PISA 2006 SCIENTIFIC LITERACY FRAMEWORK

1. An understanding of science and technology is central to a young person's "preparedness for life" in modern society. It enables an individual to fully participate in a society in which science and technology play a significant role. This understanding also empowers individuals to participate appropriately in the determination of public policy where issues of science and technology impact on their lives. An understanding of science and technology contributes significantly to the personal, social, professional and cultural lives of all people.

2. A large proportion of the situations, problems, and issues, encountered by individuals in their daily lives require some understanding of science and technology before they can be fully appreciated, understood or addressed. Science and technology-related issues confront individuals at personal, community, national and even global levels, and as such national leaders should be encouraged to ask about the degree to which citizens in their respective countries are prepared to deal with these issues. Perhaps an even more important question is, how do students respond to such issues at age 15? An answer to this question provides an early indication of how they may respond in later life to the diverse array of life situations that involve science and technology.

3. As the basis for an international assessment of 15-year-olds, it seems reasonable, therefore, to ask: *What is important for citizens to know, value, and be able to do in situations involving science and technology*? This question is central to the PISA 2006 Scientific Literacy Framework. Answering the question establishes the basis for an assessment of what 15-year old students should know, value, and be able to do in situations involving science and technology.

4. The issue of identifying what citizens should know, value, and be able to do in situations involving science and technology, seems simple and direct. Addressing the issue opens the realms of scientific understanding, but it also indicates a qualifier – citizens. As citizens, what knowledge is most appropriate? An answer to this question certainly includes basic concepts of the science disciplines, but that knowledge must be *used* in contexts individuals encounter in life. In addition, people often

encounter situations that require some understanding of science as a discipline – that is, as a process that produces knowledge and that proposes explanations about the natural world. Further, they should be aware of the complementary relationships between science and technology, and how science-based technologies pervade and influence the nature of modern life.

5. What is important for citizens to value about science and technology? Perhaps an answer includes the role and contributions to society of science, and of technology as applied science, and their importance in many personal, social, and global contexts. Accordingly, it seems reasonable to expect citizens to have an interest in science, to support the process of scientific enquiry, and to act responsibly towards natural resources and the environment.

6. What is it important for citizens to be able to do that is science related? People often have to draw appropriate conclusions from evidence and information given to them, they have to evaluate claims made by others on the basis of the evidence put forward, and they have to distinguish personal opinion from evidence-based statements. Science has a particular role to play here since it is concerned with rationality in testing ideas and theories against evidence. Of course this does not deny that science includes creativity and imagination, which have always played a central part in advancing human understanding of the world.

7. Can citizens distinguish claims of science from non-science claims? To be clear, ordinary citizens are generally not called on to judge the worth of major theories or potential advances in science. But they do make decisions based on the facts in advertisements, evidence in legal matters, information about their health, and issues concerning local environments and natural resources. An educated person should be able to distinguish the kinds of questions that can be answered by scientists, and the kinds of problems that can be solved by science-based technologies, from those that cannot be answered in these ways.

DEFINITION OF THE DOMAIN

8. Current thinking about the desired outcomes of science education emphasises knowledge of science (including scientific methodology) and an appreciation of science's contribution to society. These outcomes require a general understanding of important concepts and explanations of science, and of the strengths and limitations of science in the world. They imply a critical stance and reflective approach to science.

9. Such goals provide an orientation and emphasis for the science education of all people. The knowledge and skills assessed in PISA 2006 should be broad and include aspects of personal utility, social responsibility, and the intrinsic and extrinsic value of scientific knowledge.

10. The foregoing discussion frames a central point of the PISA 2006 science assessment: *The assessment should focus on what 15-year-olds should know, value, and be able to do within reasonable and appropriate personal, social, and global contexts*. This perspective differs from one grounded exclusively in school science programs and extensively based on the disciplines of science; but it includes educational and professional contexts, and recognises the essential place of the knowledge, methods, attitudes, and values that define scientific disciplines. The term that best describes the purposes of the PISA 2006 science assessment is *scientific literacy*.

11. PISA 2006 proposes to assess students' scientific knowledge, and their capacity to use this knowledge effectively, as they carry out certain cognitive processes that are characteristic of science and scientific enquiries of personal, social, or global relevance. In assessing scientific literacy, PISA is concerned with issues to which scientific knowledge can contribute and which will involve students, either now or in the future, in making decisions. From the point of view of their scientific literacy, students respond to such issues in terms of their understanding of relevant scientific knowledge, their ability to access and evaluate information, and interpret evidence, bearing on the issue, and their ability to identify the scientific and technological aspects of the issue. In addition to these cognitive aspects, students also respond affectively – attitudinal aspects of their response engage their interest,

sustain their support, and motivate them to take action. Through such considerations we are led to define the domain of scientific literacy for PISA 2006.

