Science achievement in Australia: Evidence from National and International surveys

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My role ...

National Project Manager
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Sources

- Trends in International Mathematics and Science Study (TIMSS) 2002
  - 230 primary schools, 230 secondary schools
  - 272 primary teachers, 536 secondary science teachers
  - 4675 Year 4 students, 5355 Year 8 students
- PISA 2003
  - 321 schools
  - 12551 students
- TIMSS Science Video study – 87 Year 8 classes
- Longitudinal Surveys of Australian Youth (LSAY)

Why teach science?

- The OECD considers science to be so pervasive in modern life that it is important for the future citizens of a country to be scientifically 'literate'. The OECD defined scientific literacy as ... *the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity.*

Format

- What do we want students to learn?
- How do we provide them with the opportunity to learn it?
- How much of it do they actually learn along the way?
- Do they like what it is we're teaching them?
- Do they 'stay the course'?

Goals for school science education in Australia

- Ensure that our future citizens are scientifically literate
- Ensure that students develop positive attitudes towards science and engage with their science learning
- Equip students with foundation skills to build on if they wish to pursue careers in science

What do we test students on?

TIMSS		PISA
Year 4	Year 8	
Life science	Life science	Science in life and health
	Chemistry	
Physical science	Physics	Science in earth and the environment
Earth science	Earth science	
	Environmental science	Science in technology

Opportunity to learn - TIMSS

- What percent - age of time is spent on each?

(source TIMSS)

Year 4

- **Life science (42%)**
- **Physical science (21%)**
- **Earth science (31%)**

Year 8

- **Life science (26%)**
- **Chemistry (23%)**
- **Physics (21%)**
- **Earth science (16%)**
- **Environmental science (11%)**

How much curricular time is devoted to science at Year 8?

Countries	Students' Average Yearly Science Instructional Time in Hours	Science Instructional Time as a Percent of Total Instructional Time[1]
General/ Integrated Science		
d Philippines	202 (4.2)	18 (0.5)
United States	s 135 (2.2)	13 (0.2)
Jordan	135 (0.8)	15 (0.2)
New Zealand	132 (2.4)	14 (0.3)
Australia	s 132 (3.6)	13 (0.4)
Sweden	r 131 (7.6)	r 14 (0.8)
Malaysia	119 (1.8)	12 (0.2)
Bahrain	119 (1.1)	14 (0.1)
Chile	r 118 (2.2)	r 11 (0.3)
Singapore	107 (1.9)	12 (0.2)
Saudi Arabia	s 106 (1.6)	11 (0.2)
Iran, Islamic Rep. of	s 106 (3.7)	11 (0.4)
Hong Kong, SAR	s 103 (4.0)	11 (0.4)
Korea, Rep. of	s 103 (2.7)	9 (0.2)
Palestinian Nat'l Auth.	s 101 (1.8)	11 (0.2)
Japan	r 99 (1.5)	r 9 (0.1)
Norway	92 (2.5)	11 (0.3)
Italy	s 69 (1.1)	7 (0.1)

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At Year 4?

Countries	Students' Average Yearly Science Instructional Time in Hours		Science Instructional Time as a Percent of Total Instructional Time[1]	
Philippines	r	176 (3.2)	r	16 (0.4)
Chinese Taipei		84 (1.0)		11 (0.2)
United States	r	83 (3.0)	r	8 (0.3)
Japan		81 (1.2)		8 (0.2)
Hong Kong, SAR	s	77 (5.4)		8 (0.5)
Slovenia	r	75 (2.2)	r	9 (0.3)
Italy	r	73 (2.3)	r	8 (0.3)
New Zealand	s	65 (3.5)		7 (0.4)
Singapore		64 (0.6)		7 (0.1)
Hungary	s	54 (1.0)		6 (0.1)
Lithuania		53 (1.6)		6 (0.2)
Cyprus	s	46 (1.4)		5 (0.2)
Australia	s	45 (2.6)		5 (0.3)
Norway	r	38 (1.8)	r	4 (0.2)
Netherlands	s	33 (1.8)		3 (0.2)
Russian Federation	s	33 (1.2)		5 (0.2)

Science teaching

- Of course all this information tells us about the intended curriculum – the TIMSS teacher questionnaires and the TIMSS Science video study are able to ‘flesh’ out the implemented curriculum…

Readiness to teach – Year 8 teachers

Most year 8 students are taught by teachers who feel well prepared to teach most areas.

- Year 8 teachers' 'weakest' area was in Environmental science, but more than 94% of students taught by teachers who were well-prepared to teach it.

Readiness to teach- Year 4 teachers

- Strongest area Earth sciences
- Weak areas (indicative, not exhaustive):
  - Life sciences
    - Reproduction and development of plants and animals (64%)
    - Human health (73%)
  - Physical sciences
    - Forming and separating mixtures (64%)
    - Chemical and physical changes (76%)
    - Common uses of electricity and electrical circuits (73%)
  - Earth sciences
    - Fossils of animals and plants (82%)

Use of ICT in science

- Computers available in around ¾ of science classes at both Year 4 and Year 8, internet in almost all of these
- Used to:
  - Explain scientific procedures? – more than two-thirds of teachers responded NEVER
  - Explain natural phenomena? – more than half of teachers responded NEVER
  - Practice skills? Almost two-thirds of teachers responded NEVER
  - Look up ideas? Around three-quarters of teachers responded SOME LESSONS
  - Process data? Around half SOME LESSONS, around half NEVER (Year 8)

TIMSS Science Video Study

- ‘value-adding’ what we know about science teaching from the TIMSS Teacher questionnaires

1999 Science Video Study

- Involved
  - Videotaping national random samples of approx. 100 Year 8 science classes in five countries, filmed across the school year (but only once per class); + questionnaires
  - Australia, Czech Republic, Japan, USA, Netherlands
  - 439 classes altogether, 87 from Australia

Science Video Study

- The videos have enabled us to look at:
  - quality of teaching, not just quality of student performance outcomes and attitudes

and also at:

  - findings in relation to ideal picture of science education in Australia (see poster display)
  - similarities and differences in teaching styles across countries

Japanese students in particular usually outperform Australian students. Does their teaching vary from ours?

Australian and Japanese lessons were very similar in many respects
(see poster display)

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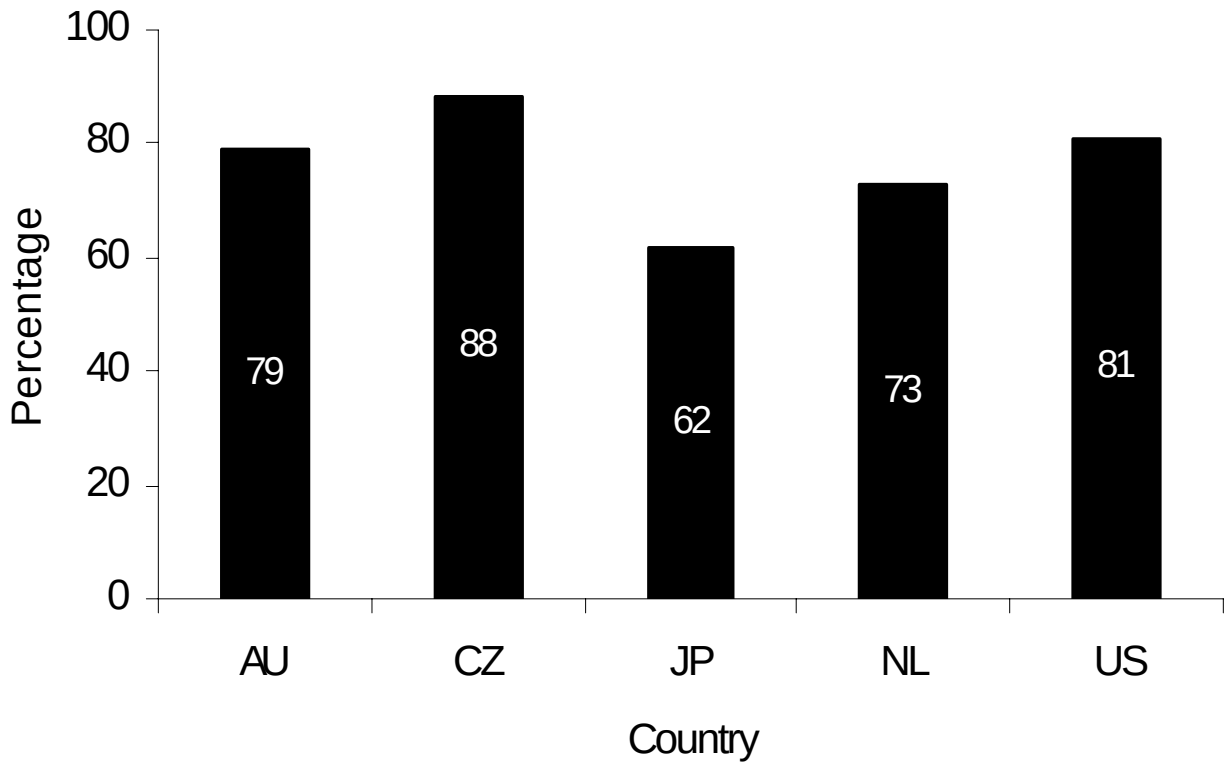
But there were also noticeable differences in teaching strategies

