1

PISA 2006 and Students' Performance in Environmental Science and Geoscience

GREEN AT FIFTEEN? – ISBN 978-92-64-06129-3 – © OECD 2009

INTRODUCTION

Never have the stakes been so high for the role of science education in shaping how people interact with the earth and its environment. The rising importance of the environment as a scientific and public policy topic over the past fifty years has been built around a framework stressing the functional interdependencies between human life and the natural environment. As science about the environment generates even more knowledge, increasingly large proportions of the world's population are challenged to understand and use this knowledge (Kastens and Turrin, 2006; NAS, 2007; Bybee, 2008).

Human activities such as the accumulation of waste, fragmentation or destruction of ecosystems, and depletion of resources have had a substantial impact on the global environment. The *OECD Environmental Outlook to 2030* (OECD, 2008a) identifies climate change, biodiversity loss, ensuring clean water and adequate sanitation for all, and reducing the health impacts of environmental degradation as some of the main global environmental challenges.

Estimates of the costs of inaction on air pollution, for example, are high and include significant impacts on human health (*e.g.* respiratory illnesses), economic productivity (reduced agricultural yields, polluted freshwater sources, loss of biodiversity) as well as material damages (*e.g.* heritage damage from acid rain). Species loss can also incur direct economic costs, as seen in the collapse of fish stocks in the North Atlantic (OECD, 2008b). Water shortages and lack of sanitation affect an important part of the world population. Out of the approximately 6.5 billion people on earth, 1.1 billion do not have access to potable water and 2.6 billion people do not have access to improved sanitation. By 2030, the number of people living under severe water stress is expected to increase by more than 1 billion to 3.9 billion people, nearly half the projected world population (OECD, 2009, OECD, 2008a).

In some areas progress has been achieved in recent years, but remaining challenges are a cause for concern. For example, OECD countries have made significant progress to "decouple" toxic air emissions from economic growth in recent decades. Despite the decrease in air emissions per unit of GDP, total emissions from transport remain high and air quality standards have not been met in many parts of the OECD, particularly in urban areas (OECD, 2008c). Good progress has also been made in establishing protected areas, which amount to nearly 17% of total area in OECD countries, up from 14% at the beginning of the decade. However, the share of plants and animals classified as endangered species continues to increase, and the total number of vertebrates in the wild continues to decline in almost all OECD countries (OECD, 2008c).

While discussions over accountability and solutions for major problems associated with environmental issues are ongoing, the role of educated communities in an effort to protect the environment is more straightforward to establish (NSF, 2000). Well-trained geoscientists, biologists, environmental scientists, and environmental policy-makers can play an important role in confronting environmental challenges in every country. Equally important are informed and motivated citizens that understand and can interpret sophisticated scientific theory and evidence and act upon this knowledge.

Of particular importance is learning at an early age, as it can shape the way people approach and interact with the environment that surrounds them. Furthermore, what students learn in school can also impact an entire household; for example, students who learn about recycling can change the habits of their family.

Therefore, those involved in the development of curriculum policy, teacher education, and science education can benefit from a better understanding of what students know about the environment and what their attitudes are towards environmental issues. How much do young adults, at 15 years of age – and therefore approaching the end of compulsory schooling – know about the earth's environment as they face a future in which

achieving planet-wide environmental sustainability is one of the biggest challenges for their generation? How much of what they have learned from school and elsewhere can be applied to this challenge? And what are their attitudes towards specific environmental topics and related socio-economic issues?

In 2006, the Programme for International Student Assessment (PISA) of the Organisation for Economic Co-operation and Development (OECD) conducted a major study on science knowledge and skills in nearly 60 countries. Focusing on young people's ability to use their knowledge and skills to meet real-life challenges, PISA tests students in three domains (reading, mathematics and science) and takes place every three years, with special attention being paid to one of the domains each time. The first study, which took place in 2000, focused on reading literacy. In 2003, PISA concentrated on mathematics literacy, while in 2006 the emphasis was on science. Its initial report, *PISA 2006 Science Competencies for Tomorrow's World* (OECD, 2007), summarised 15-year-old students' competencies across a wide range of scientific knowledge and skills.