Scientific knowledge: PISA 2006 terminology

The term "scientific knowledge" is used throughout this Framework to refer collectively to both "knowledge *of* science" and "knowledge *about* science". "Knowledge *of* science" refers to knowledge of the natural world across the major fields of physics, chemistry, biological science, and Earth and space science. "Knowledge *about* science" refers to knowledge of the means (scientific enquiry) and goals (scientific explanations) of science, and of the nature of science and technology and their complementary roles in society.

12. The term "scientific literacy" has been chosen because it is recognised as representing the goals of science education that should apply to all students; it connotes a broadness and an applied nature to the purposes of science education; it represents a continuum of scientific knowledge and the cognitive abilities associated with scientific enquiry; it incorporates multiple dimensions; and, it includes the relationships between science and technology. Together, these qualities characterise a foundation for scientific literacy, and the objective of the PISA 2006 science assessment – to assess the degree to which these qualities have been developed.

13. For purposes of the PISA 2006, 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.

The following remarks further clarify this definition.

Scientific literacy…

14. Using the term “scientific literacy” rather than “science” underscores the concern in the PISA 2006 science assessment that the application of scientific knowledge in the context of life situations has greater emphasis and traditional school science has less emphasis. The functional use of knowledge requires the application of those processes that are characteristic of science and scientific enquiry (the scientific competencies) and is regulated by the individual’s appreciation, interest, values, and action relative to scientific matters. Of necessity, a student’s ability to carry out the scientific competencies involves both knowledge *of* science and an understanding of the characteristics of science as a way of acquiring knowledge (i.e., knowledge *about* science). The definition also recognises that the disposition to carry out these processes depends upon an individual’s attitudes toward science and a willingness to engage in science-related issues.

…knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence-based conclusions…

15. Knowledge for this definition of scientific literacy implies far more than the ability to recall information, facts, and names. The definition includes knowledge *of* science (knowledge about the natural world) and knowledge *about* science itself. The former includes understanding fundamental scientific concepts and theories; the latter includes understanding the nature of science as a human activity and the power and limitations of scientific knowledge. The questions to be identified are those that can be answered by scientific enquiry, again requiring knowledge *about* science as well as scientific knowledge *of* the specific topics involved. Of significant note for the definition of scientific literacy is the fact that individuals must often acquire knowledge that is new to them, not through their own scientific investigations, but through resources such as libraries and the internet. Drawing evidence-based conclusions means knowing, selecting, and evaluating information and data, while recognising that there is often not sufficient information to draw definite conclusions, thus making it necessary to speculate, cautiously and consciously, about the information that is available.

…characteristic features of science as a form of human knowledge and enquiry…

16. As expressed here, scientific literacy implies that students should have some understanding of how scientists obtain data and propose explanations, recognise key features of scientific investigations, and the types of answers one can reasonably expect from science. For example, scientists use observations and experiments to gather data about objects, organisms, and events in the natural and material world. The data are used to propose explanations that become public knowledge and may be used in various forms of human activity. Some key features of science include: its use of data – data collection is guided by ideas and concepts (sometimes stated as hypotheses), and includes issues of relevance, context and accuracy; the tentative nature of knowledge claims; an openness to sceptical review; the use of logical arguments; and, the obligation to make connections to current and historical knowledge, and to report the methods and procedures used in obtaining evidence.

…how science and technology shape our material, intellectual, and cultural environments…

17. The key points in this statement include the idea that science is a human endeavour, one that influences our societies and us as individuals. Further, technological development also is a human endeavour. Although science and technology are fundamentally different in their purposes, processes, and products, it is the case that they also are closely related and, in many respects, complementary. In this regard, the definition of scientific literacy proposed here includes the nature of science and of technology and their complementary relationships. As individuals we make decisions through public policies, for example, that influence the directions of science and technology. Science and technology play paradoxical roles in society as they propose answers to questions and provide solutions to problems, but may also create new questions and problems.

…willingness to engage in science-related issues, and with the ideas of science as a reflective citizen.

18. The meanings conveyed in the first part of this statement are wider than taking note and taking action as required; it implies having continuing interest in, having opinions about, and participating, in relation to current and future science-based issues. The second part of the statement covers various

aspects of attitudes and values that individuals may have towards science. The phrase implies a person who has an interest in scientific topics, thinks about science-related issues, has a concern for issues of technology, resources, and the environment, and reflects on the importance of science in personal and social perspectives.

19. It is inevitable that scientific literacy will also draw upon other literacies. For example, reading literacy will be necessary when a student is demonstrating an understanding of scientific terminology. Similarly, aspects of mathematics literacy will be required in data interpretation contexts. The intersection of various *other* literacies with the PISA 2006 definition and assessment of scientific literacy cannot be avoided; however, at the core of each assessment task there should be aspects that are unambiguously scientific literacy.