- inquiry contexts
- some inquiry actions
- inquiry follow-up
- motivational aspects

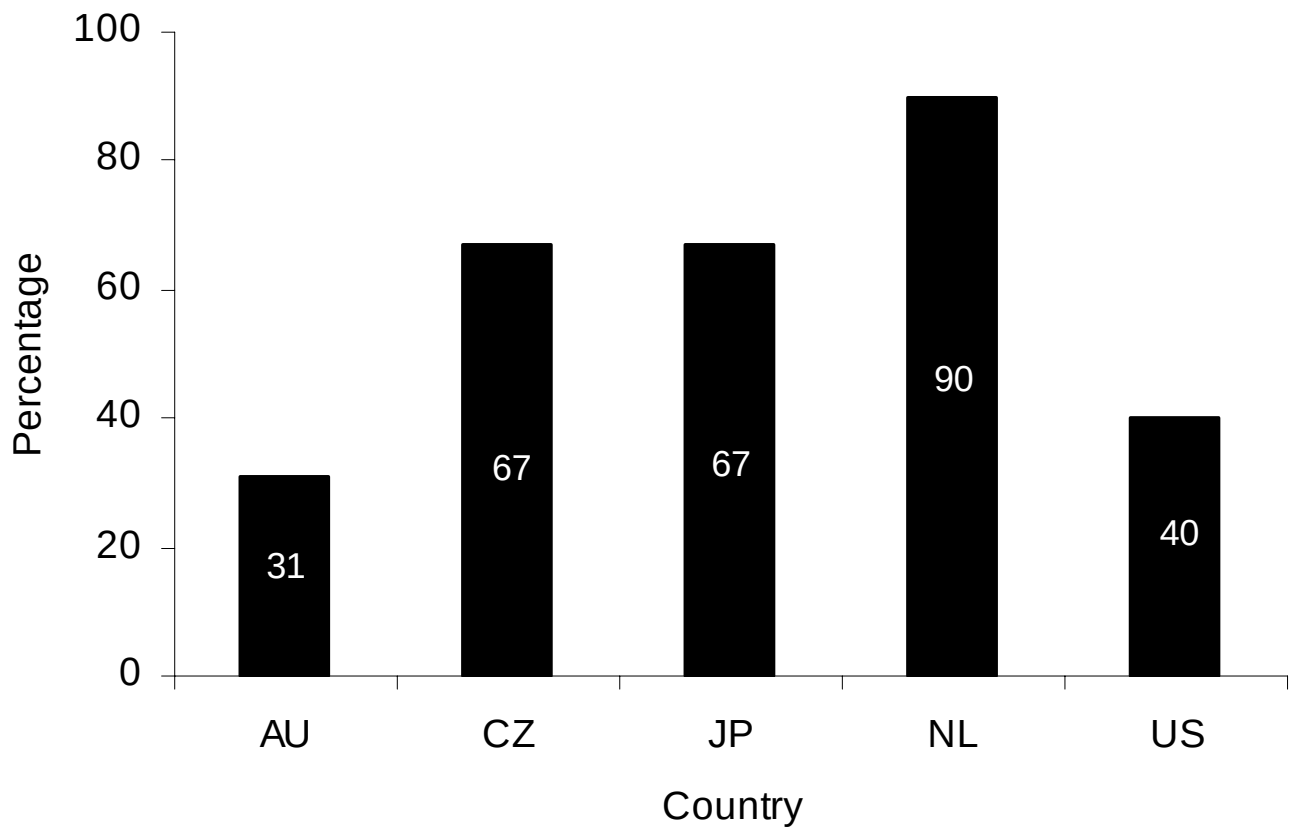
Less use of real life examples in Japan

Percentages of lessons featuring real life issues



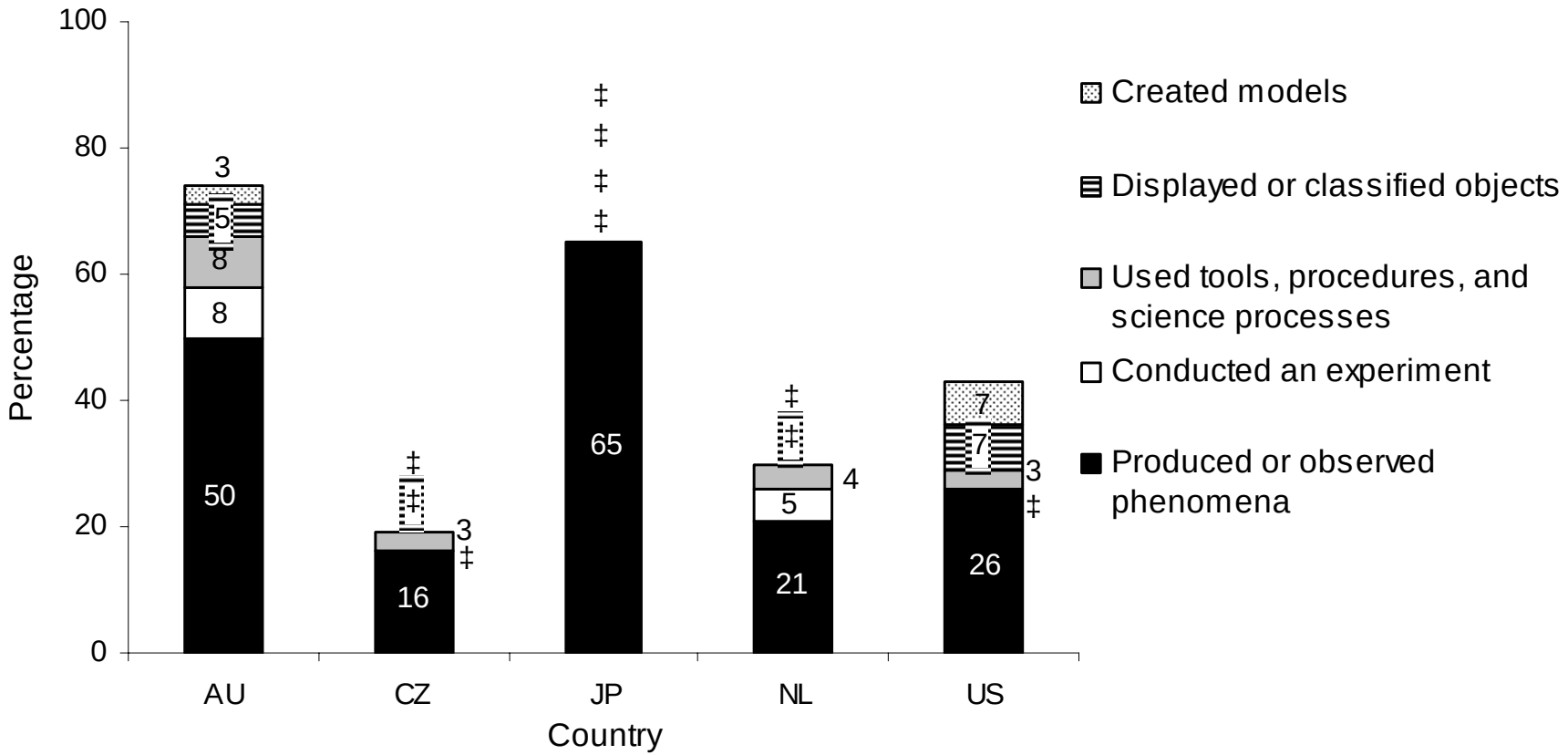
Less use of textbooks or printed workbooks in Australia

