecturer, teacher development in non-governmental organizations, participation in Ministerial Committees and conducting research at both national and international levels.

Lesson 4: Making Global Research Locally Meaningful: TIMSS in South Africa

20 years of South African Education

Pre-1994

- Separate and unequal development by racial groups.
- Africans restricted to barren and remote lands, poverty, poor quality and limited education and low skilled jobs.
- Apartheid social engineering: education the weapon for under-development "what is the use of teaching the Bantu mathematics when he cannot use it in practice? The idea is absurd".

Present

- Democratic government with single education department.
- Education is Number One Priority. Improved access but quality education & mathematics performance remains elusive.
- High levels of poverty, unemployment and inequality.
- Mathematics assessment provides a measure of: (i) the health of our educational system (ii) social inequalities of access and income and (iii) transformation distance.

South African math achievement is low

South African mathematics, science education ranked worst in the world

SA schools at rock bottom in international assessments

SA's children are sacrificial lambs

SA is again stone last for quality of science and maths education

SA ranks low on maths, no matter the report

South African math achievement is low

South African mathematics,
... worst

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Why then should South Africa participate in such studies?

SA's ...

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science and maths
education

SA ranks low on maths,
no matter the report

South Africa in 20 years of TIMSS

How can a country find its own voice in using the international performance results to extend analyses which are meaningful to the local agenda.

Three framing research questions for this presentation.

i. Understanding South African achievement, from 1995 to 2011, beyond the rank order.
ii. What contextual dynamics influences mathematics achievement?
iii. Understanding educational progression and pathways post grade 8/9 years.

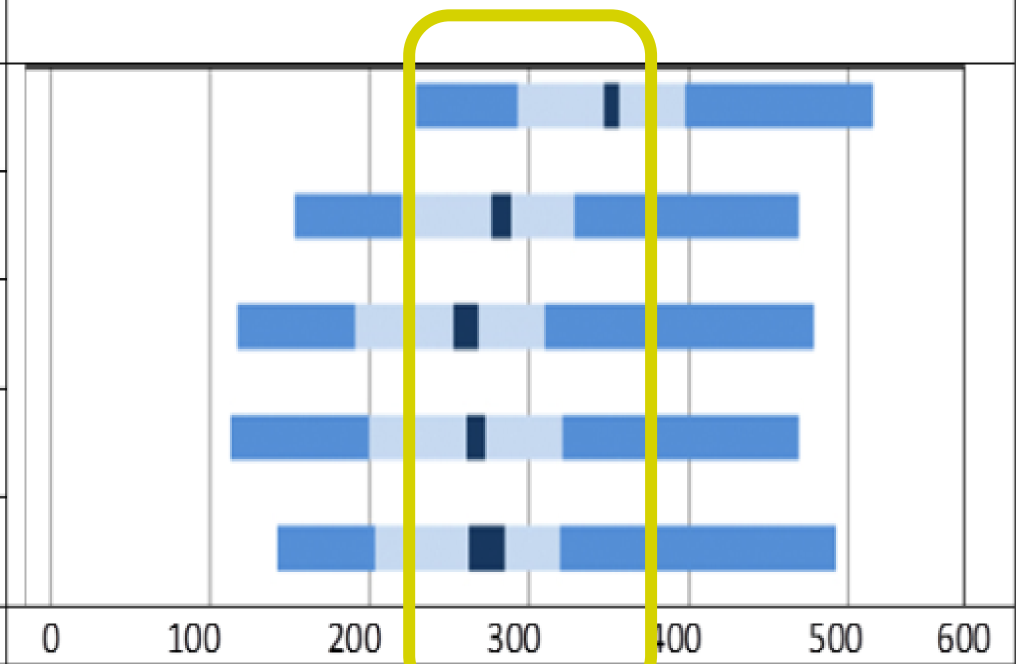
South African mathematics achievement beyond rank order

1. Mathematics and science performance in grade 8 in South Africa 1999	1. Low national mathematics mean score and last position on the rank order table.
2. Mathematics and Science Achievement in South African Schools in TIMSS 2003	2. Low national mathematics mean score and last position on the rank order table. High educational inequalities reflective of the societal inequalities.
3. Beyond Benchmarks: What twenty years of TIMSS data tells us about South African education (TIMSS 2011)	3. Low national mathematics mean score. High, but slightly reduced educational inequalities from 2002 to 2011. Trend analysis, 1995 to 2011 shows math achievement improvement by 63 TIMSS points, equivalent to 1.5 grade levels.

