What science do students want to learn?

What do students know about science?

Barry McCrae
OECD Programme for International Student Assessment (PISA)

- Objective is to measure how well 15-year-olds are prepared for life beyond school
- Takes place every three years – first assessment in 2000
- Three domains covered in all cycles:
  - Reading literacy
  - Mathematical literacy
  - Scientific literacy
PISA 2000

- Major focus: Reading literacy
- Participating countries: 32 (28 OECD)
PISA 2003

- Major focus: Mathematical literacy
- Participating countries: 41 (30 OECD)
- Special feature: Assessment of Problem Solving
PISA 2006

• Major focus: Scientific literacy
• Participating countries: 58 (30 OECD)
• Special feature: Optional computer-based assessment of science (CBAS)
  – Denmark
  – Iceland
  – Republic of Korea
The PISA 2006 Assessment

- Two-hour pen-and-paper test
- Mixture of multiple-choice and constructed-response items
- Thirteen half-hour clusters of items altogether
  - 7 science clusters, 4 maths, 2 reading
- Rotated booklet design
- 30-minute student background questionnaire
- 20-minute school questionnaire
PISA 2006 Sample Sizes

• Minimum of 150 schools per country
• Target of 35 students per school
• Minimum of 4500 students per country
• Many countries have multiple languages of instruction or over-sample
• About 400,000 students in total are expected to undertake the 2006 assessment
PISA 2006 in Australia

- Over-sample to report on States and Territories, and indigenous students
- 350+ schools
- Target of 50 students per school
- About 18,000 students overall
- Taking place during July and August
PISA 2000/2003 Definition of Scientific Literacy

• **Scientific literacy** is 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.
PISA 2006 Expanded Definition of Scientific Literacy

**Scientific literacy** refers to an individual’s:

- **Scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence-based conclusions about science-related issues;**
• understanding of the characteristic features of science as a form of human knowledge and enquiry;

• awareness of how science and technology shape our material, intellectual, and cultural environments; and

• willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen.
PISA 2006 Science Framework

Context

Life situations that involve science and technology.

Competencies

Require you to:

• Identify scientific issues;
• Explain phenomena scientifically; and
• Use scientific evidence.

Knowledge

What you know:

• about the natural world (knowledge of science); and
• about science itself (knowledge about science).

Attitudes

How you respond to science issues (interest, support for scientific enquiry, responsibility)
Contexts

• Setting
  – Personal focus: self, family and peer groups
  – Social focus: the community
  – Global focus: life across the world

• Application area
  – Health – Hazards
  – Natural resources – Environment
  – Frontiers of science & technology

• Example: *Catching the Killer*
  – Setting: Social; Application area: Frontiers
**DNA TO FIND KILLER**

*Smithville, yesterday:* A man died from multiple stab wounds in Smithville today. Police say that there were signs of a struggle and that some of the blood found at the scene of the crime did not match the victim's blood. They believe that this blood came from the killer.

To help find the killer, police scientists have prepared a DNA profile from the blood sample. When compared to DNA profiles of convicted criminals, kept on a computer database, no match was found.

Police have now arrested a local man seen arguing with the victim earlier in the day. They have applied for permission to collect a sample of the suspect's DNA.

Sergeant Brown of the Smithville police said, "We just need to take a harmless scraping from the inside of the cheek. From this scraping scientists can extract DNA and form a DNA profile like the ones pictured."

Except for identical twins, there is only a 1 in 100 million chance that two people will have the same DNA profile.

**Photo of typical DNA profiles from two people. The bars are different fragments of each person's DNA. Each person has a different pattern of bars. Like fingerprints, these patterns can identify a person.**

<table>
<thead>
<tr>
<th>Person A</th>
<th>Person B</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="DNA Profile A" /></td>
<td><img src="image2.png" alt="DNA Profile B" /></td>
</tr>
</tbody>
</table>
Competencies

• PISA 2006 Science Framework

• Identifying scientific issues

• Explaining phenomena scientifically

• Using scientific evidence
Identifying Scientific Issues

• Recognising issues that it is possible to investigate scientifically.
• Identifying keywords to search for scientific information.
• Recognising the key features of a scientific investigation.
• **Example:** *Catching the Killer, Q02*
• Question 2: CATCHING THE KILLER
• Which one of the following questions cannot be answered by scientific evidence?
  A. What was the medical or physiological cause of the victim’s death?
  B. Who was the victim thinking of just before he died?
  C. Is taking cheek scrapings a safe way to collect DNA samples?
  D. Do identical twins have exactly the same DNA profile?
Explaining Phenomena Scientifically

- Applying knowledge of science in a given situation.
- Describing or interpreting phenomena scientifically and predicting changes.
- Identifying appropriate descriptions, explanations, and predictions.
- **Example:** *Catching the Killer, Q01*
• Question 1: CATCHING THE KILLER

• This newspaper article refers to the substance DNA. What is DNA?