20. Compared to the definition of scientific literacy for PISA in 2000 and 2003, the definition for 2006 has been enhanced. For the previous two assessments, when it was a minor domain, scientific literacy was defined as follows:

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.

The initial assertions of the 2000/2003 and 2006 definitions are essentially the same. They centre on individuals' uses of scientific knowledge to draw conclusions. While the 2000 and 2003 definition embedded understandings about science within the terms of scientific knowledge, the 2006 definition separates and elaborates this aspect of scientific literacy through the addition of terms that underscore students' knowledge about the characteristic features of science. The next portion of both definitions suggests the application of scientific knowledge to understand, and ultimately to make informed decisions about, the natural and material world. In PISA 2006, this portion of the definition is enhanced by the addition of knowledge of the relationships between science and technology, an aspect of scientific literacy that was assumed but not elaborated in the earlier definition. In today's world, science and technology are closely linked, often having synergistic relationships with each other.

21. In contrast to the earlier definition, however, the PISA 2006 definition of scientific literacy has been expanded by including attitudinal aspects of students' responses to issues of scientific and technological relevance. In summary, the 2006 definition is conceptually the same as the 2000/2003 definition, with the exception of the addition of attitudinal responses. Other changes, for example clarifying the inclusion of knowledge *about* science, and technology, represent an increased emphasis on particular aspects that were embedded or assumed in the earlier definition.

ORGANISATION OF THE DOMAIN

22. The definition of scientific literacy proposed here provides for a continuum from less developed to more developed scientific literacy – that is, individuals are deemed to be more or less scientifically literate; they are not regarded as either scientifically literate or scientifically illiterate. So, for example, the student with less developed scientific literacy might be able to recall simple scientific factual knowledge and to use common scientific knowledge in drawing or evaluating conclusions. A student with more developed scientific literacy will demonstrate the ability to create or use conceptual models to make predictions or give explanations, to formulate and communicate predictions and explanations with precision, to analyse scientific investigations, to relate data as evidence, to evaluate alternative explanations of the same phenomena, and to communicate explanations with precision.

23. For purposes of assessment, the PISA 2006 definition of scientific literacy may be characterised as consisting of four interrelated aspects:

- Recognising life situations involving science and technology. This is the *context* for assessment.
- Understanding the natural world, including technology, on the basis of scientific knowledge that includes both knowledge *of* the natural world and knowledge *about* science itself. This is the *knowledge component* of the assessment.
- Demonstrating competencies that include identifying scientific questions, explaining phenomena scientifically, and drawing conclusions based on evidence. This is the *competency component*.

- Responding with an interest in science, support for scientific enquiry, and motivation to act responsibly toward, for example, natural resources and environments. This is the *attitudinal dimension* of the assessment.

This relationship is represented graphically in Figure 1.