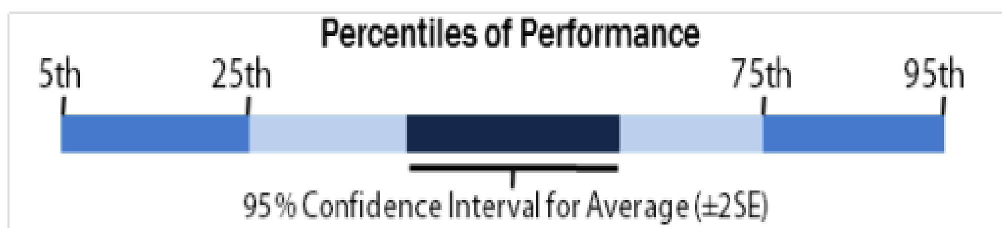
Trends in Mathematics Achievement for TIMSS 1995, 1999, 2003 & 2011

MATHS	Ave scale score	Score distribution
Grade 9 TIMSS 2011	352 (2.5)	229-516 = 287
Grade 9 TIMSS 2002	285 (4.2)	152-472= 320
Grade 8 TIMSS 2002	264 (5.5)	117-484 =367
Grade 8 TIMSS 1999	275 (6.8)	113-485=372
Grade 8 TIMSS 1995	276 (6.7)	142-496 = 354

Achievement distribution



Source: HSRC_TIMSS 2011

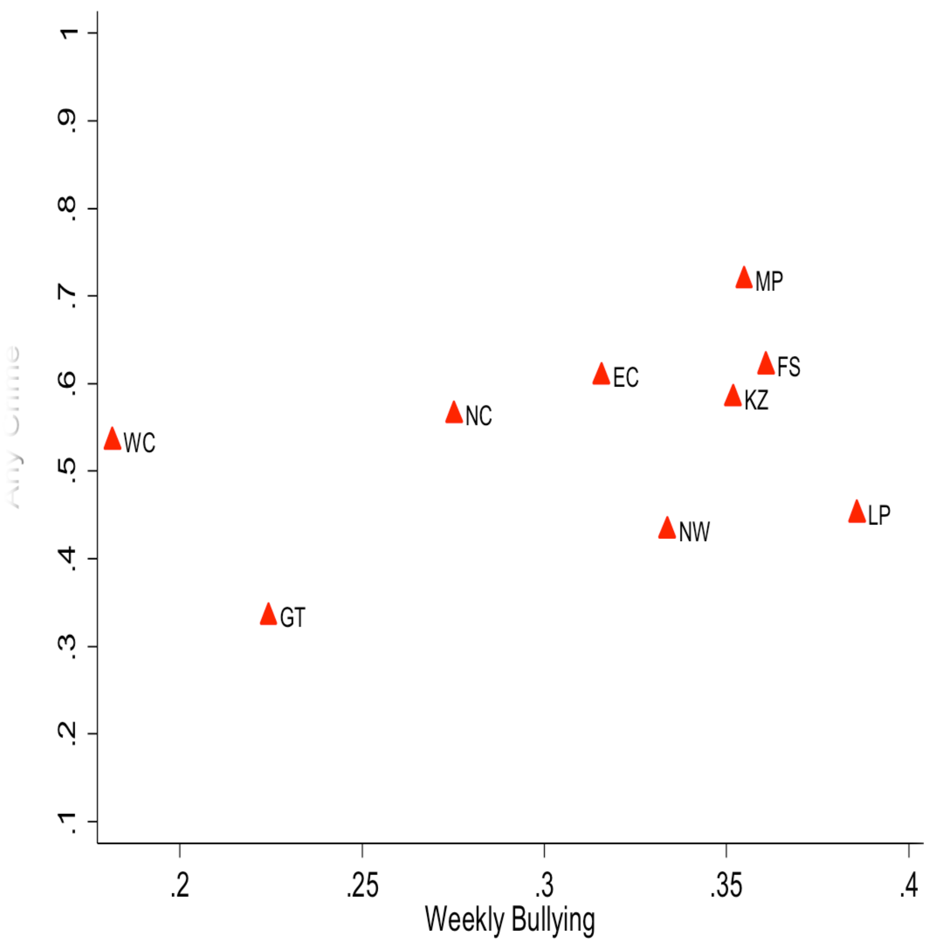


Influence of contextual dynamics on mathematics achievement

Home SES indicators	Positive as the number of assets increases. Positive as levels of parent education increases.
School SES Indicators	Positive as historical resource provision increases. Higher resourced schools outperform the no-fee paying schools.
Speaking the language of instruction at home	Positive for convergence of languages, negative for divergence.
Age	Student achievement is higher for age-grade appropriate students and negative for others
Gender	The gender achievement gap is small to non-existent. Gender differences favours girls for higher educational expectations, higher levels of parental engagement and experiencing lower levels of bullying.
School safety	Students in schools that are safer, with higher discipline tend to perform better.