Percentage of lessons in which textbooks/workbooks used



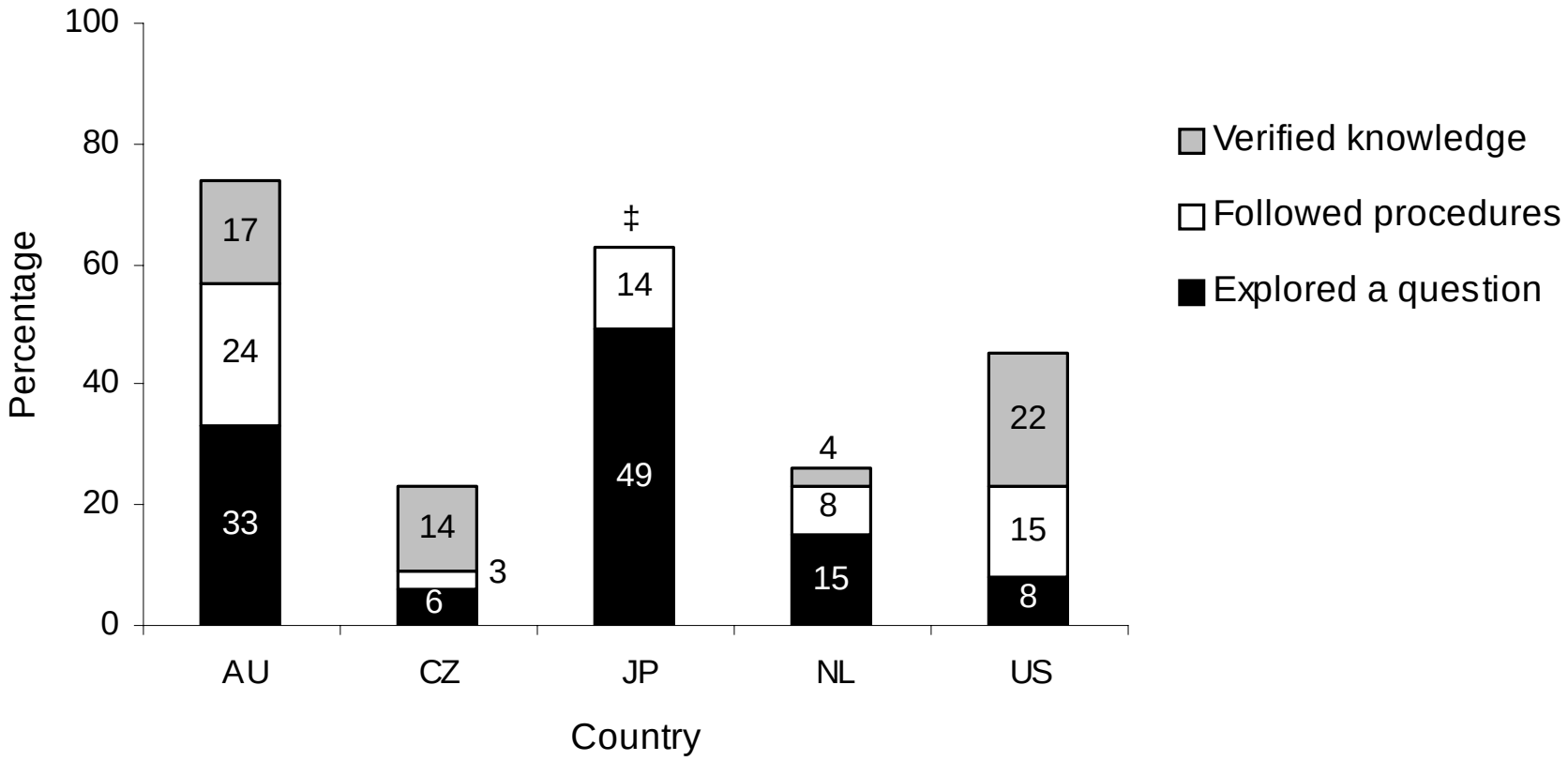
Types of independent practical activities done by students – more study of phenomena in Japan

Percentages of lessons



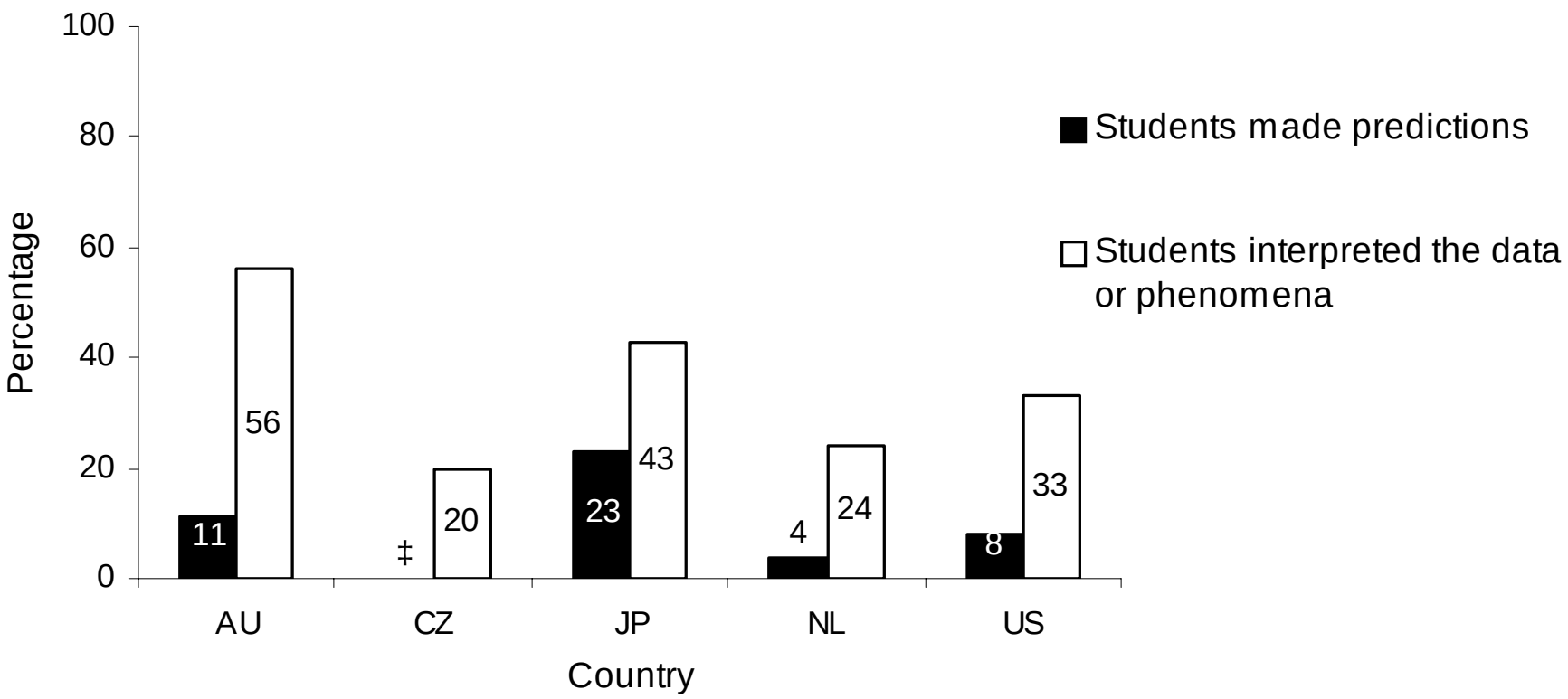
Exploration of questions as dominant stated purpose of inquiry lessons in Japan