This report examines the evidence in PISA 2006 on what 15-year-olds understand about those aspects of science most closely related to the earth's environment, including long-term environmental sustainability, as well as their interest in, awareness of, and opinions about specific environmental issues worldwide. It summarises what students know about the environment and environment-related issues, from where and how this knowledge is gained, the attitudes students have about environmental issues and how the answers to these questions vary according to the characteristics of students and schools.

THE PROGRAMME FOR INTERNATIONAL STUDENT ASSESSMENT (PISA)

PISA, an overview

PISA is a comprehensive and rigorous international programme that assesses student performance and collects data on student, family and institutional factors that can help explain variations in performance. Decisions about the scope and nature of the assessments and background information are made by leading experts in participating countries and steered jointly by governments on the basis of shared policy-driven interests. Substantial efforts and resources are devoted to achieving cultural and linguistic breadth and balance in the assessment materials. Stringent quality assurance mechanisms are applied in translation, sampling and data collection. As a consequence, the results of PISA have a high degree of validity and reliability, and can significantly improve understanding of the outcomes of education in the world's most economically developed countries, as well as in a growing number of countries in their earlier stages of economic development.

Key features of PISA are:

- *Policy orientation,* with the design and reporting methods determined by the goal of informing policy and practice.
- *Innovative approach to "literacy",* which is concerned with the capacity of students to use what they have learned and to analyse and reason as they pose, solve and interpret problems in a variety of situations.
- *Relevance to lifelong learning,* which allows PISA to not only assess students' knowledge and skills, but also understand students' motivations to learn, beliefs about themselves and attitudes towards what they are learning.
- *Regularity,* enabling countries to monitor improvements in educational outcomes in the light of other countries' performances.
- *Consideration of student performance alongside characteristics of students and schools,* in order to explore some of the main features associated with educational success.

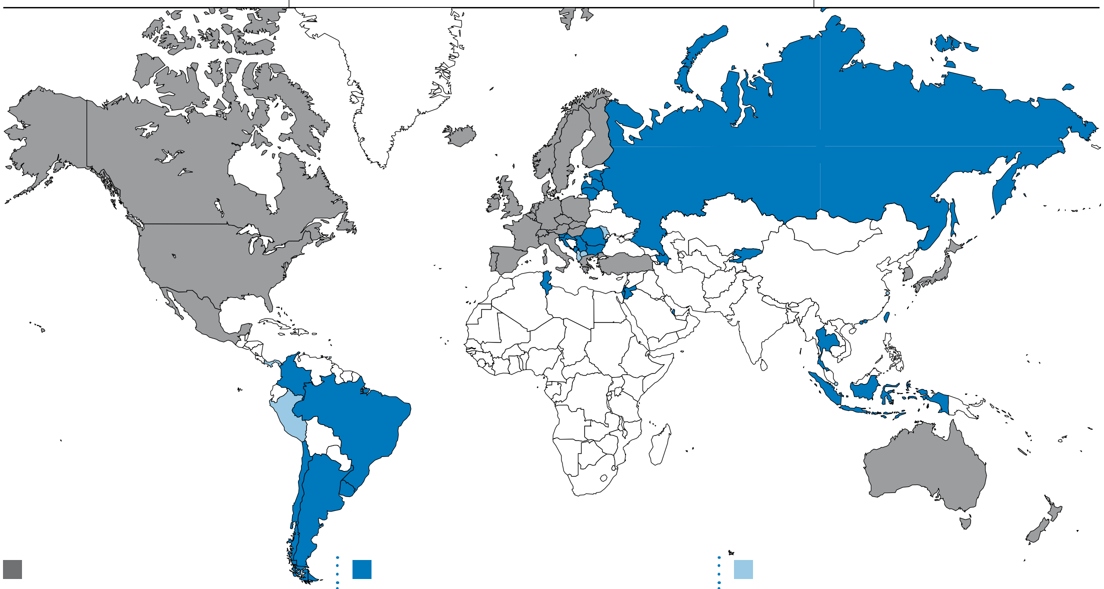
- *Breadth of geographical coverage,* with the 57 countries participating in the PISA 2006 assessment representing almost nine-tenths of the world economy. Nationally representative samples were drawn, representing 20 million 15-year-olds.

