The Impact of PISA 2015 on Science Education: The Potential Advancement of Science Teaching, Learning, and Assessment

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What is PISA?

1. The OECD (Organization for Economic Co-operation and Development) began work on PISA (Programme for International Student Assessment) in 2000.
2. The triennial assessment focuses on the core school subjects of science, reading and mathematics.
3. It evaluates students’ science, math, and reading knowledge and competencies of 15-year-old students every three years with one subject as its core for each cycle.
4. Knowledge: how well students can reproduce knowledge
5. Competencies : how well they can extrapolate from what they have learned and apply that knowledge in unfamiliar settings, both in and outside of school.
6. We can compare students' performance over time and assess the impact of educational policy on students’ performance.

PISA 2015

- PISA 2015 is the sixth cycle of the triennial assessment.
- The first time PISA evaluate “science” as its major domain in 2006.
- The major domain in 2015 is science.
- 72 countries and economies participate in PISA 2015.

PISA 2015 Innovation

1. PISA 2015 delivers the assessments of all subjects via computer.
2. Teacher Questionnaire
3. Collaborative Problem Solving
4. Science Epistemic Knowledge
5. Interactive Units: simulation

Science Framework

Aspects of Scientific Literacy

Contexts

- Personal
- Local/National
- Global

Require individuals to display

Competencies

- Explain phenomena scientifically
- Evaluate and design scientific enquiry
- Interpret data and evidence scientifically

How an individual does this is influenced by

Knowledge

- Content
- Procedural
- Epistemic

Attitudes

- Interest in science
- Valuing scientific approaches to enquiry
- Environmental awareness

PISA 2015 Scientific Competencies

Explain phenomena scientifically
Recognize, offer and evaluate explanations for a range of natural and technological phenomena demonstrating the ability to:
• Recall and apply appropriate scientific knowledge; • Identify, use and generate explanatory models and representations; • Make and justify appropriate predictions; • Offer explanatory hypotheses; • Explain the potential implications of scientific knowledge for society.

Evaluate and design scientific enquiry

Describe and appraise scientific investigations and propose ways of addressing questions scientifically demonstrating the ability to:

- Identify the question explored in a given scientific study;
- Distinguish questions that are possible to investigate scientifically;
- Propose a way of exploring a given question scientifically;
- Evaluate ways of exploring a given question scientifically;
- Describe and evaluate a range of ways that scientists use to ensure the reliability of data, and the objectivity and generalization ability of explanations.

Interpret data and evidence scientifically

Analyze and evaluate scientific data, claims and arguments in a variety of representations and draw appropriate conclusions demonstrating the ability to:

- Transform data from one representation to another;
- Analyze and interpret data and draw appropriate conclusions;
- Identify the assumptions, evidence and reasoning in science-related texts;
- Distinguish between arguments which are based on scientific evidence and theory and those based on other considerations;
- Evaluate scientific arguments and evidence from different sources (e.g. newspaper, internet, journals).

Content Knowledge

Content Knowledge

Knowledge of the Content of Science in PISA 2015		
Physical Systems that require knowledge of:	**Living Systems that require knowledge of:**	**Earth and Space Systems that require knowledge of:**
Structure of matter (e.g., particle model, bonds)	Cells (e.g., structures and function, DNA, plant and animal)	Structures of the Earth systems (e.g., lithosphere, atmosphere, hydrosphere)
Properties of matter (e.g., changes of state, thermal and electrical conductivity)	The concept of an organism (e.g., unicellular and multicellular)	Energy in the Earth systems (e.g., sources, global climate)
Chemical changes of matter (e.g., chemical reactions, energy transfer, acids/bases)	Humans (e.g., health, nutrition, subsystems such as digestion, respiration, circulation, excretion, reproduction and their relationship)	Change in Earth systems (e.g., plate tectonics, geochemical cycles, constructive and destructive forces)
Motion and forces (e.g., velocity, friction) and action at a distance (e.g., magnetic, gravitational and electrostatic forces)	Populations (e.g., species, evolution, biodiversity, genetic variation)	Earth's history (e.g., fossils, origin and evolution)
Energy and its transformation (e.g., conservation, dissipation, chemical reactions)	Ecosystems (e.g., food chains, matter and energy flow)	Earth in space (e.g., gravity, solar systems, galaxies)
Interactions between energy and matter (e.g., light and radio waves, sound and seismic waves)	Biosphere (e.g., ecosystem services, sustainability)	The history and scale of the Universe and its history (e.g., light year, Big Bang theory)

Procedural Knowledge

the general features of procedural knowledge

The concept of variables including dependent, independent and control variables;	Concepts of measurement e.g., quantitative [measurements], qualitative [observations], the use of a scale, categorical and continuous variables;
	Ways of assessing and minimizing uncertainty such as repeating and averaging measurements;
	Mechanisms to ensure the replicability (closeness of agreement between repeated measures of the same quantity) and accuracy of data (the closeness of agreement between a measured quantity and a true value of the measure);
	Common ways of abstracting and representing data using tables, graphs and charts and their appropriate use;
	The control of variables strategy and its role in experimental design or the use of randomized controlled trials to avoid confounded findings and identify possible causal mechanisms;
	The nature of an appropriate design for a given scientific question e.g., experimental, field based or pattern seeking.

Epistemic Knowledge

what are considered to be the major features of epistemic knowledge necessary for scientific literacy	
The constructs and defining features of science.	The nature of scientific observations, facts, hypotheses, models and theories;
	The purpose and goals of science (to produce explanations of the natural world) as distinguished from technology (to produce an optimal solution to human need), what constitutes a scientific or technological question and appropriate data;
	The values of science e.g., a commitment to publication, objectivity and the elimination of bias;
	The nature of reasoning used in science e.g., deductive, inductive, inference to the best explanation (abductive), analogical, and model-based;
The role of these constructs and features in justifying the knowledge produced by science.	How scientific claims are supported by data and reasoning in science;
	The function of different forms of empirical enquiry in establishing knowledge, their goal (to test explanatory hypotheses or identify patterns) and their design (observation, controlled experiments, correlational studies);
	How measurement error affects the degree of confidence in scientific knowledge;
	The use and role of physical, system and abstract models and their limits;
	The role of collaboration and critique and how peer review helps to establish confidence in scientific claims;
	The role of scientific knowledge, along with other forms of knowledge, in identifying and addressing societal and technological issues.

Attitudes

- In PISA 2015 these specific attitudes toward science will be measured by the student questionnaire.
- The PISA 2015 assessment will evaluate students' attitudes towards science in three areas:
  - Interest in science and technology
  - Environmental awareness
  - Valuing scientific approaches to enquiry

Questionnaire

1. Student Questionnaire
2. Information and Computer Technology Literacy Questionnaire
3. School Questionnaire
4. Teacher Questionnaire :10 science teacher and 15 non-science teacher each school

PISA 2015 Collaborative Problem Solving

Student background

Knowledge
- Math
- Reading and writing
- Science and environment
- Everyday learning

Characteristics
- Dispositions and attitudes
- Experience and knowledge
- Motivation
- Cognitive ability

Core Skills

Collaborative Skills
- Grounding
- Explanation
- Coordination
- Filling
- Perspective taking
- Audience design
- Argumentation
- Mutual regulation

Problem Solving Skills
- Explore and understand
- Represent and formulate
- Plan and execute
- Monitor and reflect

Collaborative Problem Solving Competencies

- Establishing and maintaining a shared understanding
- Taking appropriate action to solve the problem
- Establishing and maintaining team organization

Task Characteristics
- Openness
- Information availability
- Interdependency
- Symmetry of goals

Problem Scenario
- Task Type
- Settings
- Domain content

Medium
- Semantic richness
- Preferentiality
- Problem space

Team Composition
- Symmetry of roles
- Symmetry of status
- Size of group

Context

PISA 2015 Collaborative Problem Solving

CPS competencies / PS Skills	(1) Establishing and maintaining shared understanding	(2) Taking appropriate action to solve the problem	(3) Taking appropriate action to solve the problem
(A) Exploring and Understanding	(A1) Discovering perspectives and abilities of team members	(A2) Discovering the type of collaborative interaction required and establishing goals	(A3) Understanding roles to solve problem
(B) Representing and Formulating	(B1) Building a shared representation and negotiating the meaning of the problem (common ground)	(B2) Identifying and describing tasks to be completed	(B3) Describing roles and team organization (communication protocol /rules of Engagement)
(C) Planning and Executing	(C1) Communicating with team members about the actions performed	(C2)Enacting plans	(C3) Following rules of engagement
(D) Monitoring and Reflecting	(D1) Monitoring and repairing the shared understanding	(D2) Monitoring results of actions and evaluating success in solving the problem	(D3) Monitoring, providing feedback and adapting the team organization and roles

Bee Colony Collapse Disorder

Question 1 / 5

Refer to "Bee Colony Collapse Disorder" on the right. Type your answer to the question.