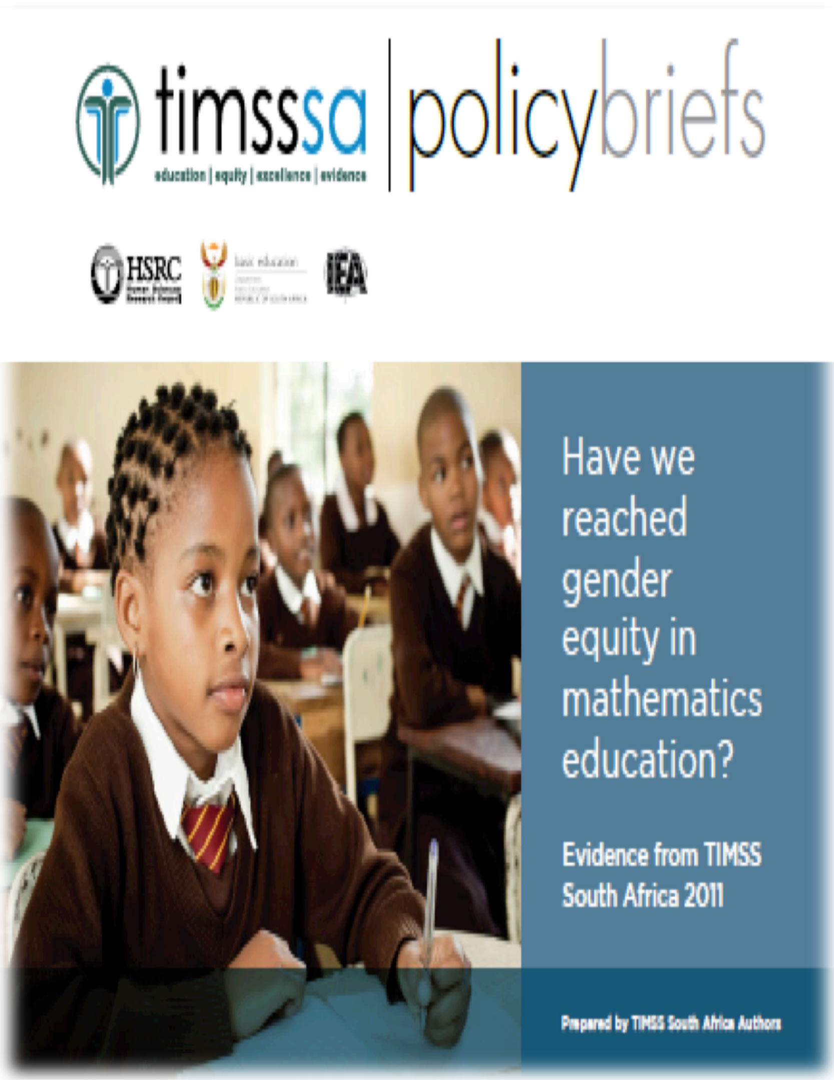
Safe and Sound?
Violence and South African Education

Community Violence and School Safety



- Violence in South African schools is higher than other countries.
- The SES of students in a school is a strong indicator of how vulnerable students are to acts of violence. The chances of being bullied regularly are higher for learners of low SES who have weaker support systems at home.
- There is higher levels of bullying for boys than girls in similar school types.
- Schools where there are no discipline or safety problems achieve better results but this link is dependent on the size of the school.

The complexities of gender dynamics



- Achievement gaps has to less to do with gender and more with educational environment.
- Drop out rates for boys are higher than for girls.
- Girls were at an advantage in all forms of engagement with parents.
- Boys are more likely to be victims of bullying
- Boys are the 'at risk' group at schools – middle class indifference and working class safety.