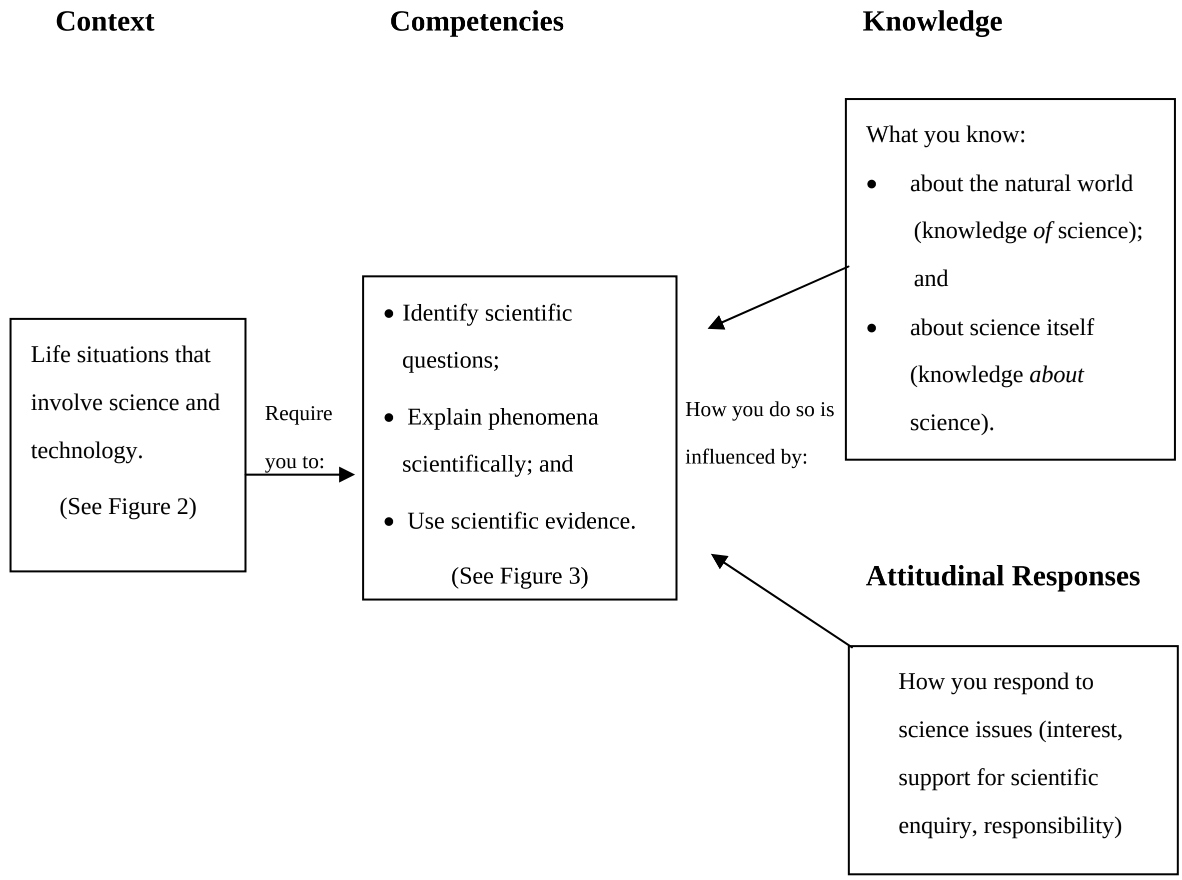

Figure 1. Framework for PISA 2006 science assessment

24. The following sections restate and elaborate the organising aspects of scientific literacy. In laying out these aspects, the PISA 2006 scientific literacy framework has ensured that the focus of the assessment is upon the outcomes of science education as a whole. Several questions, based on the perspective of scientific literacy lay behind the organisation of this section of the framework. They are:

What CONTEXTS would be appropriate for assessing 15-year-olds?

What COMPETENCIES would be appropriate for 15-year-olds?

What KNOWLEDGE might we reasonably expect 15-year-olds to demonstrate?

What ATTITUDES might we reasonably expect 15-year-olds to demonstrate?

CONTEXTS FOR ASSESSMENT ITEMS

25. PISA 2006 will assess important scientific knowledge relevant to the science education curricula of participating countries without being constrained to the common aspects of participants' national curricula. It will do this by requiring application of selected scientific knowledge, the use of scientific competencies, and an evaluation of attitudes, in important situations reflecting the world and in accordance with its focus on scientific literacy.

26. Assessment items will be framed in situations of general life and not limited to life in school. In the PISA 2006 science assessment, the focus of the items will be on situations relating to the self, family and peer groups(personal), to the community (social) and to life across the world (global). A further type of setting, appropriate to some topics, is the historical one, in which understanding of the advances in scientific knowledge can be assessed.

27. Figure 2 lists recommended applications of science, within personal, social, and global settings, for use as the contexts for assessment exercises. Other settings (e.g., historical) and areas of application may be used, however. The recommended applications are drawn from a wide variety of life situations and are generally consistent with the areas of application for scientific literacy in the 2000 and 2003 PISA frameworks. These areas of application are: health, natural resources, environmental quality, hazards, and the frontiers of science and technology. They are the areas in which scientific literacy has particular value for individuals and communities in enhancing and sustaining quality of life, and in the development of public policy.

Personal
➢ Health (e.g., maintenance of health, accidents, nutrition).

- Resources (e.g., personal consumption of materials and energy).
- Environment (e.g., environmentally friendly behaviour, use and disposal of materials).
- Hazards (e.g., natural and human-induced, decisions about housing).
- Frontiers (e.g., interest in science's explanations of natural phenomena, science-based hobbies, sport and leisure, music and personal technology).

Social

- Health (e.g., control of disease, social transmission, food choices, community health).
- Resources (e.g., maintain human populations, quality of life, security, production and distribution of food, energy supply).
- Environment (e.g., population distribution, disposal of waste, environmental impact, local weather).
- Hazards (e.g., rapid changes [earthquakes, severe weather], slow and progressive changes [coastal erosion, sedimentation], risk assessment).
- Frontiers (e.g., new materials, devices and processes, genetic modification, weapons technology, transport).

Global

- Health (e.g., epidemics, spread of infectious diseases).
- Resources (e.g., renewable and non-renewable, natural systems, population growth, sustainable use of species).
- Environment (e.g., biodiversity, ecological sustainability, control of pollution, production and loss of soil).
- Hazards (e.g., climate change, impact of modern warfare).
- Frontiers (e.g., extinction of species, exploration of space, origin and structure of the universe).