Percentages of lessons



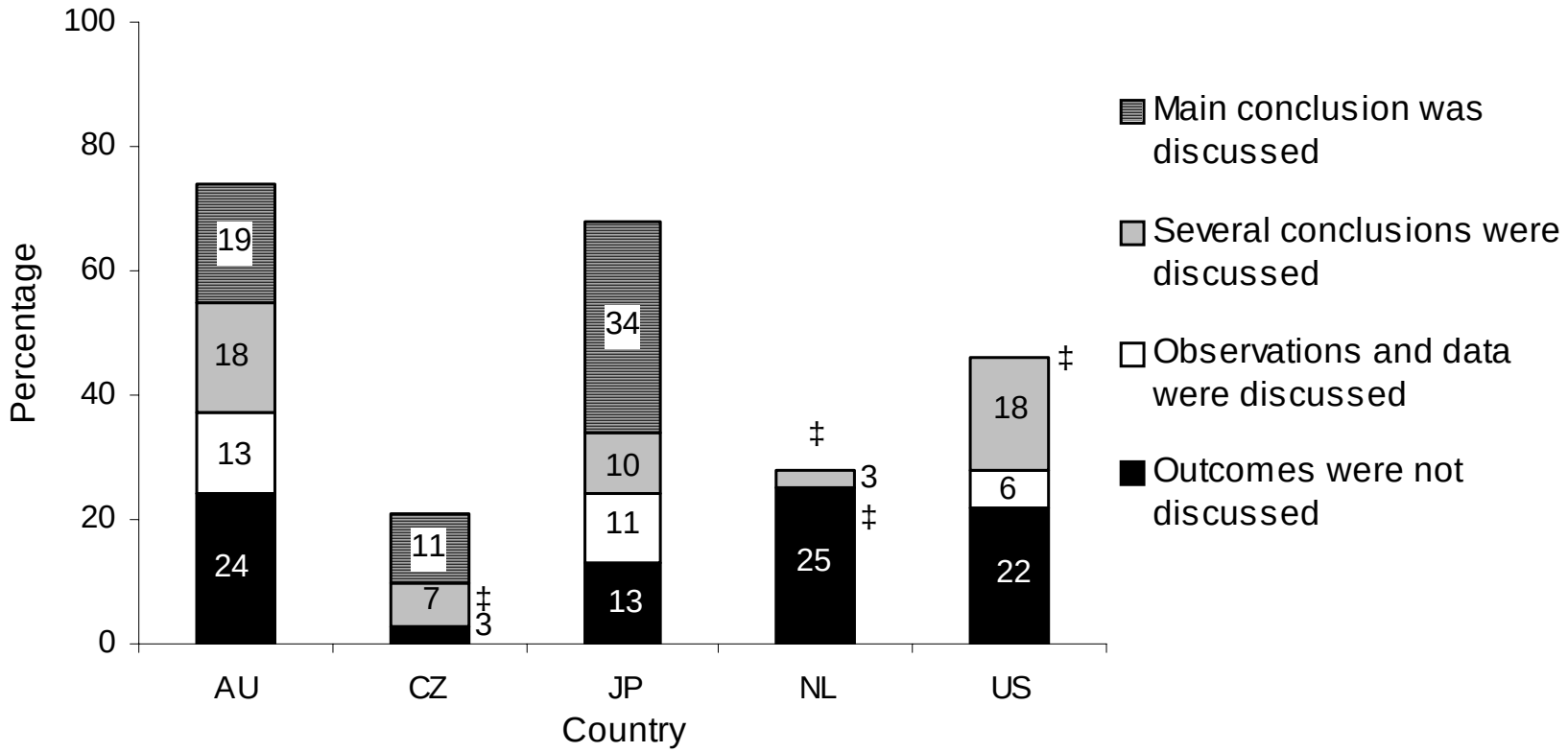
More prediction of inquiry outcomes in Japan; more interpretation in Australia

Percentages of lessons



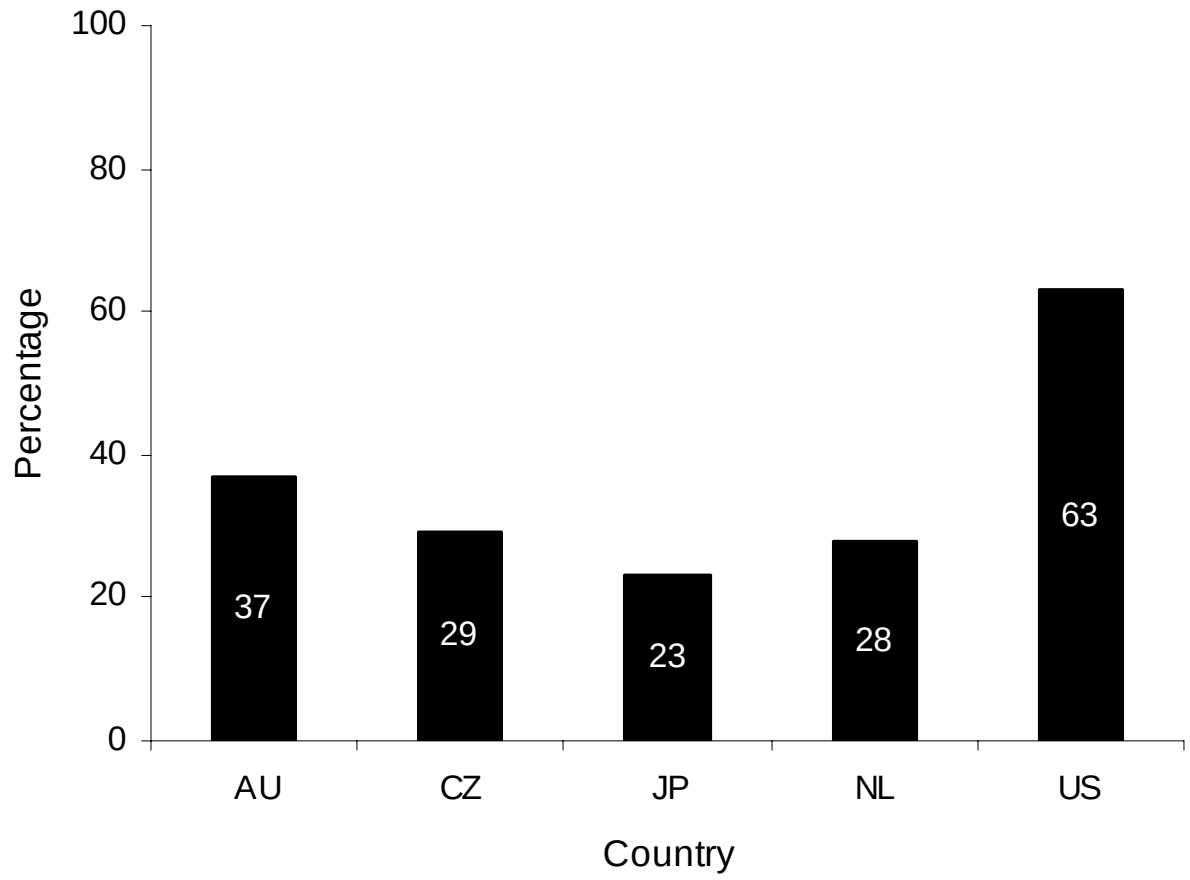
Follow-up of investigations: more emphasis on discussion of main conclusion in Japan

Percentages of lessons



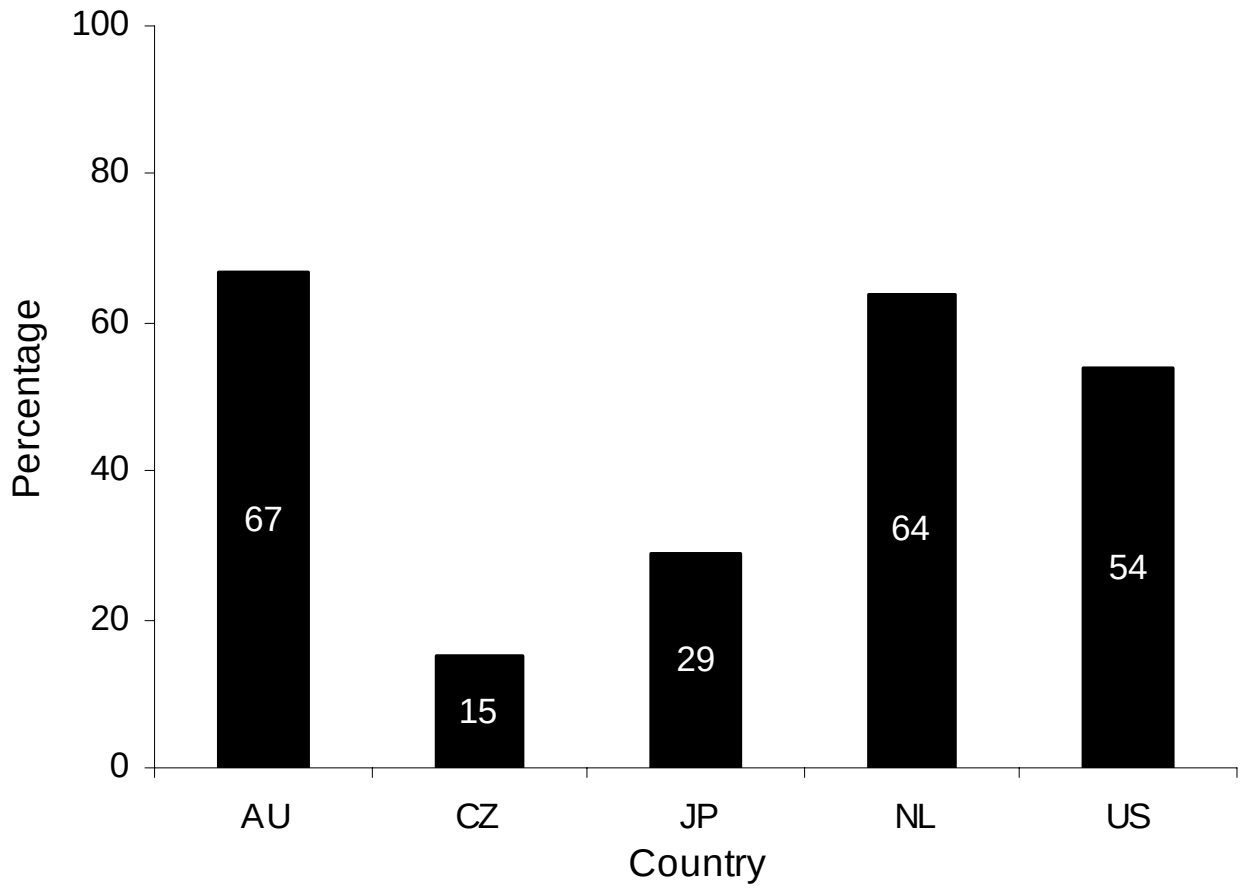
Use of motivating activities – more in Australia (but most in USA!)