Understanding colony collapse disorder is important for people who keep and study bees, but colony collapse disorder also has an effect beyond the bees. People who study birds have identified an impact. The sunflower is a food source for both bees and certain birds. Bees feed on the nectar of the sunflower, while the birds feed on the seeds.

Given this relationship, why might the disappearance of bees result in a decline in the bird population?

BEE COLONY COLLAPSE DISORDER

An alarming phenomenon is threatening bee colonies around the world. This phenomenon is called colony collapse disorder. Colony collapse occurs when bees abandon the beehive. Separated from the hive, the bees die, so colony collapse disorder has caused the death of tens of billions of bees. Researchers believe that there are a number of causes for colony collapse.

Competency	**Explain Phenomena Scientifically**
Knowledge – System	**Content – Living**
Context	**Local/National – Environmental Quality**

Bee Colony Collapse Disorder
Question 2 / 5

Refer to "Exposure to Imidacloprid" on the right. Select from the drop-down menus to complete the sentence.

Describe the researchers' experiment by completing the following sentence.

The researchers tested the effect of
Select ▾ on
Select ▾ .

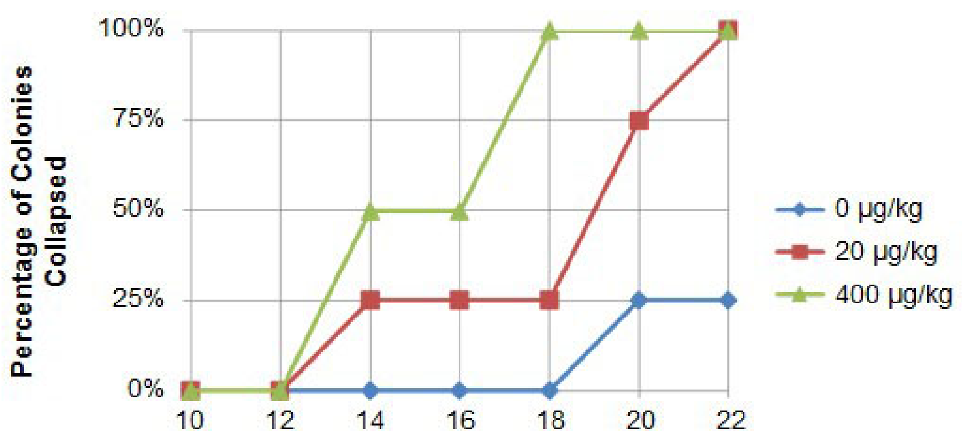
Competency	**Evaluate and Design Scientific Enquiry**
Knowledge – System	**Procedural**
Context	**Local/National – Environmental Quality**

BEE COLONY COLLAPSE DISORDER
Exposure to Imidacloprid

Scientists believe that there are multiple causes for colony collapse disorder. One possible cause is the insecticide imidacloprid, which may cause bees to lose their sense of orientation when outside the hive.

Researchers tested whether exposure to imidacloprid leads to colony collapse. In a number of hives, they added the insecticide to the bees' food for three weeks. Different hives were exposed to different concentrations of the insecticide, measured in micrograms of insecticide per kilogram of food (µg/kg). Some hives were not exposed to any insecticide.

None of the colonies collapsed immediately after exposure to the insecticide. However, by week 14, some of the hives had been abandoned. The following graph records the observed results:



Number of Weeks After Exposure to Insecticide

Bee Colony Collapse Disorder
Question 3 / 5

Refer to "Exposure to Imidacloprid" on the right. Click on a choice to answer the question.

Which one of the following conclusions matches the results shown in the graph?

- Colonies exposed to a higher concentration of imidacloprid tend to collapse sooner.
- Colonies exposed to imidacloprid collapse within 10 weeks of exposure.
- Exposure to imidacloprid at concentrations below 20 µg/kg does not harm colonies.
- Colonies exposed to imidacloprid cannot survive for more than 14 weeks.

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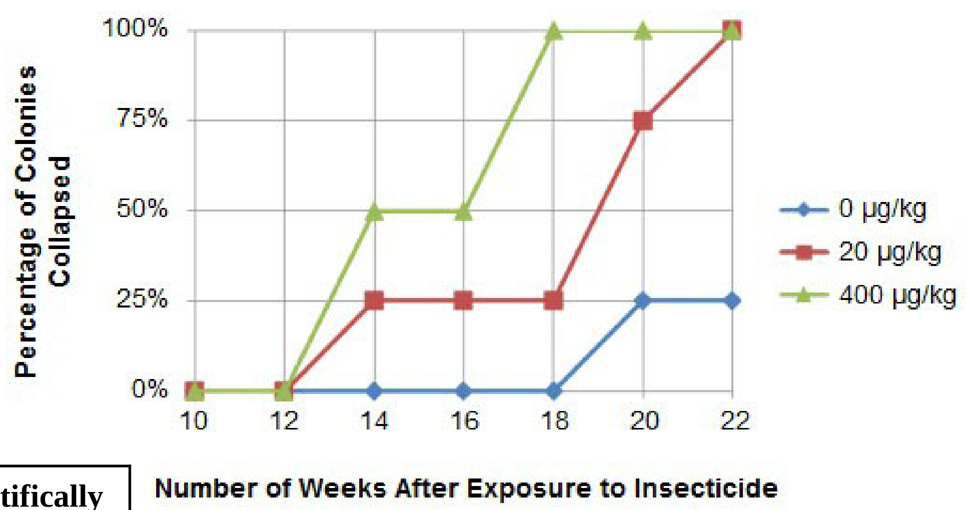

Competency	**Interpret Data and Evidence Scientifically**
Knowledge – System	**Procedural**
Context	**Local/National – Environmental Quality**

Bee Colony Collapse Disorder
Question 4 / 5

Refer to "Exposure to Imidacloprid" on the right. Type your answer to the question.

Look at the result in week 20 for the hives that the researchers did not expose to imidacloprid (0 µg/kg). What does it indicate about causes of collapse among the studied colonies?

BEE COLONY COLLAPSE DISORDER
Exposure to Imidacloprid

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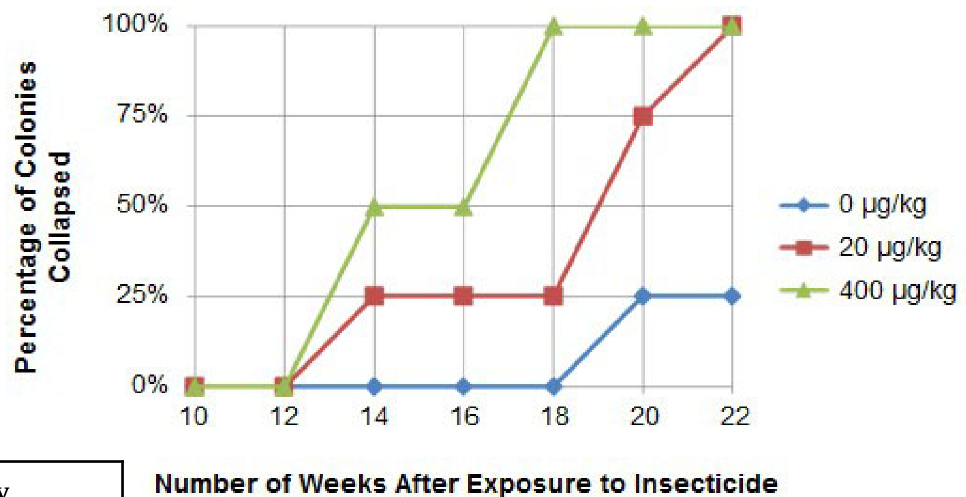


Competency	Explain Phenomena Scientifically
Knowledge – System	**Content – Living**
Context	**Local/National – Environmental Quality**

Bee Colony Collapse Disorder

Question 5 / 5

Click on a choice to answer the question

Scientists have proposed two additional causes for colony collapse disorder:

- A virus that infects and kills the bees.
- A parasitic fly that lays its eggs in the abdomen of the bees.