Student progression and pathways through secondary school & predicting future outcomes

1. Importance of foundational mathematics skills

1. Mathematics achievement gaps persists through secondary school.

Mathematics performance in early grades is strongly predictive of survival to grade 12

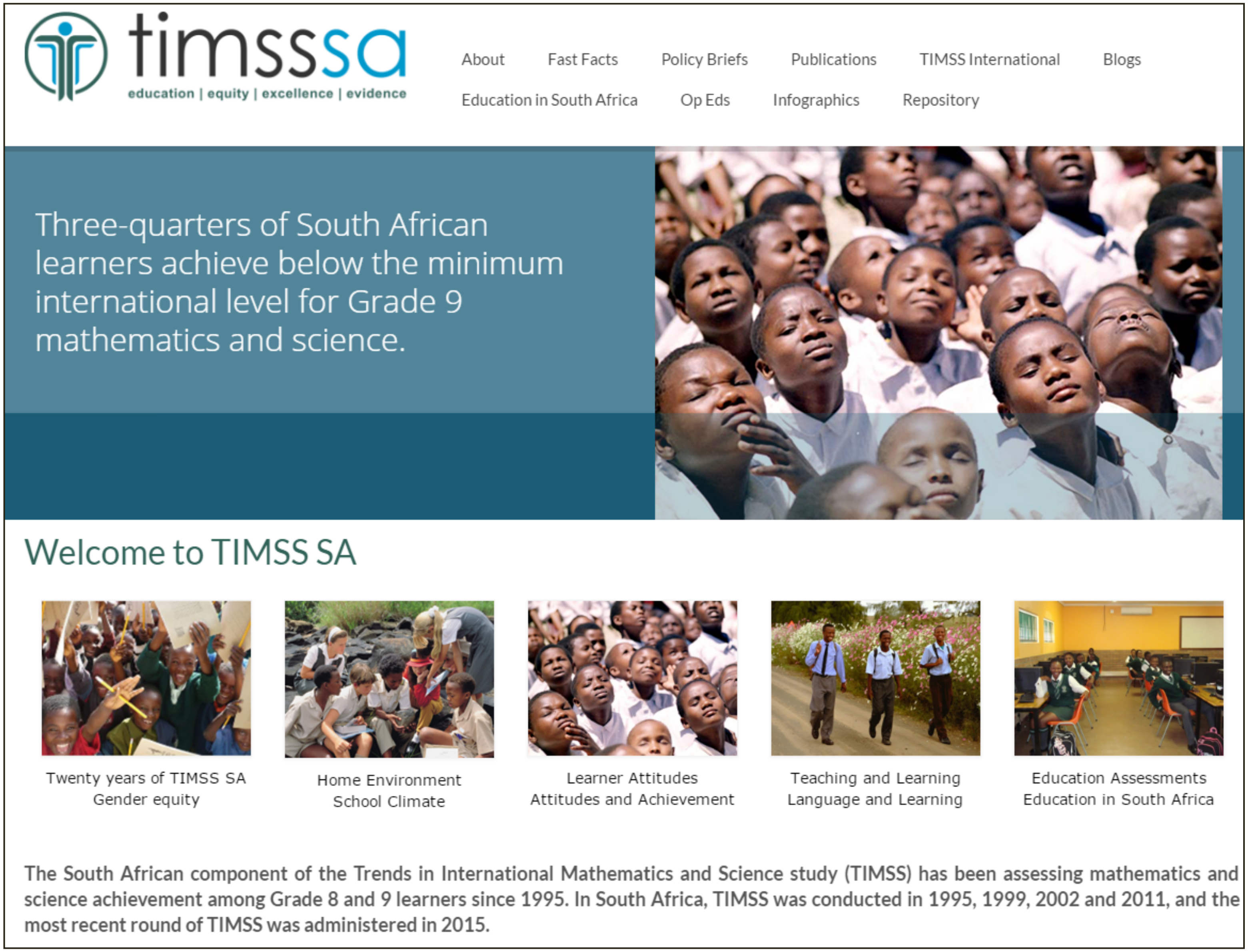
2. Educational pathways and progression through secondary school

2. TIMSS math performance in 9th grade predicts educational pathways and performance in subsequent years. There is the predictable story of who succeeds in school (resourced schools, parental education, positive attitudes), but there are also some students who succeed against the odds (from under-resourced low fee paying schools).

Educational Pathways of Students in the South African Youth Panel Study

Smooth	Staggered	Stuck	Stopped
Neat, year-on-year grade progression through school.	Learners in school for all four waves of SAYPS, who make some grade progress but have at least one episode of grade repetition.	Learners in school for all four waves of SAYPS, but stuck in grade 9 or 10 for three or more periods.	Individuals who leave school before Wave 4 and do not return
47%	**39%**	**7%**	**7%**

TIMSS website



www.timss-sa.org.za

Looking into the Future:

Extending Our Understanding

- Interpreting data within contexts
- Revealing the possibilities
- Expanding the scope

Building Capacity of Researchers

- Mentoring
- International Collaborations
- Intra-national Research Projects

Thank you

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