Percentages of lessons with at least one motivating activity



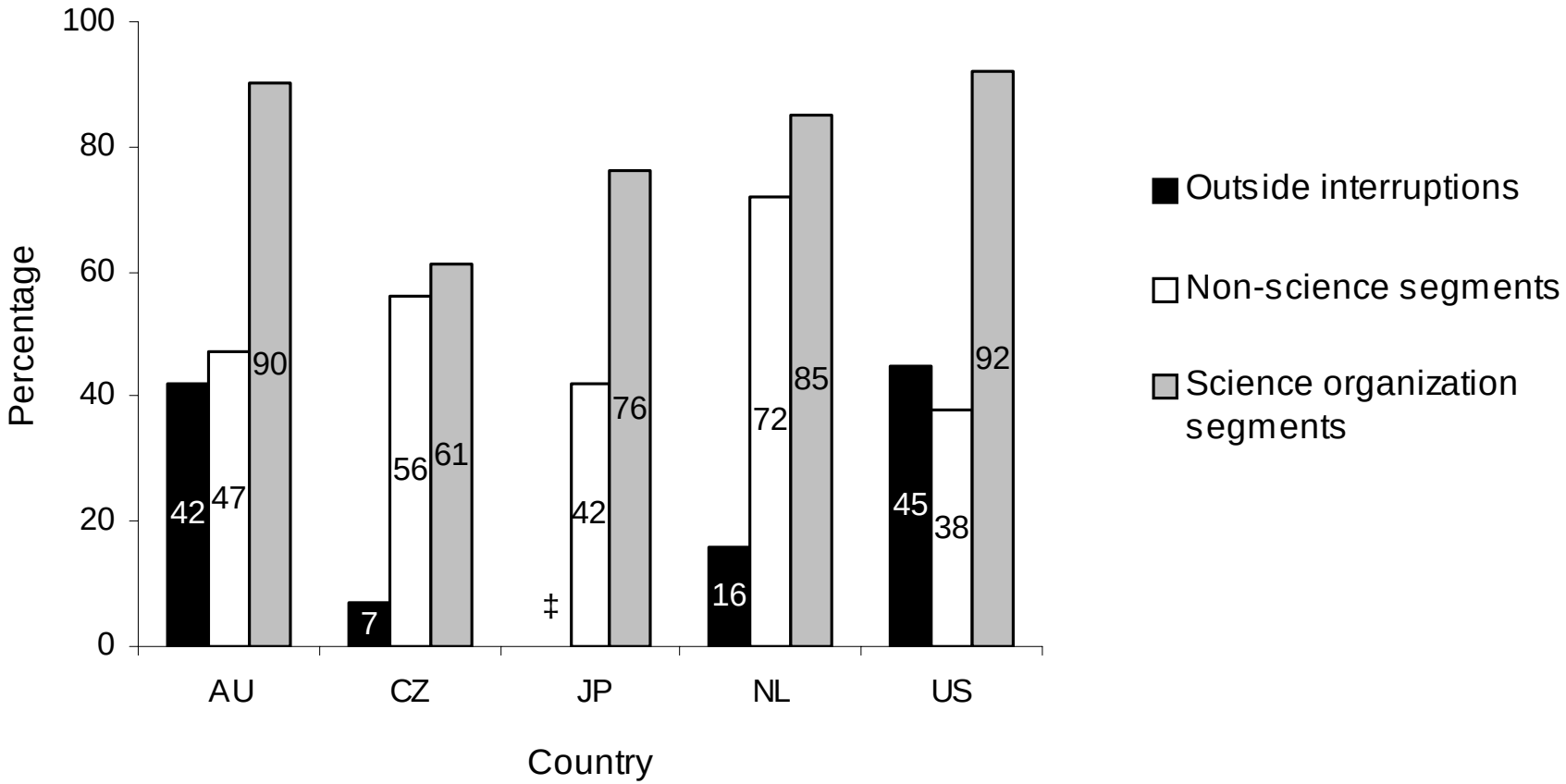
Student involvement in initiating questions – more in Australia

Percentages of lessons with at least one student-initiated science question



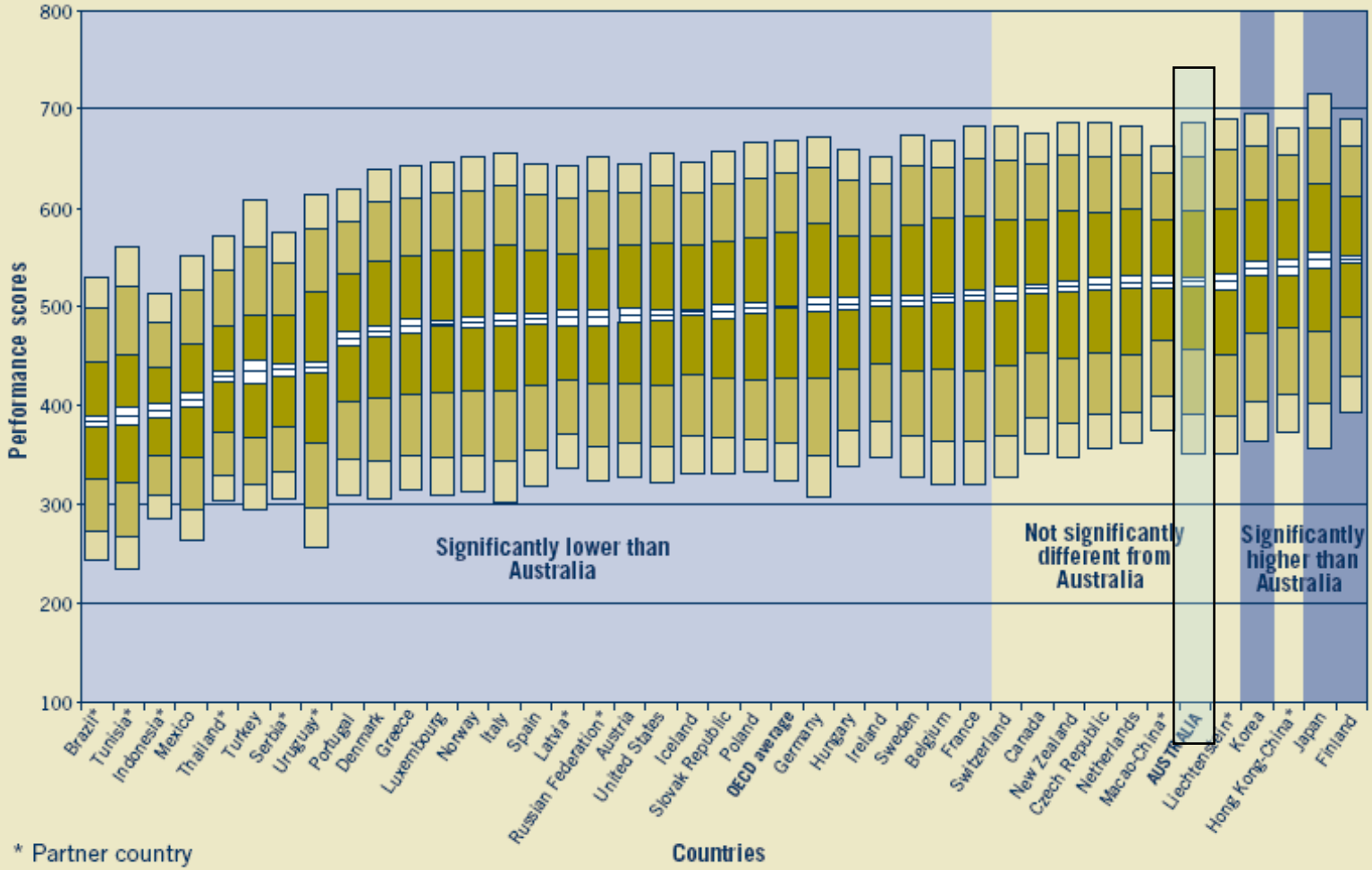
Lesson interruptions!