Which of the following findings supports the claim that bees die because of a virus?

- ◯ Eggs of another organism were found in hives.
- ◯ Insecticides were found inside the bees' cells.
- ◯ Non-bee DNA was found inside the bees' cells.
- ◯ Dead bees were found in hives.

Competency	**Explain Phenomena Scientifically**
Knowledge – System	**Content – Living**
Context	**Local/National – Environmental Quality**

Running in Hot Weather
Introduction

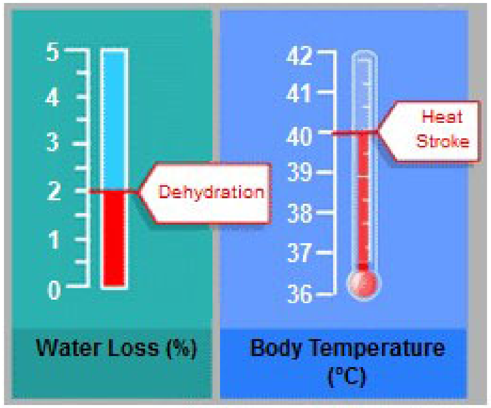
Read the introduction. Then click on the NEXT arrow.

RUNNING IN HOT WEATHER

During long-distance running, body temperature rises and sweating occurs.

If runners do not drink enough to replace the water they lose through sweating, they can experience dehydration. Water loss of 2% of body mass and above is considered to be a state of dehydration. This percentage is labelled on the water loss meter shown below.

If the body temperature rises to 40°C and above, runners can experience a life-threatening condition called heat stroke. This temperature is labelled on the body temperature thermometer shown below.



Running in Hot Weather

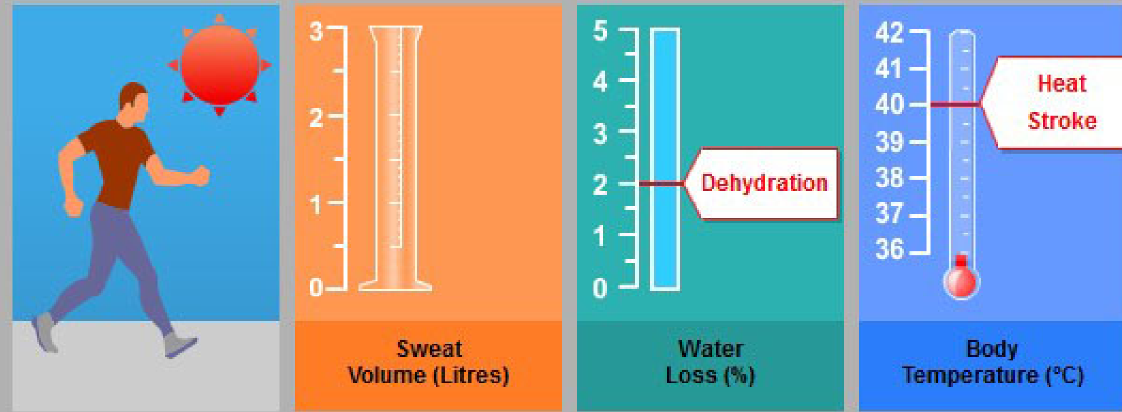
Introduction

This simulation is based on a model that calculates the volume of sweat, water loss, and body temperature of a runner after a one-hour run.

To see how all the controls in this simulation work, follow these steps:

1. Move the slider for **Air Temperature.**
2. Move the slider for **Air Humidity.**
3. Click on either "Yes" or "No" for **Drinking Water.**
4. Click on the "Run" button to see the results. Notice that a water loss of 2% and above causes dehydration, and that a body temperature of 40°C and above causes heat stroke. The results will also display in the table.

Note: The results shown in the simulation are based on a simplified mathematical model of how the body functions for a particular individual after running for one hour in different conditions.



Air Temperature (°C) 20 25 30 35 40

Air Humidity (%) 20 40 60

Drinking Water ◉ Yes ○ No

Run

Air Temperature (°C)	Air Humidity (%)	Drinking Water	Sweat Volume (Litres)	Water Loss (%)	Body Temperature (°C)

Running in Hot Weather
Question 1 / 6

▸ **How to Run the Simulation**

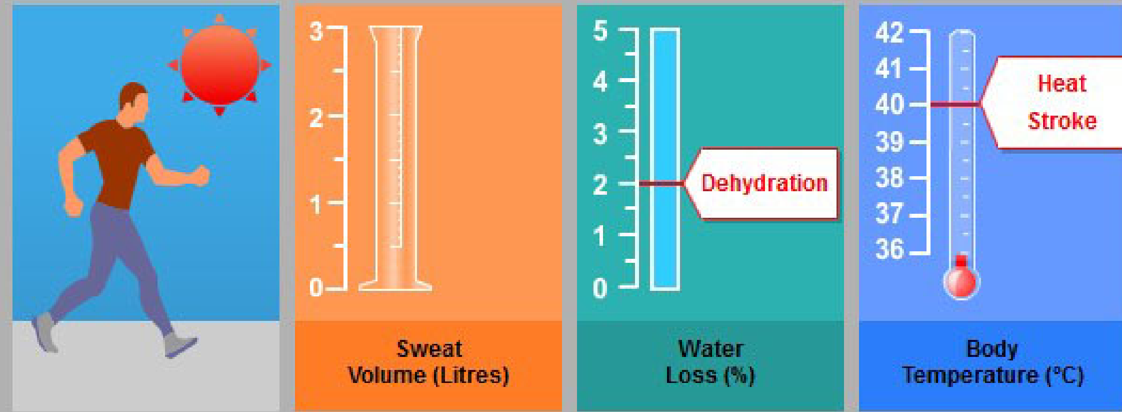
Run the simulation to collect data based on the information below. Select from the drop-down menus to answer the question.

A runner runs for one hour on a hot, dry day (air temperature 40°C, air humidity of 20%). The runner does not drink any water.

What health danger does the runner encounter by running under these conditions?

The health danger that the runner encounters is [select ▾].

This is shown by the [select ▾] of the runner after a one-hour run.



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Air Humidity (%) 20 40 60

Drinking Water ◉ Yes ○ No

Run

Air Temperature (°C)	Air Humidity (%)	Drinking Water	Sweat Volume (Litres)	Water Loss (%)	Body Temperature (°C)

Competency	**Interpret Data and Evidence Scientifically**
Knowledge – System	**Procedural**
Context	**Personal – Health and Disease**

PISA 2015

Running in Hot Weather

Question 2 / 6

▸ **How to Run the Simulation**

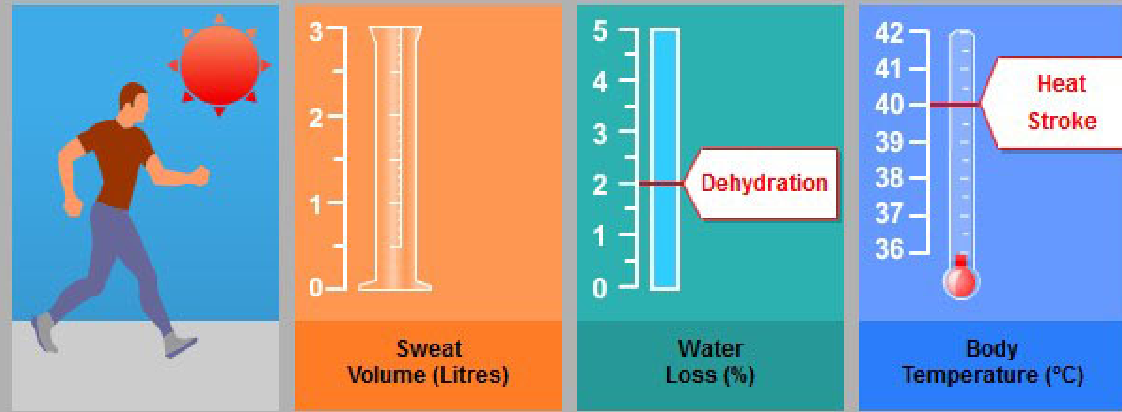
Run the simulation to collect data based on the information below. Click on a choice and then select data in the table to answer the question.