A. A substance in cell membranes that stops the cell contents leaking out.
B. A molecule that contains the instructions to build our bodies.
C. A protein found in blood that helps carry oxygen to our tissues.
D. A hormone in blood that helps regulate glucose levels in body cells.
Using Scientific Evidence

• Interpreting scientific evidence and making and communicating conclusions.
• Identifying the assumptions, evidence and reasoning behind conclusions.
• Reflecting on the societal implications of science and technological developments.
• Example: Malaria
Knowledge Component

- **PISA 2006 Science Framework**
- **Knowledge of science**
  - Knowledge of the natural (and material) world
  - Physical systems; Living systems; Earth and space systems; Technology systems
  - Example: Catching the Killer Q01
- **Knowledge about science**
  - Knowledge of the means and goals of science
  - Scientific enquiry; Scientific explanations
  - Example: Malaria Q01
Scientific Enquiry

- **origin** (e.g., curiosity, scientific questions).
- **purpose** (e.g., to produce evidence that helps answer scientific questions, current ideas/models/theories guide enquiries).
- **experiments** (e.g., different questions suggest different scientific investigations, design).
- **data type** (e.g., quantitative [measurements], qualitative [observations]).
- **measurement** (e.g., inherent uncertainty, replicability, variation, accuracy/precision in equipment and procedures).
- **characteristics of results** (e.g., empirical, tentative, testable, falsifiable, self-correcting).
Scientific Explanation

- **types** (e.g., hypothesis, theory, model, law).
- **formation** (e.g., data representation; role of extant knowledge and new evidence, creativity and imagination, logic).
- **rules** (e.g., must be logically consistent; based on evidence, historical and current knowledge).
- **outcomes** (e.g., produce new knowledge, new methods, new technologies; lead to new questions and investigations).
- **Example:** [Catching the Killer Q02](#)
Attitudinal Dimension

- PISA 2006 Science Framework
- Interest in science
- Support for scientific enquiry
- Responsibility towards resources and environments
- These are important outcomes of science education
Interest in Science

• Indicate curiosity in science and science-related issues and endeavours.
• Demonstrate willingness to acquire additional scientific knowledge and skills, using a variety of resources and methods.
• Demonstrate willingness to seek information and have an ongoing interest in science, including consideration of science-related careers.
Support for Scientific Enquiry

• Acknowledge the importance of considering different scientific perspectives and arguments.
• Support the use of factual information and rational explanations.
• Express the need for logical and careful processes in drawing conclusions.
Responsibility towards Resources and Environments

• Show a sense of personal responsibility for maintaining a sustainable environment.
• Demonstrate awareness of the environmental consequences of individual actions.
• Demonstrate willingness to take action to maintain natural resources.
Assessing Students’ Attitudes

• The student questionnaire will be used to gather data on students’ attitudes in all three area in a non-contextualised manner

• In addition, Likert-style items will be embedded in test units to assess Interest in learning about science and Support for scientific enquiry

• Example: Catching the Killer, Q03
Question 3: CATCHING THE KILLER

How much interest do you have in the following information?

Tick only one box in each row.

<table>
<thead>
<tr>
<th></th>
<th>High Interest</th>
<th>Medium Interest</th>
<th>Low Interest</th>
<th>No Interest</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a) Knowing more about the use of DNA in solving crime.

b) Learning more about how DNA profiling works.

c) Understanding better how crime can be solved using science.
Embedded Attitudinal Items

• Placed at the end of units
• Distinctively formatted to remind students that they have no “correct” answer and will not count towards their test score
• Occur in about two-thirds of the test units
Test Balance

• Knowledge of science: 60%
Knowledge about science: 40%

• Each competency will be assessed by at least 25% of the items

• Answering the attitudinal items should occupy about 14% of students’ test time
Reporting Scales

• Separate scales, with described proficiency levels, will be constructed for each of the competencies or for the two types of knowledge

• Scales should also be able to be constructed for *Interest in learning about science* and *Support for scientific enquiry*
Examples of Science Items

- PISA items are arranged in groups (units) based around a common stimulus
- Bread Dough
- Health Risk?
- These examples were included in the field trial (in some form) but are not included in the main study
PISA 2006 Field Trial Results

• Conducted in all 58 PISA countries during 2005
• Convenience samples
  – Results must be treated with caution
• Minimum of about 1200 students per country
• About 95,000 students overall
### Question 3: HEALTH RISK?