Percentages of lessons with at least one occurrence



So, what have they learned of what we wanted to teach them?

PISA


800
700
600
500
400
300
200
100
Performance scores
Significantly lower than Australia
Not significantly different from Australia
Significantly higher than Australia
Brazil*
Tunisia*
Indonesia*
Mexico
Thailand*
Turkey
Serbia*
Uruguay*
Portugal
Denmark
Greece
Luxembourg
Norway
Italy
Spain
Latvia*
Russian Federation*
Austria
United States
Iceland
Slovak Republic
Poland
OECD average
Germany
Hungary
Ireland
Sweden
Belgium
France
Switzerland
Canada
New Zealand
Czech Republic
Netherlands
Macao-China*
AUSTRALIA
Liechtenstein*
Korea
Hong Kong-China*
Japan
Finland
* Partner country
Countries

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PISA proficiency levels

Highest described level (around 690 points)

Students are generally able to create or use conceptual models to make predictions or give explanations; to analyse scientific investigations in order to grasp, for example, the design of an experiment or to identify an idea being tested; to compare data in order to evaluate alternative viewpoints or differing perspectives; and to communicate scientific arguments and/or descriptions in detail and with precision.

Middle described level (around 550 points)

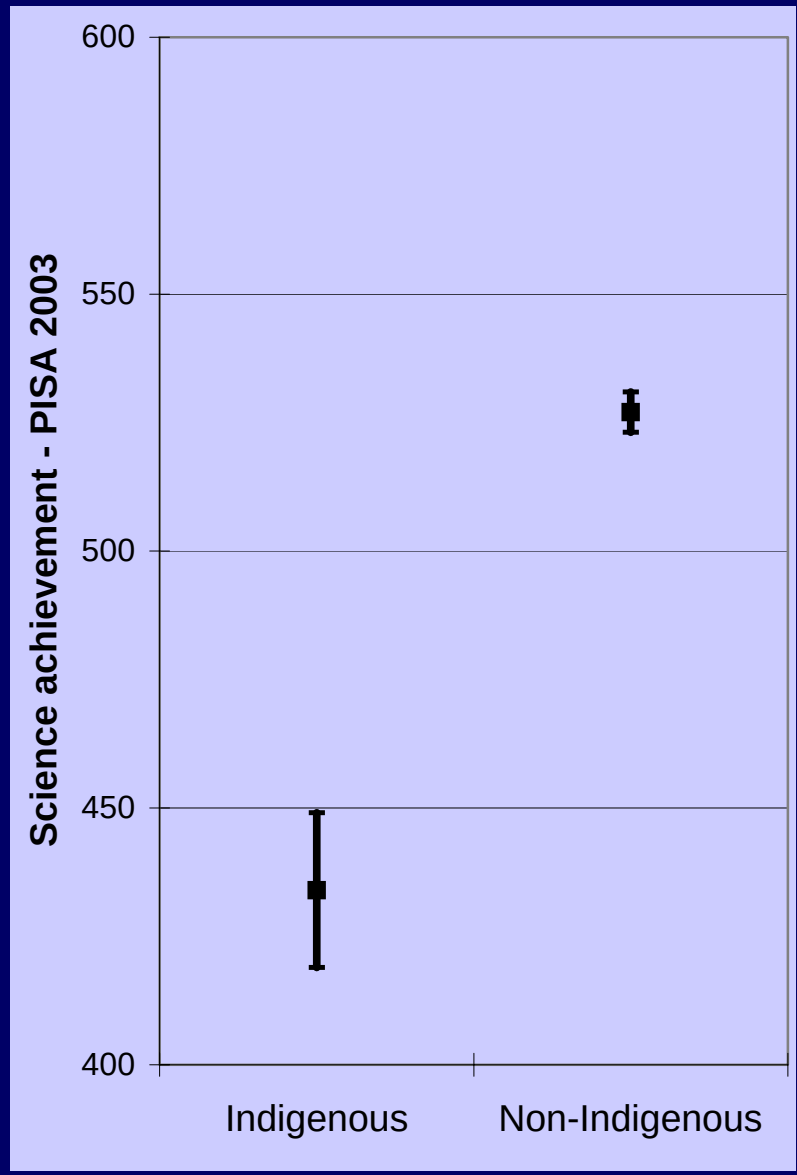
Students are typically able to use scientific concepts to make predictions or provide explanations; to recognise questions that can be answered by scientific investigation and/or identify details of what is involved in a scientific investigation; and to select relevant information from competing data or chains of reasoning in drawing or evaluating conclusions.

Lowest described level (around 400 points)

Students are able to recall simple factual scientific knowledge (e.g. names, facts, terminology, simple rules); and to use common scientific knowledge in drawing or evaluating conclusions

Indigenous students -PISA

- The mean for Indigenous students was, on average, almost 70 score points lower than the OECD average, and 93 below the average for non-Indigenous Australian students.



TIMSS Year 4

All Year 4 TIMSS 2002/03 countries	Average scale score (se)	2002/03	1994/95
Singapore	565 (5.5)	▲	•
Chinese Taipei	551 (1.7)	▲	-
Japan	543 (1.5)	▲	▲
†Hong Kong SAR	542 (3.1)	▲	▼
†England	540 (3.6)	▲	•
†United States of America	536 (2.5)	▲	•
Latvia	532 (2.5)	▲	▼
Hungary	530 (3.0)	•	▼
Russian Federation	526 (5.2)	•	-
†Netherlands	525 (2.0)	•	•
†Australia	521 (4.2)		
New Zealand	520 (2.5)	•	▼
Belgium (Flemish)	518 (1. 8)	•	-
Italy	516 (3.8)	•	-
†Lithuania	512 (2.6)	•	-
†Scotland	502 (2.9)	▼	▼
Moldova, Rep. of	496 (4.6)	▼	-
Slovenia	490 (2.5)	▼	-
International average	489 (0.9)		

- Australian students achieved at a level significantly higher than the international average, but did not change from TIMSS 2002.
- Of the countries that participated in TIMSS in 1994 and 2002, almost half had a higher score than Australia in 2002, compared with just one in 1994.

TIMSS Year 8

All Year 8 TIMSS 2002/03 countries	Average scale score (se)	2002/03	1994/9
Singapore	578 (4.3)	▲	▲
Chinese Taipei	571 (3.5)	▲	-
Korea, Rep. of	558 (1.6)	▲	▲
†Hong Kong SAR	556 (3.0)	▲	▼
Estonia	552 (2.5)	▲	-
Japan	552 (1.7)	▲	▲
†England	544 (4.1)	▲	•
Hungary	543 (2.8)	▲	•
†Netherlands	536 (3.1)	•	•
‡United States of America	527 (3.1)	•	•
Australia	527 (3.8)		
Sweden	524 (2.7)	•	•
Slovenia	520 (1.8)	•	•
New Zealand	520 (5.0)	•	▼
†Lithuania	519 (2.1)	•	▼
Slovak Republic	517 (3.2)	▼	-
Belgium (Flemish)	516 (2.5)	▼	•
Russian Federation	514 (3.7)	▼	•
Latvia	512 (2.6)	▼	▼
†Scotland	512 (3.4)	▼	▼
Malaysia	510 (3.7)	▼	-
Norway	494 (2.2)	▼	▼
Italy	491 (3.1)	▼	-
²Israel	488 (3.1)	▼	▼
Bulgaria	479 (5.2)	▼	•
Jordan	475 (3.8)	▼	-
International average	474 (0.6)	▼	

- Australian students achieved at a level significantly higher than the international average
- Australia's achievement at Year 8 increased significantly from 1994
- Other countries have improved more dramatically and now significantly outscore us