A runner runs for an hour on a hot and humid day (air temperature 35°C, air humidity of 60%) without drinking any water. This runner is at risk of both dehydration and heat stroke.

What would be the effect of drinking water during the run on the runner's risk of dehydration and heat stroke?

- ○ Drinking water would reduce the risk of heat stroke but not dehydration.
- ○ Drinking water would reduce the risk of dehydration but not heat stroke.
- ○ Drinking water would reduce the risk of both heat stroke and dehydration.
- ○ Drinking water would not reduce the risk of either heat stroke or dehydration.

Select two rows of data in the table to support your answer.



Air Temperature (°C) — 20 25 30 35 40

Air Humidity (%) — 20 40 60

Drinking Water — ◉ Yes ○ No

Run

Air Temperature (°C)	Air Humidity (%)	Drinking Water	Sweat Volume (Litres)	Water Loss (%)	Body Temperature (°C)

Competency	**Explain Phenomena Scientifically**
Knowledge – System	**Content – Living**
Context	**Personal – Health and Disease**

Running in Hot Weather
Question 3 / 6

▸ How to Run the Simulation

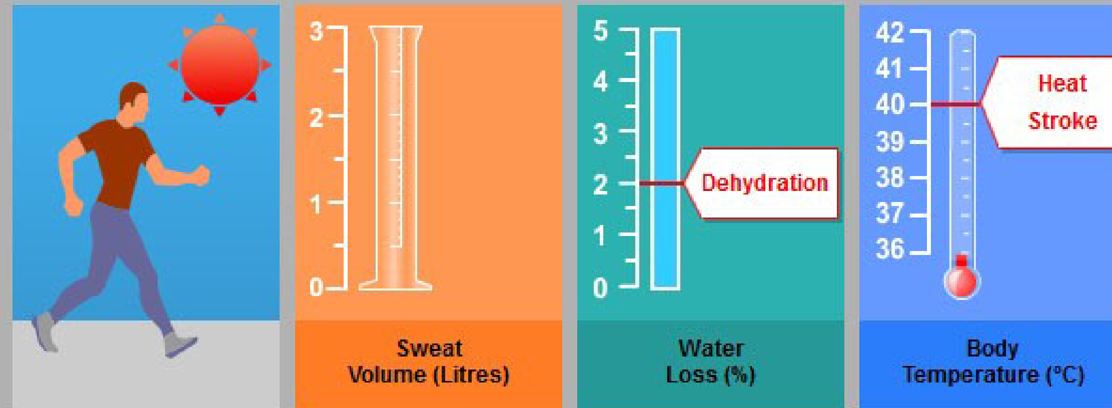
Run the simulation to collect data based on the information below. Click on a choice, select data in the table, and then type an explanation to answer the question.

When the air humidity is 60%, what is the effect of an increase in air temperature on sweat volume after a one-hour run?

- ○ Sweat volume increases
- ○ Sweat volume decreases

Select two rows of data in the table to support your answer.

What is the biological reason for this effect?



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Air Humidity (%) 20 40 60

Drinking Water ◉ Yes ○ No

Run

Air Temperature (°C)	Air Humidity (%)	Drinking Water	Sweat Volume (Litres)	Water Loss (%)	Body Temperature (°C)

Competency	**Evaluate and Design Scientific Enquiry** **Explain Phenomena Scientifically**
Knowledge – System	**Procedural** **Content – Living**
Context	**Personal – Health and Disease**

Running in Hot Weather
Question 4 / 6

▸ **How to Run the Simulation**

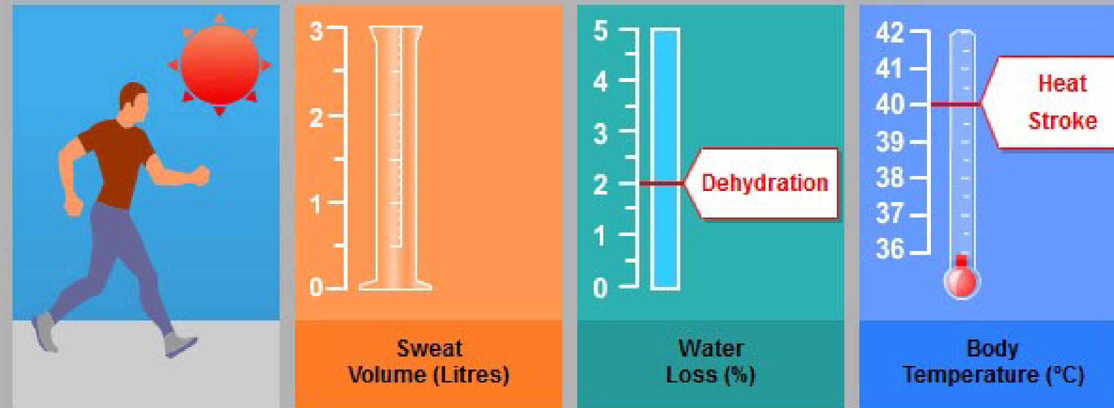
Run the simulation to collect data based on the information below. Click on a choice, select data in the table, and then type an explanation to answer the question.

Based on the simulation, when the air humidity is 40%, what is the highest air temperature at which a person can run for one hour without getting heat stroke?

- 20°C
- 25°C
- 30°C
- 35°C
- 40°C

Select two rows of data in the table to support your answer.

Explain how this data supports your answer.



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Air Humidity (%) 20 40 60

Drinking Water ◉ Yes ○ No

Run

Air Temperature (°C)	Air Humidity (%)	Drinking Water	Sweat Volume (Litres)	Water Loss (%)	Body Temperature (°C)

Competency	**Evaluate and Design Scientific Enquiry**
Knowledge – System	**Procedural**
Context	**Personal – Health and Disease**

Running in Hot Weather
Question 5 / 6

▸ **How to Run the Simulation**

Run the simulation to collect data based on the information below. Click on a choice, select data in the table, and then type an explanation to answer the question.

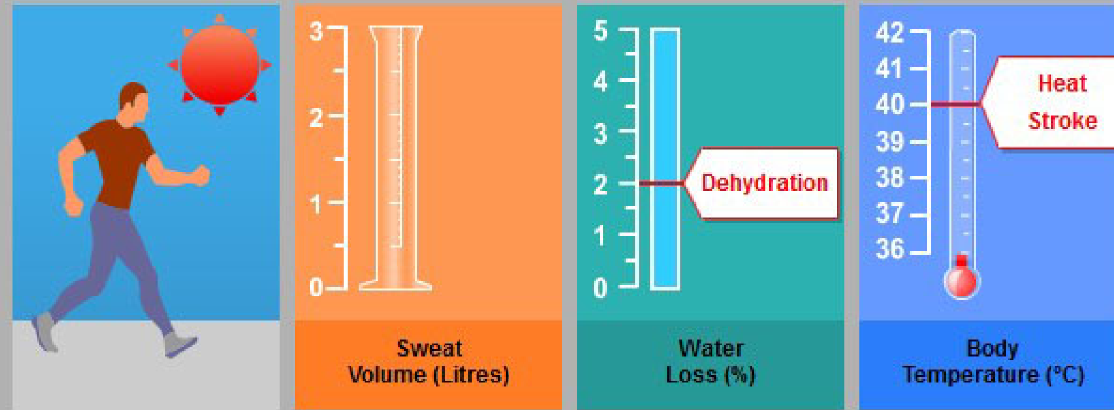
The simulation allows you to choose 20%, 40% or 60% for air humidity.