Three PISA surveys have taken place so far, in 2000, 2003 and 2006, focusing on reading, mathematics and science, respectively, but with each domain assessed to some extent in each turn. This sequence will be repeated with surveys in 2009, 2012 and 2015, allowing continuous and consistent monitoring of educational outcomes. Figure 1.1 shows the participating countries and economies in PISA.

Some key innovations of PISA 2006 are related to the environment:

- A profile of student performance in science including environmental science and geoscience.
- Measures of students' attitudes towards learning science and towards environmental issues.
- Measures of school contexts, instruction and activities that promote learning about environmental issues, and parental perceptions of environmental issues.

Figure 1.1
A map of PISA countries and economies



OECD countries

Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Finland
France
Germany
Greece
Hungary
Iceland
Ireland
Italy
Japan
Korea
Luxembourg
Mexico
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

Partner countries and economies in PISA 2006

Argentina
Azerbaijan
Brazil
Bulgaria
Chile
Colombia
Croatia
Estonia
Hong Kong-China
Indonesia
Israel
Jordan
Kyrgyzstan
Latvia
Liechtenstein
Lithuania
Macao-China
Montenegro
Qatar
Romania
Russian Federation
Serbia
Slovenia
Chinese Taipei
Thailand
Tunisia
Uruguay

Partner countries and economies in previous PISA surveys or in PISA 2009

Albania
Shanghai-China
Former Yugoslav Republic of Macedonia
Moldova
Panama
Peru
Singapore
Trinidad and Tobago

GREEN AT FIFTEEN? – ISBN 978-92-64-06129-3 – © OECD 2009

The value of PISA in monitoring performance over time is growing, although it is not yet possible to assess to what extent the observed differences are indicative of longer-term trends. With science being the main assessment area for the first time, results in PISA 2006 provide the baseline for future measures of change in this subject.

Focus on students' science performance

With more than one half of the assessment time devoted to science, PISA 2006 can report in much greater detail on science performance than was the case in PISA 2000 and PISA 2003. As well as calculating overall performance scores, it is possible to report separately on different science competencies and establish for each performance scale conceptually grounded proficiency levels that relate student performance scores to what students are typically able to do. Students received scores for their capacity in each of the three science competencies (*identifying scientific issues, explaining phenomena scientifically* and *using scientific evidence*). Estimates were also obtained at the country level for students' *knowledge about science* (*i.e.* their knowledge of the processes of science as a form of enquiry) and *knowledge of science* (*i.e.* their capacity in the science content areas of "Earth and space systems", "Physical systems" and "Living systems").

ENVIRONMENTAL SCIENCE EDUCATION: A CONCEPTUAL FRAMEWORK

One of the main challenges of environmental discourses is to define environmental science and subsequently policies, programmes, and practices for environmental science education. People frequently use environmental education to describe what could also be designated as "environmental information". This includes information that can be acquired from the media, through advertisements, or even in simple story books. Science education, in some instances, can also provide environmental information without necessarily providing environmental education. This section presents a definition of environmental science education that serves as the conceptual basis for this report.

A well-established definition of environmental education was set by Hines, Hungerford and Tomera (1986-87), who stated that environmental education is more than just mere transfer of information. It involves four aspects: a working knowledge of environmental issues, a specific knowledge of approaches to address those issues, the competency to make appropriate decisions, and the possession of certain affective qualities and attitudes that make people care about and pay more attention to environmental conditions.

In 1994, the North American Association for Environmental Education provided a definition of environmental science education that expanded the four aspects used by Hines *et al.* into: environmental and socio-political knowledge, knowledge of environmental issues, cognitive skills and affective qualities, and environmentally responsible behaviour.