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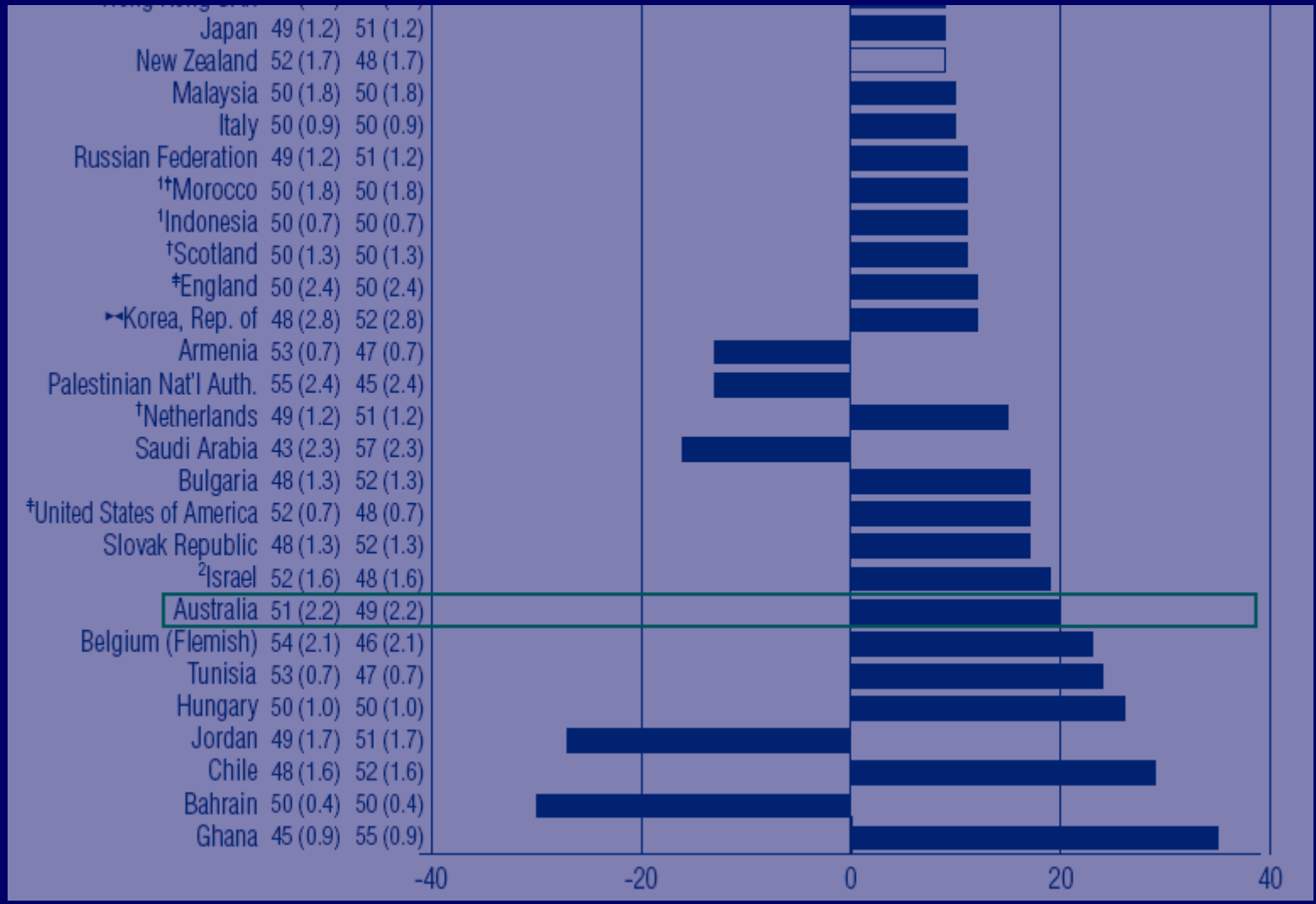
Gender differences

- None in PISA or in TIMSS Year 4 … but in TIMSS Year 8 the average score for males increased significantly, while that of females did not …

TIMSS Year 8



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Indigenous students

- Year 4 differences in achievement
  - TIMSS 1994/95 : 62 score points
  - TIMSS 2002/03 : 71 score points
- Year 8 differences in achievement
  - TIMSS 1994/95 : 83 score points
  - TIMSS 2002/03 : 58 score points
- Indigenous students' achievement has improved significantly

TIMSS Benchmarks

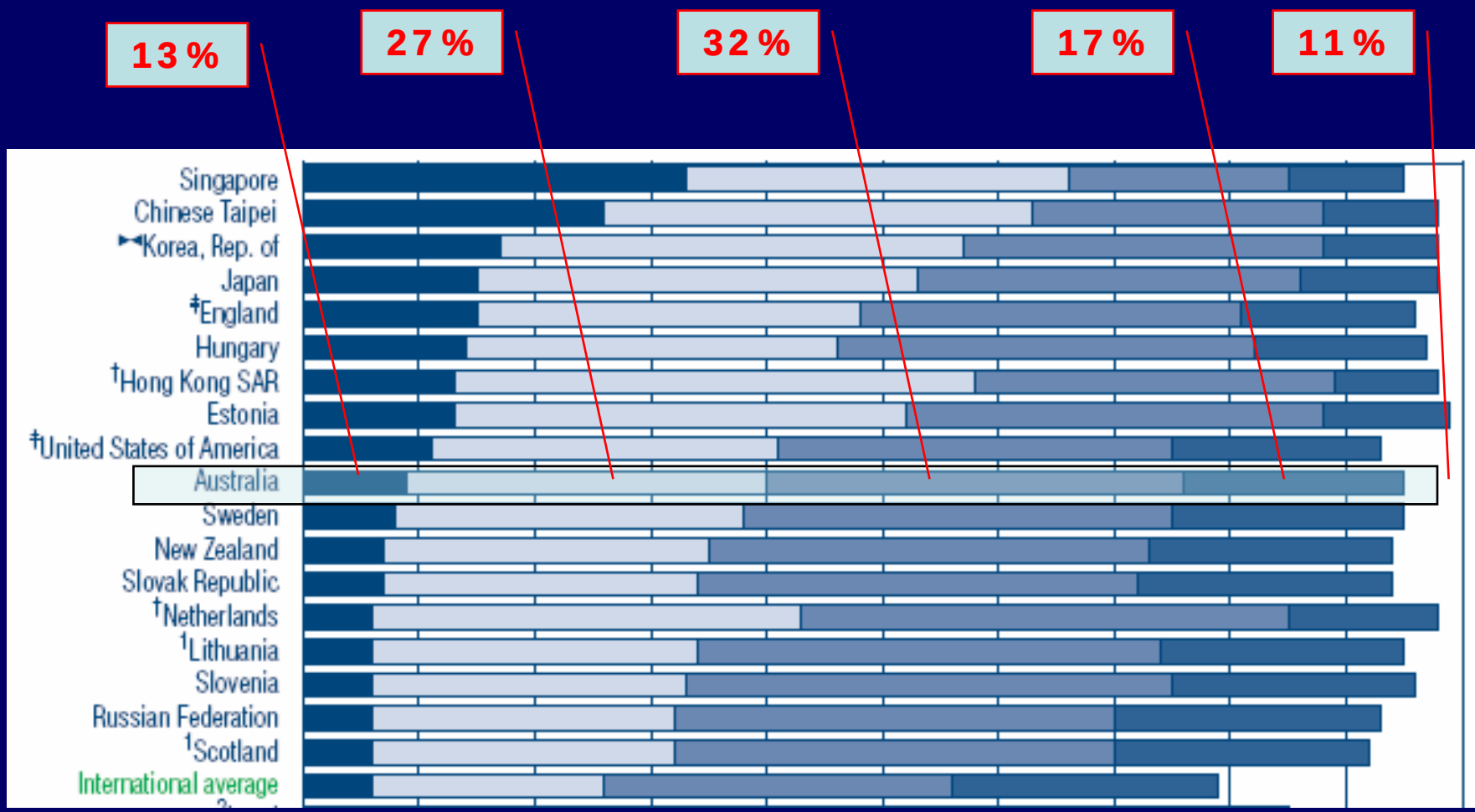
Year 4

- Low – recognise some basic facts from the life and physical sciences
- Advanced – can apply knowledge and understanding in beginning scientific enquiry