Figure 2. Recommended contexts for the PISA 2006 science assessment

28. The PISA science assessment is not an assessment of contexts. It will assess knowledge, competencies (including critical thinking skills) and attitudes as these are presented or relate to contexts. In selecting the contexts, it will be important to keep in mind that the purpose of the assessment is to assess scientific understandings, abilities, and attitudes that students have acquired by the end of the compulsory years of schooling, and that the contexts chosen can affect the fairness of the assessment.

29. In an international study, the contexts used for assessment items should be chosen in the light of relevance to students' interests and lives. Sensitivity to linguistic and cultural differences is a priority in item development and selection, not only for the sake of the validity of the assessment, but to respect these differences in participating countries. In developing an international test it is not possible, however, to include the differences in traditional and local knowledge about natural phenomena that exist among groups in the participating countries. This is not to deny the contribution such knowledge can and has made to the respective cultures.

SCIENTIFIC COMPETENCIES

30. The PISA 2006 science assessment gives priority to the competencies listed in Figure 3: the ability to identify scientifically-oriented questions; describe, explain, or predict phenomena based on scientific knowledge; interpret evidence and conclusions; and use evidence to make and communicate decisions. These competencies involve scientific knowledge – both knowledge *of* science and knowledge *about* science.

Scientific competencies – the role of scientific knowledge

The use of scientific knowledge, both knowledge *of* science and knowledge *about* science, is a fundamental characteristic of **each** of the three scientific competencies – not only of "Explaining phenomena scientifically". If the focus of an item is the understanding of a given scientific enquiry, or the interpretation of evidence that is provided in the unit, then "Explaining phenomena scientifically" is **not** the appropriate competency classification. "Explaining phenomena scientifically" applies when the main focus and cognitive demand of the item is the application of scientific knowledge to describe, explain or predict.

Identifying Scientific Questions
➢ Recognising questions that it is possible to investigate scientifically. ➢ Identifying keywords to search for scientific information. ➢ Recognising the key features of a scientific investigation.
Explaining phenomena scientifically

- Applying knowledge *of* science or knowledge *about* science in a given situation.
- Describing or interpreting phenomena scientifically and predicting changes
- Identifying appropriate descriptions, explanations and predictions.

Using Scientific Evidence

- Interpreting scientific evidence and making conclusions.
- Giving reasons for or against conclusions and identifying assumptions made in reaching conclusions.
- Communicating conclusions and the evidence and reasoning behind them.

Figure 3. PISA 2006 scientific competencies

31. Some cognitive processes have special meaning and relevance for scientific literacy. Among the cognitive processes that are implied in the scientific competencies are: inductive/deductive reasoning, critical and integrated thinking, transforming representations (e.g., data to graphs, tables), constructing explanations based on data, thinking in terms of models, and using mathematics.

32. Justification for an emphasis on the scientific competencies of Figure 3 rests on the importance of these competencies for scientific enquiry. These abilities are grounded in logic, reasoning, and critical analysis. An elaboration of the scientific competencies for PISA 2006 follows.

IDENTIFYING SCIENTIFIC QUESTIONS

33. The essential feature here is discriminating scientific questions from other forms of questions. Importantly, scientific questions must lend themselves to answers based on scientific evidence. This includes recognising questions that it would be possible to investigate scientifically in a given situation, and identifying keywords to search for scientific information on a given topic. It also includes recognising key features of a scientific investigation: for example, what things should be compared, what variables should be changed or controlled, what additional information is needed, or what action should be taken so that relevant data can be collected?

"Identifying scientific questions" example item[1]

Question 5: 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. Why was the victim stabbed many times?

C. Is taking cheek scrapings a safe way to collect DNA samples?

D. Do all identical twins have exactly the same DNA profile?

EXPLAINING PHENOMENA SCIENTIFICALLY

34. Students demonstrate this competency by applying appropriate knowledge *of* science and/or knowledge *about* science in a given situation. The competency includes describing or interpreting phenomena and predicting changes, and may involve recognising or identifying appropriate descriptions, explanations, and predictions.

"Explaining phenomena scientifically" example item

Question 4: SOLAR TOWER

Why is it proposed to have the water in bags rather than in a large pond open to the air?

USING SCIENTIFIC EVIDENCE

35. This competency requires students to make sense of scientific findings as evidence for claims or conclusions. It involves both knowledge *of* science and knowledge *about* science. It may involve accessing scientific information and producing conclusions based on scientific evidence. It may also involve: selecting from alternative conclusions in relation to evidence; giving reasons for or against a given conclusion in terms of the process by which the conclusion was derived from the data provided; identifying the assumptions made in reaching a conclusion; and, reflecting on the societal implications of scientific conclusions.