Do you expect that it would be safe or unsafe to run while drinking water with the air humidity at 50% and air temperature of 40°C?

- ○ Safe
- ○ Unsafe

Select two rows of data to support your answer.

Explain how this data supports your answer.



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Competency	**Evaluate and Design Scientific Enquiry**
Knowledge – System	**Procedural**
Context	**Personal – Health and Disease**

http://pisa2015.nctu.edu.tw

PISA 2012 Results

■ Table I.A ■

SNAPSHOT OF PERFORMANCE IN MATHEMATICS, READING AND SCIENCE

- Countries/economies with a mean performance/share of top performers above the OECD average; Countries/economies with a share of low achievers below the OECD average
- Countries/economies with a mean performance/share of low achievers/share of top performers not statistically significantly different from the OECD average
- Countries/economies with a mean performance/share of top performers below the OECD average; Countries/economies with a share of low achievers above the OECD average

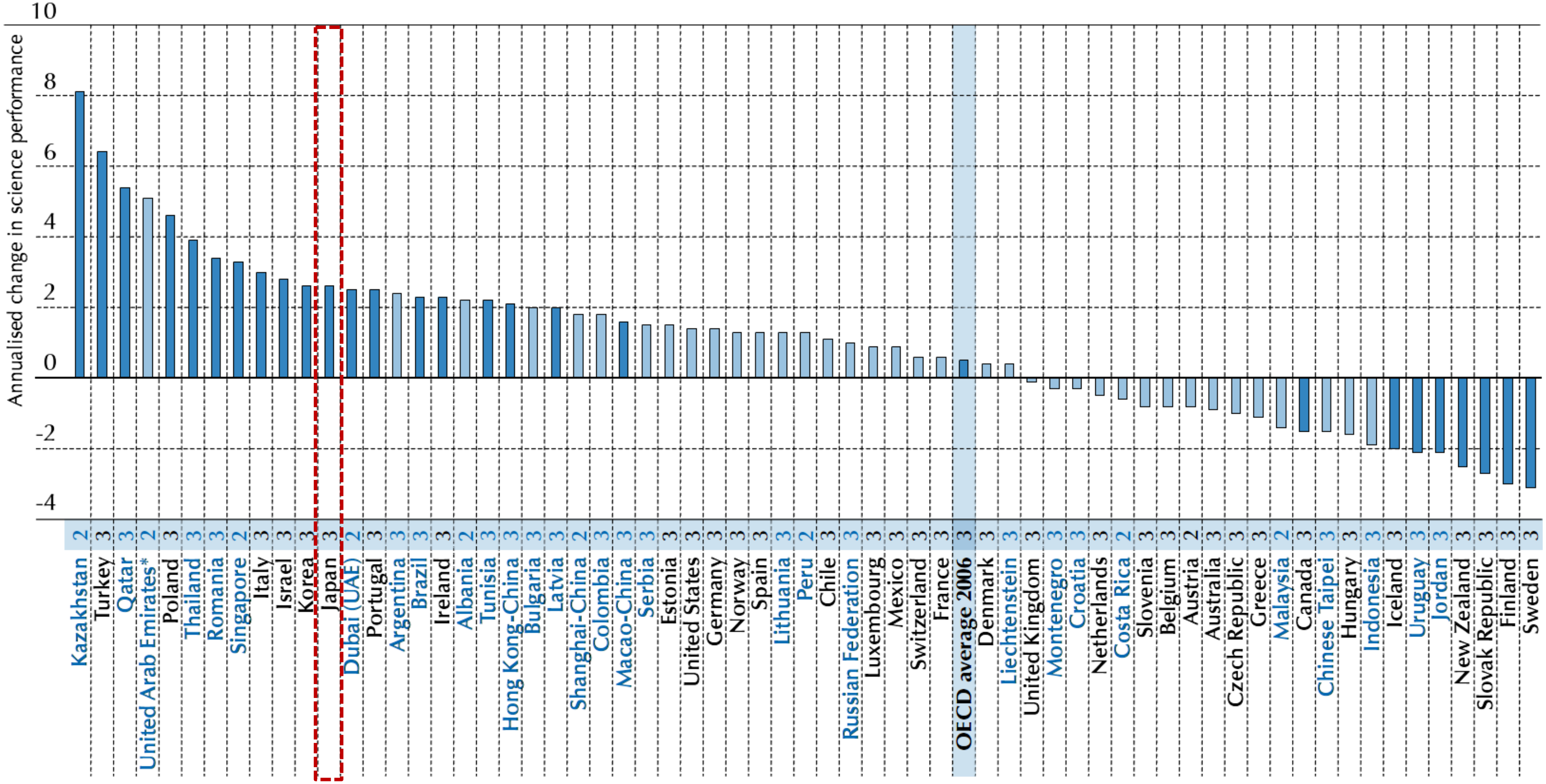
	Mathematics				Reading		Science	
	Mean score in PISA 2012	Share of low achievers (Below Level 2)	Share of top performers in mathematics (Level 5 or 6)	Annualised change	Mean score in PISA 2012	Annualised change	Mean score in PISA 2012	Annualised change
OECD average	494	23.1	12.6	**-0.3**	496	**0.3**	501	**0.5**
Shanghai-China	613	3.8	55.4	**4.2**	570	**4.6**	580	1.8
Singapore	573	8.3	40.0	**3.8**	542	**5.4**	551	**3.3**
Hong Kong-China	561	8.5	33.7	**1.3**	545	**2.3**	555	**2.1**
Chinese Taipei	560	12.8	37.2	1.7	523	**4.5**	523	-1.5
Korea	554	9.1	30.9	1.1	536	**0.9**	538	**2.6**
Macao-China	538	10.8	24.3	**1.0**	509	**0.8**	521	**1.6**
Japan	536	11.1	23.7	0.4	538	**1.5**	547	**2.6**
Liechtenstein	535	14.1	24.8	0.3	516	**1.3**	525	0.4
Switzerland	531	12.4	21.4	0.6	509	**1.0**	515	0.6
Netherlands	523	14.8	19.3	**-1.6**	511	-0.1	522	-0.5
Estonia	521	10.5	14.6	0.9	516	**2.4**	541	1.5
Finland	519	12.3	15.3	**-2.8**	524	**-1.7**	545	**-3.0**
Canada	518	13.8	16.4	**-1.4**	523	**-0.9**	525	**-1.5**
Poland	518	14.4	16.7	**2.6**	518	**2.8**	526	**4.6**
Belgium	515	18.9	19.4	**-1.6**	509	0.1	505	-0.8
Germany	514	17.7	17.5	**1.4**	508	**1.8**	524	1.4
Viet Nam	511	14.2	13.3	m	508	m	528	m
Austria	506	18.7	14.3	0.0	490	-0.2	506	-0.8
Australia	504	19.7	14.8	**-2.2**	512	**-1.4**	521	-0.9
Ireland	501	16.9	10.7	-0.6	523	**-0.9**	522	**2.3**

Source: PISA 2012 Results: What Students Know and Can Do Student Performance in Mathematics, Reading and Science (Volume I)