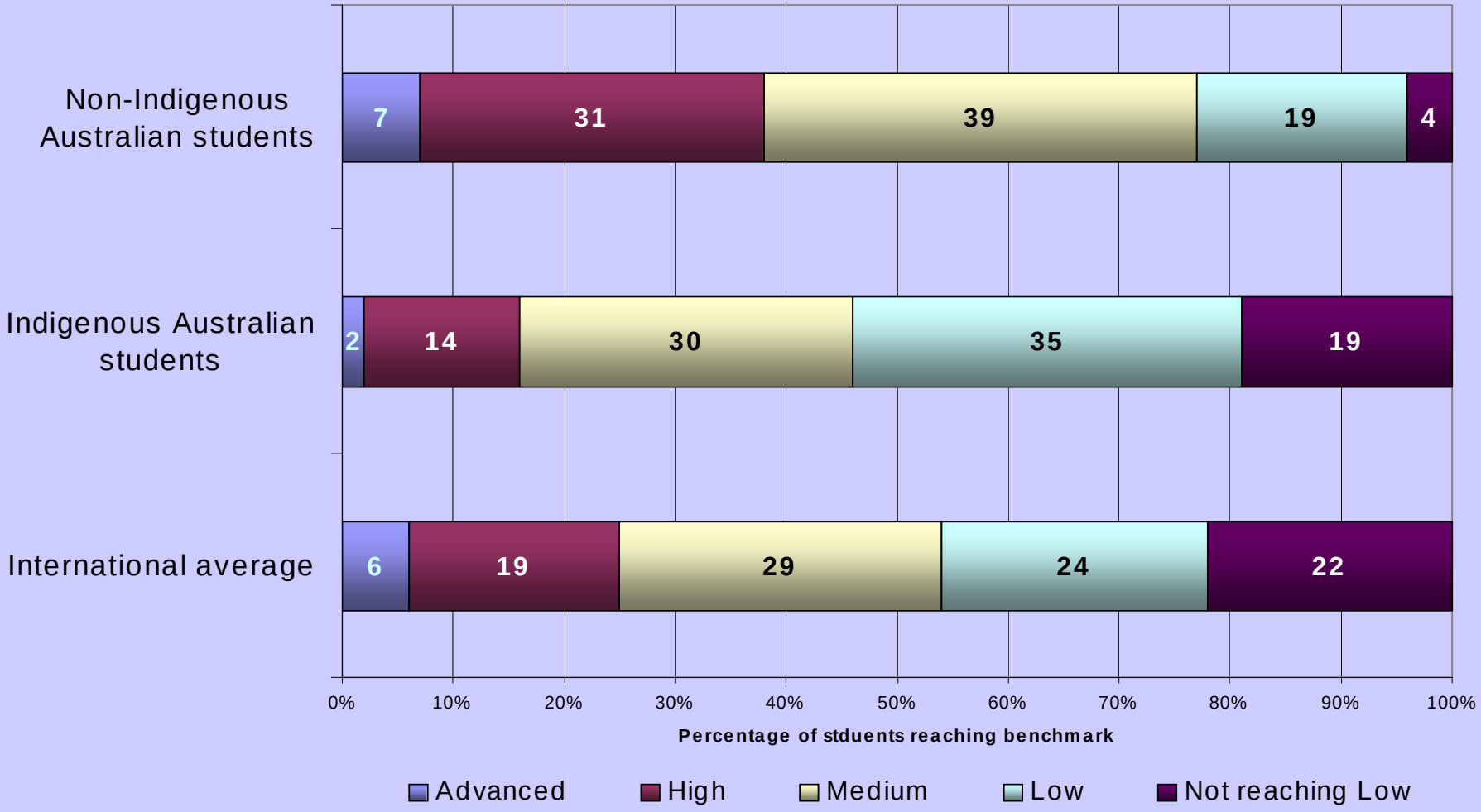
Year 8

- Low – recognise some basic facts from the life and physical sciences
- Advanced – demonstrate a grasp of some complex and abstract science concepts

Benchmarks – Year 8



Proficiency levels –Year 8 students



Do we care whether students like it?

- Of course we do!
- So we build in measures of confidence, liking, enjoyment … perceptions of learning environment, etc
- Not all countries find these variables necessary …

Self-confidence in learning science

- Index based on students' responses to four statements about science:
  - I usually do well in science;
  - Science is more difficult for me than for many of my classmates (Reversed);
  - Science is not one of my strengths (Reversed);
  - I learn things quickly in science
- Combined to form High, Medium and Low on the index

Self-confidence – Year 4

	HIGH	MEDIUM	LOW
International	59% (508)	32% (469)	9% (459)
Australia	66% (535)	27% (501)	7% (491)
(non-Indigenous)	67% (538)	26% (507)	7% (492)
(Indigenous)	53% (486*)	39% (454)	8% (474*)
Singapore	32% (592)	41% (554)	27% (552)

- No gender differences

Self-confidence – Year 8

	HIGH	MEDIUM	LOW
International	48% (490)	38% (445)	14% (430)
Australia	49% (550)	34% (513)	17% (499)
Males	52% (562)	34% (521)	15% (500)
Females	46% (536)	35% (506)	19% (498)
Non-Indigenous	49% (552)	34% (515)	16% (501)
Indigenous	39% (477)	31% (473)	30% (465)
Japan	20% (595)	46% (551)	34% (529)

Enjoyment of science

	HIGH	MEDIUM	LOW
Year 4			
International	55%	27%	18%
Australia	64%	23%	14%
Year 8			
International	44%	33%	23%
Australia	29%	38%	33%
Males	33%*	39%	28%*
Females	26%	37%	37%
Indigenous	33%	31%	36%

Valuing science – Year 8

- Index based on students' responses to seven statements about science:
  - I would like to take more science in school;
  - I enjoy learning science;
  - I think learning science will help me in my daily life;
  - I need science to learn other school subjects;
  - I need to do well in science to get into the university of my choice;
  - I would like a job that involved using science;
  - I need to do well in science to get the job I want.

Valuing science

	HIGH	MEDIUM	LOW
International	57% (477)	31% (450)	12% (463)
Australia	36% (551)	37% (522)	27% (506)
Males	40% (562)	37% (529)	23% (515)
Females	33% (538)	37% (515)	30% (499)
Indigenous	30% (488)	42% (474)	28% (453)
Singapore	62% (599)	33% (551)	6% (505)

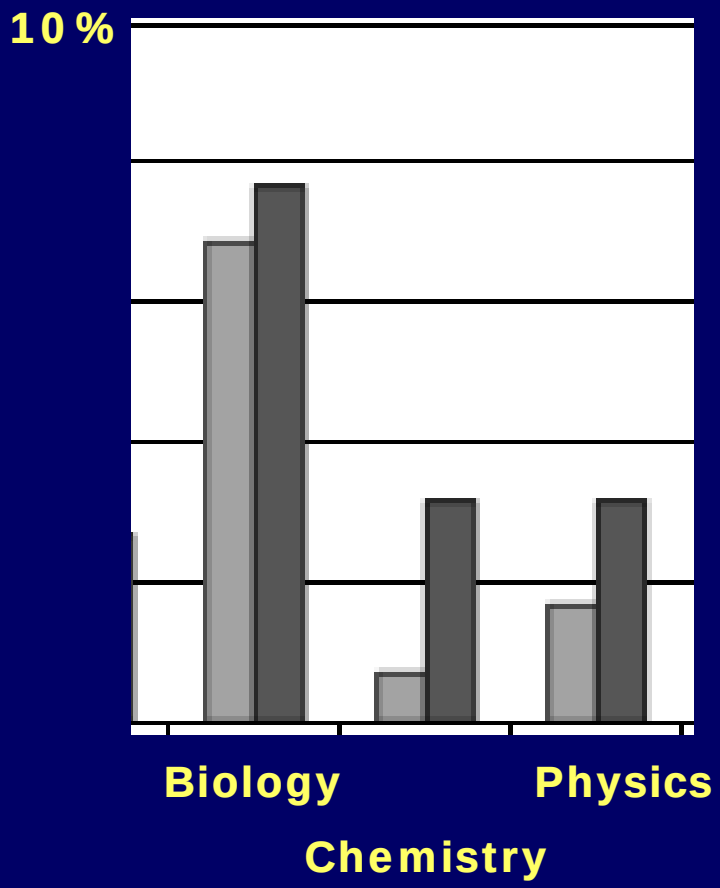
Persistence in studying science

- Overall, 55% of Year 12 students enrolled in at least one science subject
- Enrolments in all areas declined between 1995 and 2001
  - Chemistry: 23% to 18%
  - Physics: 20% to 17%
  - Biology: 32% to 25%

Gender differences

- The odds of a female being enrolled in a biological science is twice the odds of a male being enrolled
- The odds of a female being enrolled in physics is 0.3 the odds of a male being enrolled
- The odds of a female being enrolled in chemistry is 0.8 the odds of a male being enrolled

Indigenous students



- While the proportion of Indigenous students enrolled in Year 12 in this LSAY cohort is too small to draw many conclusions, it is apparent that there are large differences

And after school...?

- Of those in the LSAY Y95 cohort who studied sciences in Year 12, 77% went on to higher education:
  - 22% into natural or physical sciences
  - 17% into engineering or related areas
  - 12% into health related courses

‘Blueprint’ for effective science teaching in Australia

- Students experience a curriculum that us relevant to their lives and interests within a supportive and safe learning environment
- Classroom science is linked to the broader community
- Students are actively engaged with inquiry, evidence and ideas
- Students are challenged to develop and extend meaningful understandings
- Assessment facilitates learning and is focused on scientific literacy
- ICTS are exploited to enhance students’ learning of science.