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[1] All example items are taken from the sample units that are contained in the Appendix.

36. This competency also requires students to express their evidence and decisions, through their own words, diagrams or other representations as appropriate, to a specified audience. In short, students should be able to present clear and logical connections between evidence and conclusions or decisions.

"Using scientific evidence" example item

Question 2: FLY SPRAY

Early in June, insecticide from the same batch was used to spray the flies in a pig shed on a second farm 100 kilometres away from the first farm. This spraying killed 98% of the flies at the second farm.

Does this evidence support the following conclusions? Circle "Yes" or "No" in each case.

Is this conclusion supported by the evidence?	**Yes or No?**
The insecticide has decomposed with age.	Yes / No
The insecticide has not decomposed with age.	Yes / No
The population of flies on the first farm has developed immunity.	Yes / No
The two populations of flies are of different species.	Yes / No

SCIENTIFIC KNOWLEDGE

37. Given that only a sample of students' knowledge *of* science can be assessed in the PISA 2006 science assessment, it is important that clear criteria are used to guide the selection of knowledge that will be assessed. Moreover, the objective of PISA is to describe the extent to which students can *apply* their knowledge in contexts of relevance to their lives. Accordingly, the knowledge that is assessed will be selected from the major fields of physics, chemistry, biological science, and Earth and space science, according to the following criteria:

- The first criterion centres on relevance to real-life situations. Scientific knowledge differs in the degree to which it is useful in the life of individuals.
- The second criterion is that the knowledge selected should represent important scientific concepts and thus have enduring utility.
- The third criterion is that the knowledge selected should be appropriate to the development level of 15-year-olds.

38. Figure 4 shows the outcome of applying these criteria to the content of the major fields of science. This knowledge is required for understanding the natural world and for making sense of experiences in personal, social, and global contexts. For these reasons the framework uses the term “systems” instead of “sciences” as descriptors of the major fields. The intention is to convey the idea that citizens have to understand concepts from the physical and life sciences, Earth science, and technology, in contexts that have components that interact in a more or less united way. That is, they have to apply scientific knowledge and deploy scientific competencies in considering contexts that can be viewed as systems. The examples listed in Figure 4 convey the meanings of the categories; there is no attempt to list comprehensively all the knowledge that could be related to each of the knowledge *of* science categories.

Physical Systems
➢ structure and properties of matter (e.g., thermal and electrical conductivity) ➢ physical changes of matter (e.g., states of matter, elements, bonds) ➢ 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)

Figure 4. PISA 2006 knowledge *of* science categories

"Living systems" example item

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 the blood that helps carry oxygen to all the tissues.

D. A hormone in blood that helps regulate glucose levels in the body cells.

39. As already noted, in addition to assessing students' knowledge *of* science, PISA 2006 will include assessments of students' knowledge and understanding of ideas *about* science, and of the interactions among science and technology and the material, intellectual, and cultural environments.

40. Figure 5 displays the categories and examples of content for knowledge *about* science. The first category, "Scientific Enquiry," centres on enquiry as the central process of science and the various components of that process. Next is a category closely related to enquiry, that of "Scientific Explanations." Scientific explanations are the results of scientific enquiry. One can think of enquiry and explanations as the means of science (how scientists *get* data) and the goals of science (how scientists *use* data), respectively. The third category, "Science and Technology in Society," requires the understanding and differentiation of science and technology as distinct yet complementary disciplines. There is the further element of understanding the influence, limits, and challenges of science and technology in society. The examples listed in Figure 5 convey the general meanings of the categories; there is no attempt to list comprehensively all the knowledge that could be related to each category.

“Scientific explanations” example item

Question 4: FLY SPRAY

How can the farmer use the model of the life cycle of a fly to reduce the number of flies in the barn without using insecticide?

Scientific Enquiry
➢ origin (scientific questions). ➢ purpose (e.g., to produce evidence that helps answer scientific questions, current ideas/models/theories guide enquiries). ➢ observations and experiments (e.g., different questions suggest different scientific investigations, current scientific knowledge). ➢ data (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 Explanations
➢ types (e.g., hypothesis, theory, model, law). ➢ formation (e.g., extant knowledge and new evidence, creativity and imagination, logic). ➢ rules (e.g., logically consistent, based on evidence, based on historical and current knowledge). ➢ outcomes (e.g., new knowledge, new methods, new technologies, new investigations).
Science and Technology in Society
➢ role of science (e.g., understand the natural world, answers questions) and role of science-based technology (e.g., attempts to solve human problems, develop artefacts, design processes, human adaptation [non-biological]). ➢ relationships between science and technology (e.g., science often advances due to new technologies, advances in scientific knowledge can advance technology). ➢ risks (e.g., may create new problems, knowledge is often not public, benefits versus costs, unintended consequences). ➢ influence (e.g., science and technology influence society through their knowledge, procedures, products, and world views). ➢ challenges (e.g., societal issues and aspirations often inspire questions for scientific research and problems for technological innovations). ➢ limits (e.g., science cannot answer all questions and technology cannot solve all societal problems or meet all human aspirations).