■ Figure I.5.3 ■

Annualised change in science performance throughout participation in PISA

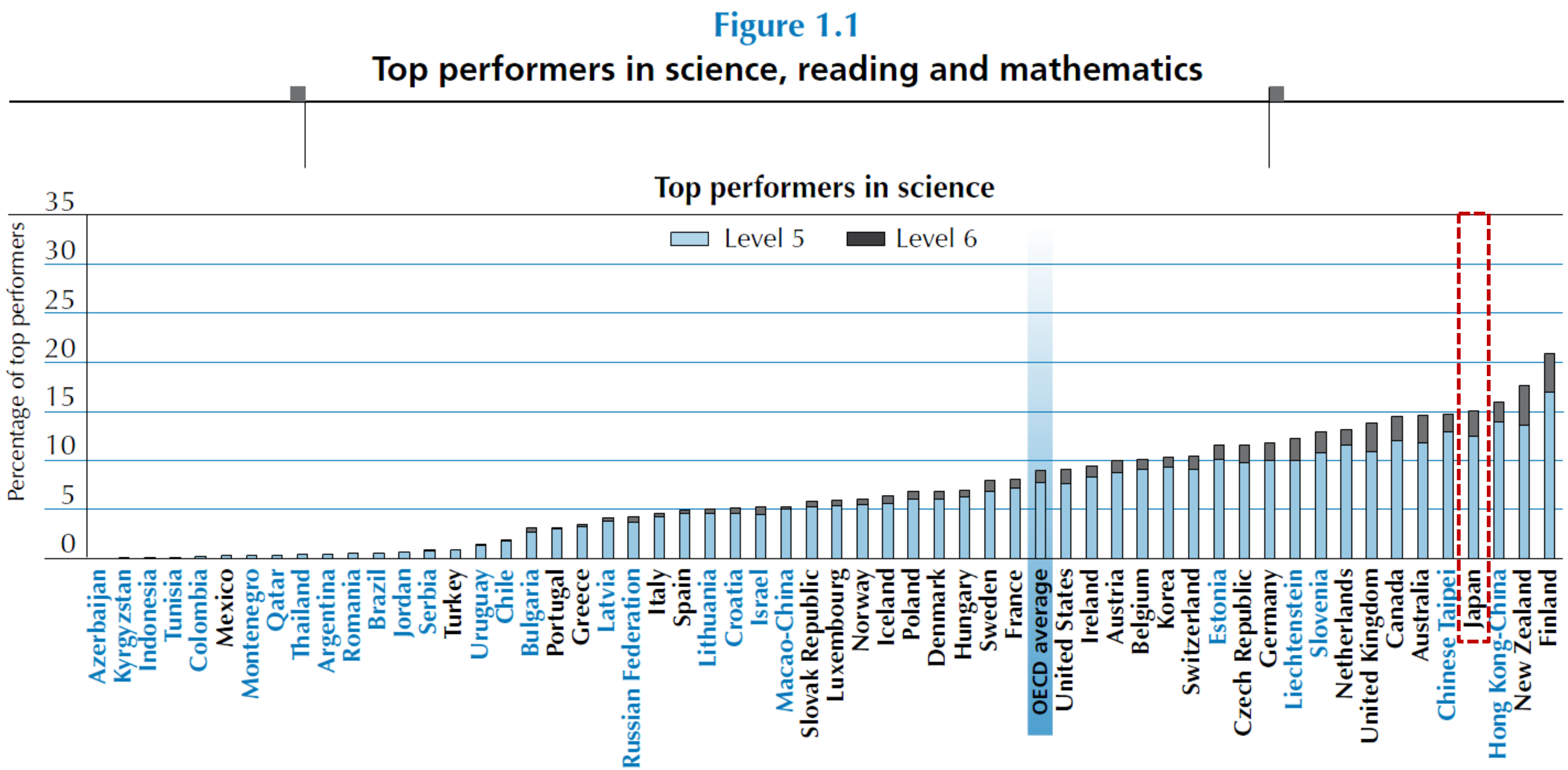
Science score-point difference associated with one calendar year



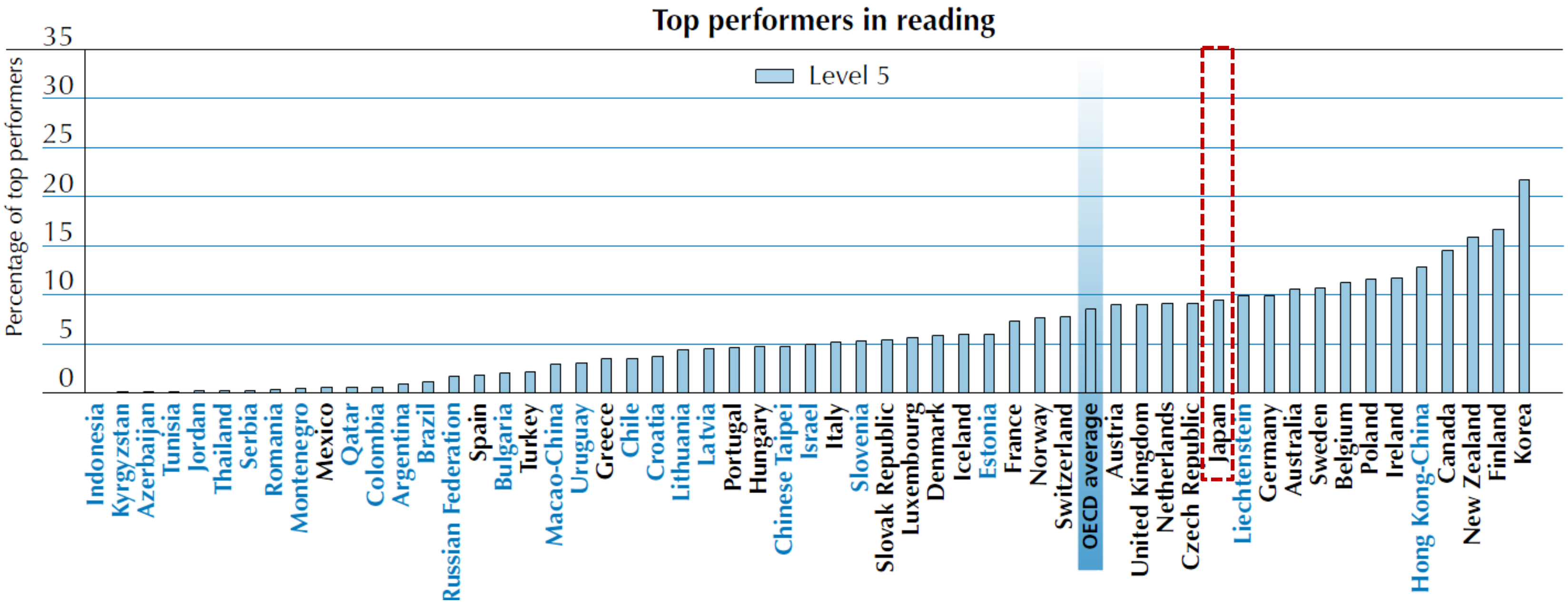
* United Arab Emirates excluding Dubai.

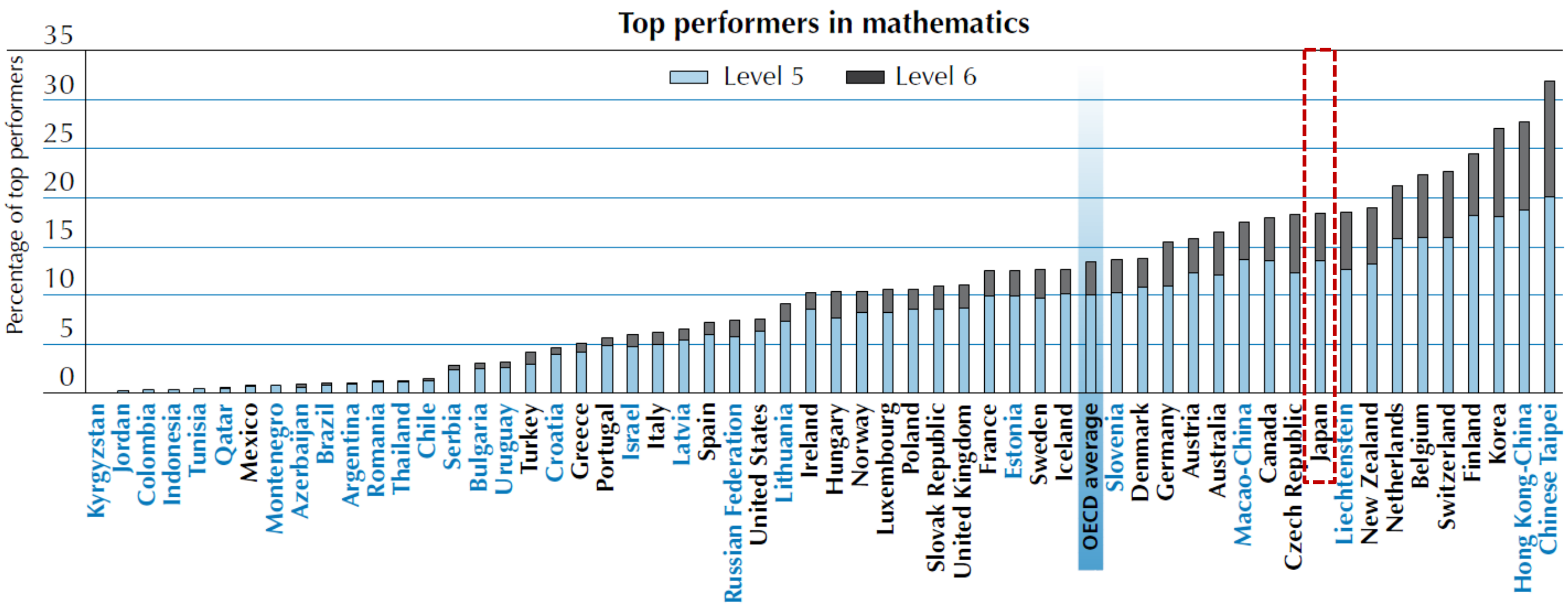
Source: PISA 2012 Results: What Students Know and Can Do Student Performance in Mathematics, Reading and Science (Volume I)