More recently, Coyle (2005) equated information to awareness and stated that environmental education "involves a sequenced series of steps that results in a thorough understanding of the subject and its dynamics, including developing skills and learning how to apply them in a real world setting". Coyle (2005) classified environmental awareness into three categories: simple awareness (just knowing of the existence of the issues); personal conduct knowledge (understanding the easy concepts and global ideas); and environmental science literacy (understanding the underlying scientific principles, the skills needed to investigate the subject, and how to use those principles and skills). In this definition, environmental science literacy is considered the highest level outcome of environmental education.

This report describes an empirical approach to measuring aspects of environmental science literacy through an index using PISA 2006 data. The report also includes an in-depth description of a relevant subfield of environmental sciences: Geoscience. A major component of environmental sciences, geoscience focuses

on the structures of earth systems (*e.g.* lithosphere, atmosphere, hydrosphere), energy in earth systems (*e.g.* sources, global climate), change in earth systems (*e.g.* plate tectonics, geochemical cycles, constructive and destructive forces), earth in space (*e.g.* gravity, solar systems), and earth's history (*e.g.* fossils, origin and evolution). The report presents an index of geoscience performance to provide a deeper understanding of environmental science education within a specific context for countries that participated in PISA 2006.

ENVIRONMENTAL SCIENCE PERFORMANCE IN PISA 2006

The development of the PISA 2006 science framework was guided by reference to what science knowledge and skills citizens require (OECD, 2006). Consistent with this guiding principle, the international group of science experts that was appointed by OECD governments decided to include aspects of environmental science and geoscience in the assessment framework. Science knowledge and skills in PISA 2006 are broadly defined in terms of competencies, contexts, knowledge and attitudes. While this framework did not identify environmental science as a subfield in itself, the content and contexts of some of the PISA tasks are drawn from environmental issues.

In terms of *knowledge of science*, the framework identified four categories: "Physical systems", "Living systems", "Earth and space systems" and "Technology systems". Table 1.1 sets out the contents of the four knowledge of science categories, highlighting examples relevant to the environment. For instance, conservation is mentioned in the "Physical systems" category while sustainability occurs within "Living systems" and global climate within "Earth and space systems".

Table 1.1
PISA 2006 knowledge of science categories

Physical systems
Structure of matter (*e.g.* particle model, bonds)
Properties of matter (*e.g.* changes of state, thermal and electrical conductivity)
Chemical changes of matter (*e.g.* reactions, energy transfer, acids/bases)
Motions and forces (*e.g.* velocity, friction)
Energy and its transformation (*e.g. conservation,* dissipation, chemical reactions)
Interactions of energy and matter (*e.g.* light and radio waves, sound and seismic waves)
Living systems
Cells (*e.g.* structures and function, *DNA,* plant and animal)
Humans (*e.g.* health, nutrition, subsystems [*i.e.* digestion, respiration, circulation, excretion, and their relationship], disease, reproduction)
Populations (*e.g.* species, evolution, *biodiversity, genetic variation*)
Ecosystems (*e.g.* food chains, matter and energy flow)
Biosphere (*e.g.* ecosystem services, *sustainability*)
Earth and space systems
Structures of the Earth systems (*e.g. lithosphere, atmosphere, hydrosphere*)
Energy in the Earth systems (*e.g.* sources, *global climate*)
Change in Earth systems (*e.g.* plate tectonics, geochemical cycles, constructive and destructive forces)
Earth's history (*e.g.* fossils, origin and evolution)
Earth in space (*e.g.* gravity, solar systems)
Technology systems
Role of science-based technology (*e.g.* solve problems, help humans meet needs and wants, design and conduct investigations)
Relationships between science and technology (*e.g.* technologies contribute to scientific advancement)
Concepts (*e.g.* optimisation, trade-offs, cost, risk, benefit)
Important principles (*e.g.* criteria, constraints, innovation, invention, problem solving)

Note: Examples of environment-related topics are in italics.

In terms of contexts, Table 1.2 outlines the issues identified in the PISA 2006 science framework. These context areas were chosen because of their relevance to students' interests and lives.