How much interest do you have in the following information?

*Tick only one box in each row.*

<table>
<thead>
<tr>
<th>a) Knowing more about the chemical composition of agricultural fertilisers</th>
<th>High Interest</th>
<th>Medium Interest</th>
<th>Low Interest</th>
<th>No Interest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>b) Understanding what happens to toxic fumes emitted into the atmosphere</th>
<th>High Interest</th>
<th>Medium Interest</th>
<th>Low Interest</th>
<th>No Interest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>c) Learning about respiratory diseases that can be caused by chemical emissions</th>
<th>High Interest</th>
<th>Medium Interest</th>
<th>Low Interest</th>
<th>No Interest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
Interest in …

- Understanding what happens to toxic fumes emitted into the atmosphere
  - Above average interest
- Learning about respiratory diseases that can be caused by chemical emissions
  - Above average interest
- Knowing more about the chemical composition of agricultural fertilisers
  - Low interest
Interest in Learning about Science: Tentative Findings

- Most interest in learning about health or safety issues that they may encounter personally
- Least interest in learning about abstract scientific explanations and how a particular research study was conducted
- Confirms findings of Osborne & Collins (2001) and the ROSE project
## Question 5: BREAD DOUGH

How much do you agree with the following statements?

*Tick only one box in each row.*

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>I would trust a scientific report more than a baker’s explanation of the weight loss in dough.</td>
<td>□₁</td>
<td>□₂</td>
<td>□₃</td>
</tr>
<tr>
<td>b)</td>
<td>Chemical analysis is the best way to identify the products of fermentation.</td>
<td>□₁</td>
<td>□₂</td>
<td>□₃</td>
</tr>
<tr>
<td>c)</td>
<td>Research into the changes that occur when food is prepared is important.</td>
<td>□₁</td>
<td>□₂</td>
<td>□₃</td>
</tr>
</tbody>
</table>
Do you agree that …

• Chemical analysis is the best way to identify the products of fermentation.
  – Below average support

• Research into the changes that occur when food is prepared is important.
  – Below average support

• I would trust a scientific report more than a baker’s explanation of the weight loss in dough.
  – Low support
Support for Scientific Enquiry: Tentative Findings

- “Personal relevance” influence once again the main issue
  - High support for “It is important to research how diseases are spread”
  - Low support for “Studying fish in a tank is important even though the fish may behave differently in the wild”
- Quite high support for research that would assist the survival of endangered species
Students’ Scientific Knowledge: Tentative Findings

• **No gender difference** apparent overall internationally, **but** apparent when performance is analysed according to the knowledge component of the items

• **However**, this finding needs to be disassociated from any “competency type” effect in the main study analyses
Per Cent Correct According to Knowledge Component

Per cent correct (Males - Females)

Knowledge component

PHS  ESS  LSS  KAS

INT
Per Cent Correct Australia

Per cent correct (Boys - Girls)

Knowledge component

- PHS
- ESS
- LSS
- KAS

INT
AUS
TIMSS 2002/2003 Results

Year 8 score (Boys - Girls)

Content area

PH  CH  ES  EnvS  LS

INT  AUS
Summary

- **Science** is the major assessment domain for the first time in PISA 2006
- A total of about 400,000 students from the **58 participating countries** are being assessed
- Some **tentative conclusions** can be drawn from the field trial conducted during 2005
Summary (cont.)

• The definition of scientific literacy has been expanded for 2006 to include
  – aspects of individual’s attitudes towards science
  – a much stronger emphasis on an individual’s knowledge about science

• Embedded items are used to help assess students’ Interest in learning about science and Support for scientific enquiry
Summary (cont.)

• Field trial results support findings of others that students are most/least interested in topics that they perceive as being of most/least interest to themselves

• In the field trial, girls out-performed boys on knowledge about science items
  – Subject to confirmation in the main study

• What are the implications for Boosting Science Learning?