PISA 2006 Results



Source: Top of the Class - High Performers in Science in PISA 2006

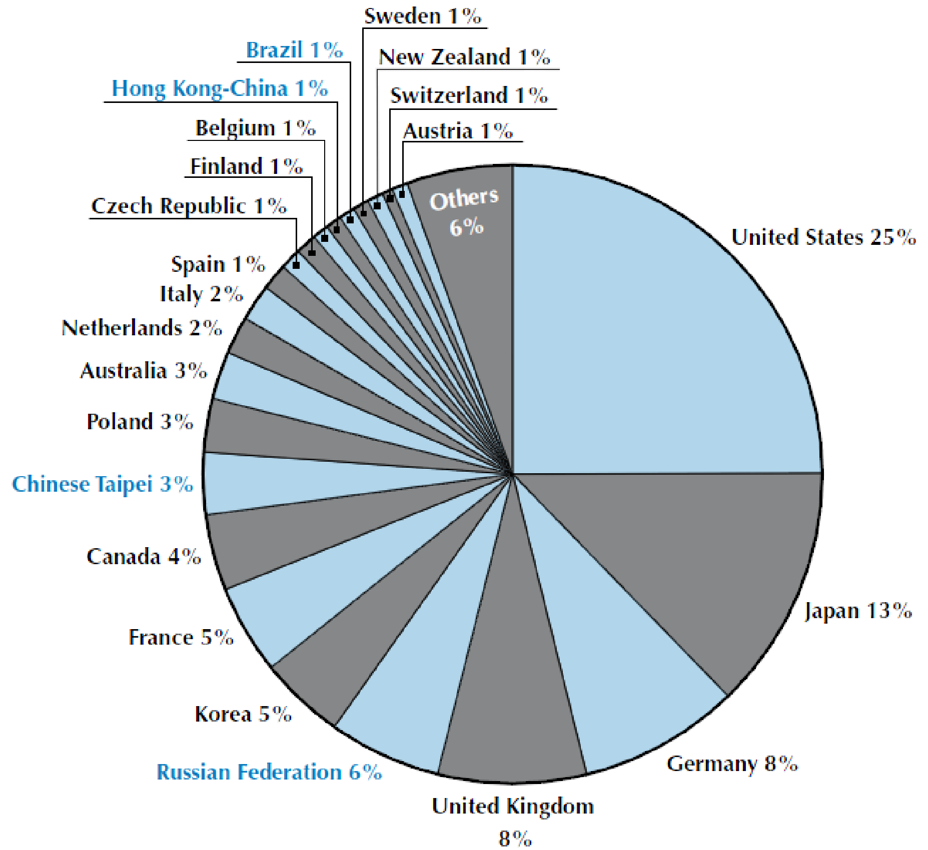




Source: Top of the Class - High Performers in Science in PISA 2006

Figure 1.2
The global talent pool: a perspective from PISA

Percentage of top performers across all PISA countries and economies

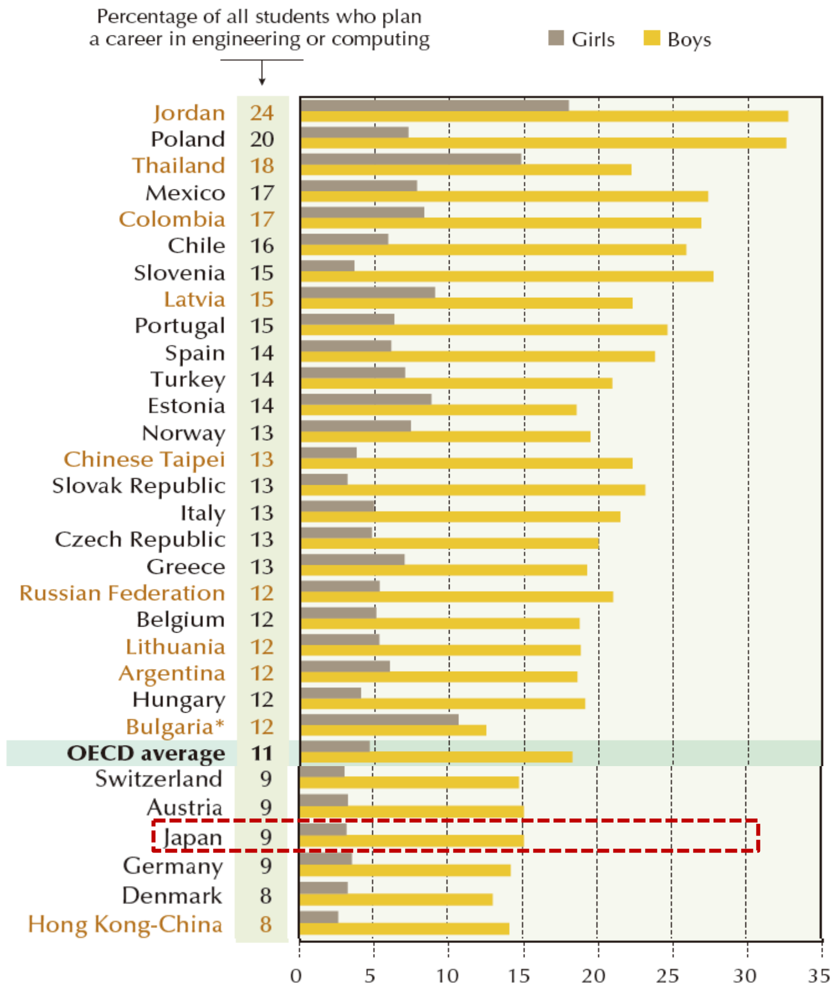


Note: "Others" includes countries that account for 0.5% or less: Hungary, Turkey, Ireland, Israel, Chile, Slovak Republic, Denmark, Norway, Mexico, Greece, Portugal, Slovenia, Thailand, Lithuania, Argentina, Croatia, Bulgaria, Estonia, Latvia, Romania, Colombia, Indonesia, Serbia, Jordan, Uruguay, Macao-China, Iceland, Luxembourg, Tunisia, Liechtenstein, Qatar, Azerbaijan, Kyrgyzstan, Montenegro.

Source: *OECD PISA 2006 Database.*

Source: Top of the Class - High Performers in Science in PISA 2006

Proportion of boys and girls planning a career in engineering or computing



Note: Countries are ranked in descending order of the percentage of all students who plan a career in engineering or computing (including architecture).