Table 1.2
Contexts for the PISA 2006 science assessment

	Personal (self, family and peer groups)	**Social** (the community)	**Global** (life across the world)
Health	maintenance of health, accidents, nutrition	control of disease, social transmission, food choices, community health	*epidemics,* spread of infectious diseases
Natural resources	personal *consumption* of materials and energy	maintenance of human populations, quality of life, security, production and distribution of food, energy supply	renewable and non-renewable, *natural systems,* population growth, *sustainable use of species*
Environmental quality	*environmentally friendly behaviour, use and disposal of materials*	*population distribution, disposal of waste, environmental impact, local weather*	*biodiversity, ecological sustainability, control of pollution, production and loss of soil*
Hazard	natural and human-induced, decisions about housing	rapid changes [earthquakes, severe weather], slow and progressive changes (*coastal erosion, sedimentation*), risk assessment	*climate change,* impact of modern warfare
Frontiers of science and technology	interest in science's explanations of natural phenomena, science-based hobbies, sport and leisure, music and personal technology	new materials, devices and processes, *genetic modification,* weapons technology, transport	*extinction of species,* exploration of space, origin and structure of the universe

Note: Examples of environment-related topics are in italics.

This report focuses on how students performed in answering the PISA science questions that were related to environmental science and geoscience. While as noted above, a broad definition of environmental science education includes both knowledge and attitudes towards the environment, the latter are not used in the development of the environmental science or geoscience performance indices nor in any other of the established PISA performance scales. Only PISA science test assessment questions relating to environmental science and geoscience were included in the computation of these indices.

The PISA 2006 science framework did not identify an independent conceptual basis for analysing environmental science or geoscience with PISA data. Rather, the performance measures presented in this report were established *post-hoc* through additional analyses of the PISA data. To distinguish these performance measures from the established PISA science, reading and mathematics literacy scales that were established in the assessment and formally adopted by participating countries, the report uses the term index for the environmental science and geoscience performance measures.

ORGANISATION OF THIS REPORT

The report presents an assessment of students' performance on environmental science and geoscience as well as information on their attitudes toward the environment, using data from PISA 2006. It also reports on the sources of students' knowledge and on the factors associated with student performance.

Chapter 2 provides an overview of students' performance across the 57 countries that took part in PISA 2006 in both environmental science and geoscience. It also studies the relationships between performance and students' socio-economic and other family characteristics.

Chapter 3 analyses 15-year-olds' attitudes toward the environment and compares them across countries. It provides an overview of the relationship between students' and parents' attitudes toward environmental issues. The chapter also describes the association of attitudes and performance in environmental science.

The sources of environmental knowledge and ways this knowledge is delivered in schools are discussed in Chapter 4. The chapter also reviews the association of these variables and performance in environmental science.

Table of contents

GREEN AT FIFTEEN? – ISBN 978-92-64-06129-3 – © OECD 2009

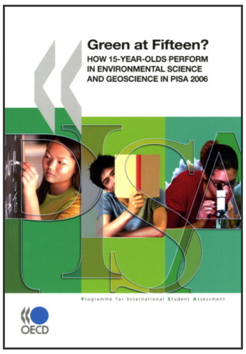
GREEN AT FIFTEEN? – ISBN 978-92-64-06129-3 – © OECD 2009

LIST OF BOXES

LIST OF FIGURES

LIST OF TABLES

GREEN AT FIFTEEN? – ISBN 978-92-64-06129-3 – © OECD 2009



From:

Green at Fifteen?

How 15-Year-Olds Perform in Environmental Science and Geoscience in PISA 2006

Access the complete publication at:
https://doi.org/10.1787/9789264063600-en

Please cite this chapter as:

OECD (2009), “PISA 2006 and Students' Performance in Environmental Science and Geoscience”, in *Green at Fifteen?: How 15-Year-Olds Perform in Environmental Science and Geoscience in PISA 2006*, OECD Publishing, Paris.

DOI: https://doi.org/10.1787/9789264063600-4-en

OECD