Figure 5. PISA 2006 knowledge *about* science categories

41. The PISA 2006 science assessment will include a small number of units that target students' misconceptions regarding knowledge *of* science or knowledge *about* science. Such units will be developed on the basis of research on students' conceptions and be designed to promote knowledge about *major* misconceptions of *fundamental* concepts. Items within these units will be contextualised in a similar manner to other units and constitute a set that, when they are analysed together, will allow some generalisations about students' conceptions and misconceptions *in context* to be reported. The sample unit *Snow Leopards* is an example of such a unit.

Sample focus unit: Snow Leopards

Snow Leopards is designed to target students' misconceptions about inheritance and (in later questions) adaptation. A full rationale is given in *PISA 2006 Scientific Literacy Sample Units.*

Question 1: SNOW LEOPARDS

In December 2003, two snow leopard cubs were born at Mogo Zoo in Australia: one male and one female.

Would the cubs have inherited their features from their mother (Lena) or their father (Mangar)? Circle "Agree" or "Disagree" for each of these possibilities.

Inheritance of characteristics	**Agree or Disagree?**
Lena passed on all her features to both the male and female cubs. Mangar did not pass on his features.	Agree / Disagree
Lena passed on her features only to the female cub, and Mangar passed on his features only to the male cub.	Agree / Disagree
Mangar passed on all his features to both the male and female cubs. Lena did not pass on her features.	Agree / Disagree
Mangar passed on all his features to both the male and female cubs because males are dominant to females.	Agree / Disagree
Lena and Mangar both passed on some features to both cubs.	Agree / Disagree

SNOW LEOPARDS SCORING 1

Full Credit

Code 2: All five correct: Disagree, Disagree, Disagree, Disagree, Agree in that order.

Partial Credit

Code 1: Four of the five correct.

No Credit

Code 0: Other responses.

Code 9: Missing.

Scoring Note:

As well as the overall score, the response to each statement will be recorded. Each incorrect statement corresponds to a particular misconception as follows:

A Agree (misconception: shows a lack of understanding of the equality of parental genetic contribution. Mothers pass on all of the characteristics.)

B Agree (misconception: shows a lack of understanding of the equality of parental genetic contribution. Mothers pass on characteristics to daughters and fathers pass on characteristics to sons).

C Agree (misconception: shows a lack of understanding of the equality of parental genetic contribution. Fathers pass on all of the characteristics).

D Agree (misconception: shows a lack of understanding of the term ‘dominant’).

ATTITUDINAL RESPONSES

42. Peoples' attitudes play a significant role in their interest, attention, and response to science and technology in general and to issues that affect them in particular. One goal of science education is students' development of attitudes that support attending to scientific issues and the subsequent acquisition and application of scientific and technological knowledge to personal, social, and global benefit.

43. The point of reference for the attitudinal responses is a multidimensional construct of scientific literacy. That is, a person's scientific literacy includes certain attitudes, beliefs, motivational orientations, self-efficacy, values, and ultimate actions. In many PISA 2006 units, students will be asked to respond to contextualised and embedded items designed to assess their attitudes to science in different contexts. These items will be systematically linked to topics so that relationships between levels of understanding and attitudes (interest, support and responsibility) may be reported.

44. The PISA 2006 science assessment will evaluate students' attitudes in three areas: interest in science, support for scientific enquiry, and responsibility for sustainable development (see Figure 6). These areas were selected because they will provide an international portrait of students' general appreciation of science, their specific scientific attitudes and values, and their responsibility toward selected science-related issues that have national and international ramifications. Note that this is not an assessment of students' attitudes toward school science programs or teachers. The results will provide information about the emerging problem of declining interest for science studies among young people. Information about students' attitudes to science will have implication for many OECD countries. Inclusion of attitudinal responses, and the specific areas selected for PISA 2006, is supported by, and builds upon, a structure for the affective domain in science education (Klopfer, 1976) and reviews of research (for example, Gardner, 1975; Gould & Hukins, 1980; Blosser, 1984; Laforgia, 1988).

45. *Interest in science* was selected because of its established relationships with achievement, course selection, career choice, and lifelong learning. The relationship between (individual) interest in science and achievement has been the subject of research for more than 40 years although there is still debate about the causal link (see, for example, Baumert & Köller, 1998; Osborne, Simon & Collins, 2001). The PISA 2006 science assessment will address students' interest in science through knowledge about their valuing of the contributions of science and technology, their engagement in science-related social issues, and their consideration of science-related careers.