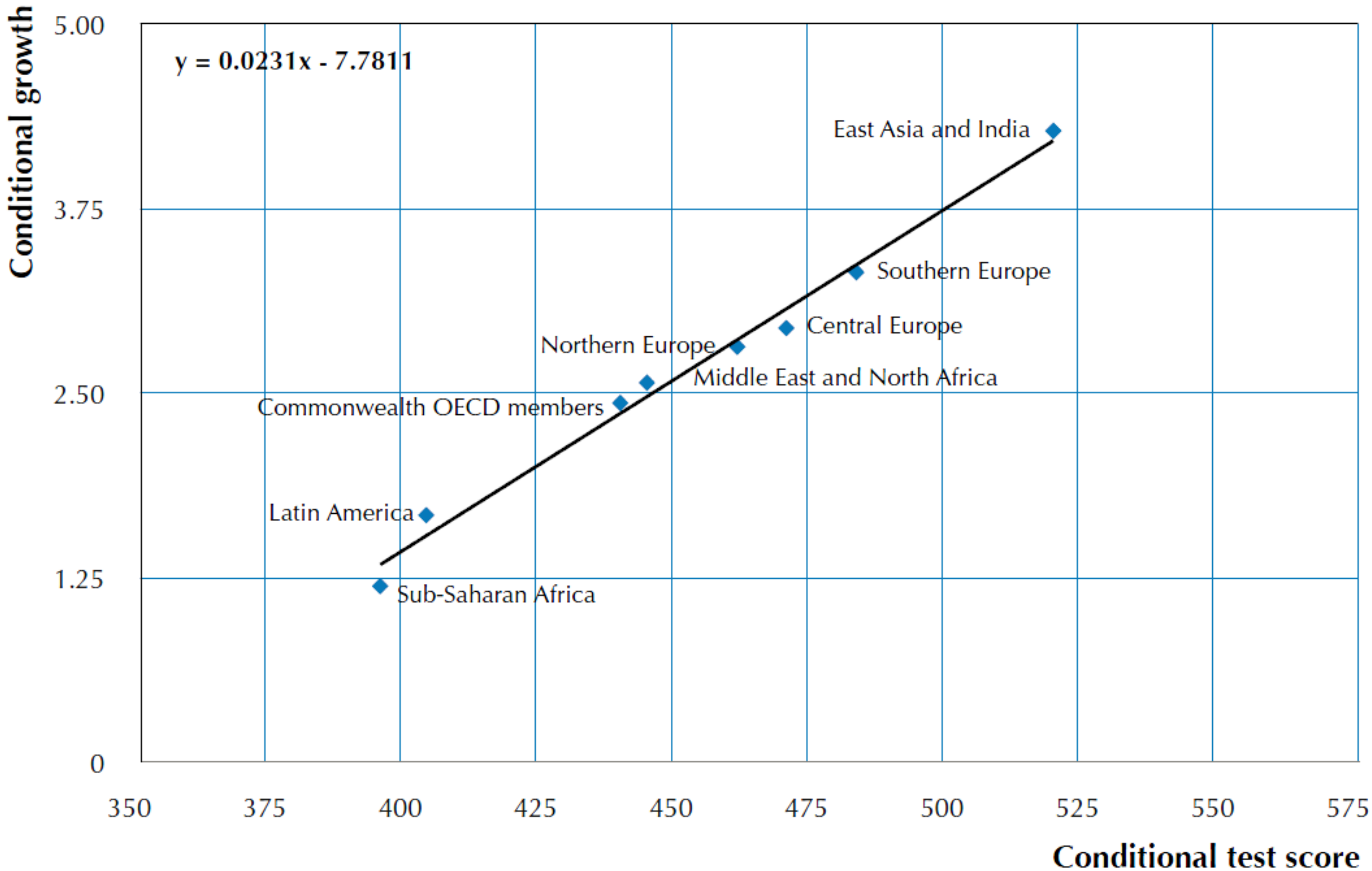
Countries in which gender differences are not statistically significant are shown with an asterisk.

Source: OECD, *PISA 2006 Database*.

Source: What Kinds of Careers Do Boys and Girls Expect for Themselves? PISA in Focus. No. 14

Figure 6

Educational performance and economic growth across world regions

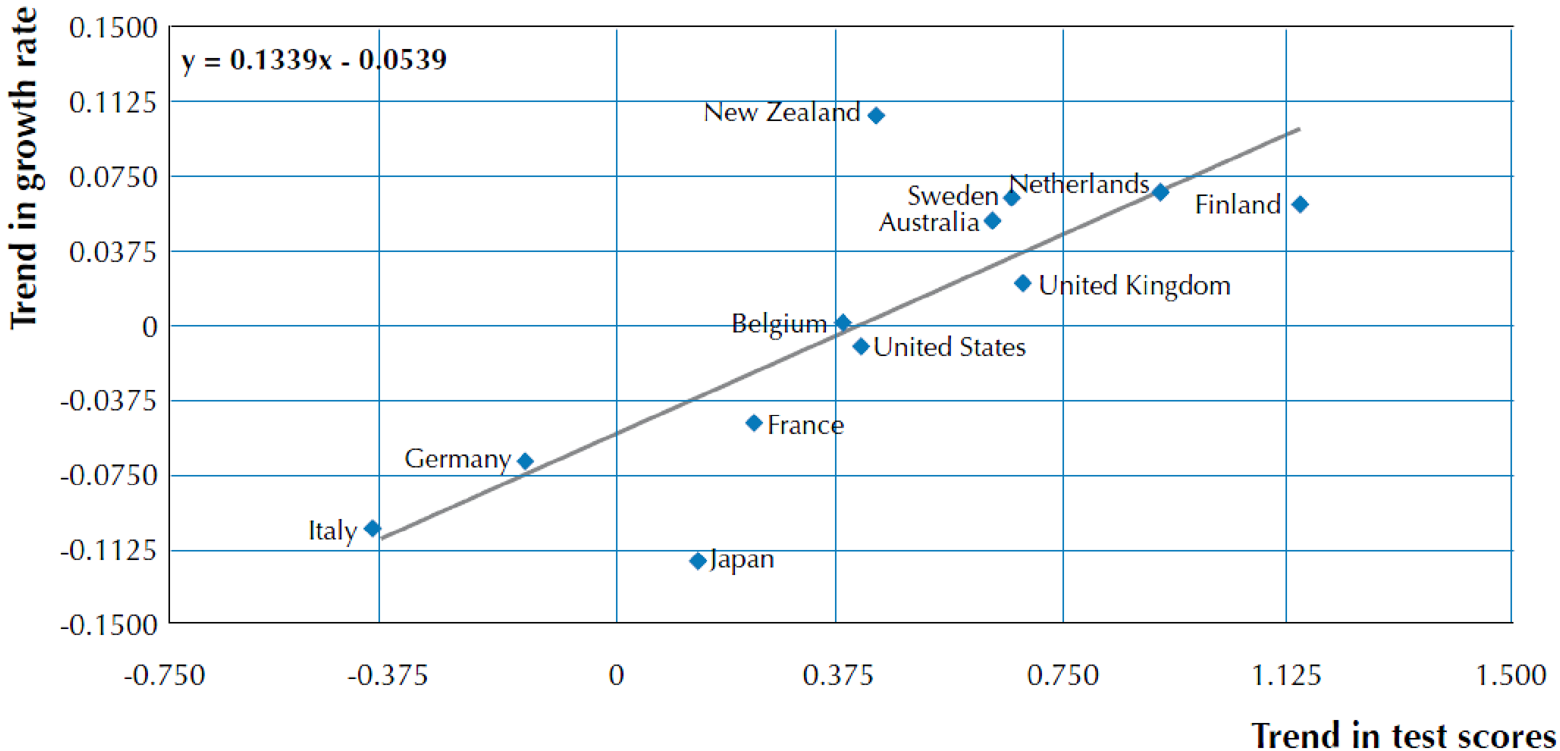


Notes: Added-variable plot of a regression of the average annual rate of growth (in percentage) of real GDP per capita in 1960-2000 on the initial level of real GDP per capita in 1960 and average test scores on international student achievement tests (mean of the unconditional variables added to each axis). Own depiction based on the database derived in Hanushek and Woessmann (2009).

Source: The High Cost of Low Educational Performance The Long-Run Economic Impact of Improving PISA Outcomes

Figure 8

Trends in educational performance and trends in economic growth rates



Notes: Scatter plot of trend in the growth rate of GDP per capita from 1975 to 2000 against trend in test scores for countries whose test scores range back before 1972. Own depiction based on the database derived in Hanushek and Woessmann (2009).

Source: The High Cost of Low Educational Performance The Long-Run Economic Impact of Improving PISA Outcomes