Interest in Science

- Show 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

- Support the importance of considering different scientific perspectives and arguments.
- Support the use of factual information and rational explanations.
- Support the need for logical and careful processes in drawing conclusions.

Responsibility for Sustainable Development

- Show a sense of personal responsibility for achieving a healthy population and safe environments.
- Demonstrate awareness of the environmental consequences of individual actions.
- Demonstrate willingness to take action to maintain natural resources.

Figure 6. PISA 2006 areas for assessment of attitudinal responses

46. *Support for scientific enquiry* is widely regarded as a fundamental objective of science education and as such warrants assessing. It is a similar construct to "adoption of scientific attitudes" as identified by Klopfer (1971). Appreciation of and support for scientific enquiry implies that students' value scientific ways of gathering evidence, thinking creatively, reasoning rationally, responding critically, and communicating conclusions as they confront life situations related to science. Aspects of this area

that may be incorporated in PISA 2006 include the use of evidence (knowledge) in decisions, the appreciation for logic, and rationality in formulating conclusions.

47. *Responsible attitude toward sustainable development* is of international concern, as well as being of economic relevance. Attitudes in this area have been the subject of extensive research since the 1970s (see, for example, Bogner & Wiseman, 1999; Eagles & Demare, 1999; Weaver, 2002; Rickinson, 2001). In December 2002, the United Nations approved resolution 57/254 declaring the ten-year period beginning on 1 January 2005 to be the "United Nations Decade of Education for Sustainable Development". The draft framework (UNESCO, July 2003) identifies "Health promotion", "Environmental conservation and protection" and "Sustainable production and consumption" as three of the key themes in education for sustainable development. The assessment of "Responsibility for sustainable development" will provide insights about students' attitudes toward specific, defined science topics – ones that relate to meaningful contexts. The assessment will differ from most studies of students' attitudes towards science which, as pointed out by Zacharia and Calabrese Barton (2004), have used a backdrop of "generalized science."

48. PISA 2006 will use both contextualised test items *and* the student questionnaire to gather data about student's attitudes in these areas. Students' attitudinal responses will be assessed in the test using embedded items that target personal, social, and global issues. The inclusion of contextualised items will add value to the assessment in that it will provide data, for each attitude, on the extent to which a student's responses differ when assessed in and out of context, how much they vary between contexts, and how this affects achievement. Hidi and Berndorff (1998) argue, for example, that *situational* interest can have a potentially powerful affect on both cognitive and motivational functioning, but that investigations of its role have been "haphazard and scattered".

Student questionnaire scales

The student questionnaire will be used to gather "shadow" data on student interest, support for scientific enquiry, and responsibility for sustainable development, in a less-contextualised manner. Further data concerning students' "engagement in science" (e.g., self-efficacy, anxiety, and enjoyment/boredom) will also be collected via the student questionnaire, as will students' views on the value of science for their own lives (e.g., further education and career choices).

49. The results of PISA 2006 must be valid, informative and precise enough to inform educational policies in the participating countries. The combined richness of the data obtained through both the student questionnaire and the embedded items should generate new knowledge about students' predisposition towards scientifically literate behaviours. Using the model described in the preceding paragraphs to assess attitudes will make it possible to link the attitudinal dimension data with that of student performance. Although the literature contains conflicting reports on the correlation between attitudes and performance in science, it remains to be seen how student attitudinal data (interest in science, support for scientific enquiry, and responsibility for sustainable development), collected via the test, correlate with student performance from the three knowledge *of* science categories described in Figure 4. Other data obtained from the student questionnaire, such as students' "engagement in science" and science-related behaviours, also will be reported and linked with student performance.

TEST CHARACTERISTICS

50. In accordance with the PISA definition of scientific literacy, assessment questions (items) require the application of scientific knowledge (see Figures 4 and 5) and the use of the scientific competencies (see Figure 3) within a context (see Figure 2). An assessment unit will take the form of several items linked to some initial stimulus material. Four sample units are included in the companion document, *PISAQ 2006 Scientific Literacy Sample Units*.

51. Figure 7 is a minor variation of Figure 1. It presents the basic components of the PISA framework for the 2006 scientific literacy assessment in a way that can be used to relate the framework with the structure and the content of assessment units. This may be used both synthetically as a tool to plan assessment exercises, and analytically as a tool to study the results of standard assessment exercises. As a starting point to construct assessment units, we could consider the contexts that would serve as

stimulus material, the competencies required to respond to the questions or issues, or the knowledge and attitudes central to the exercise.

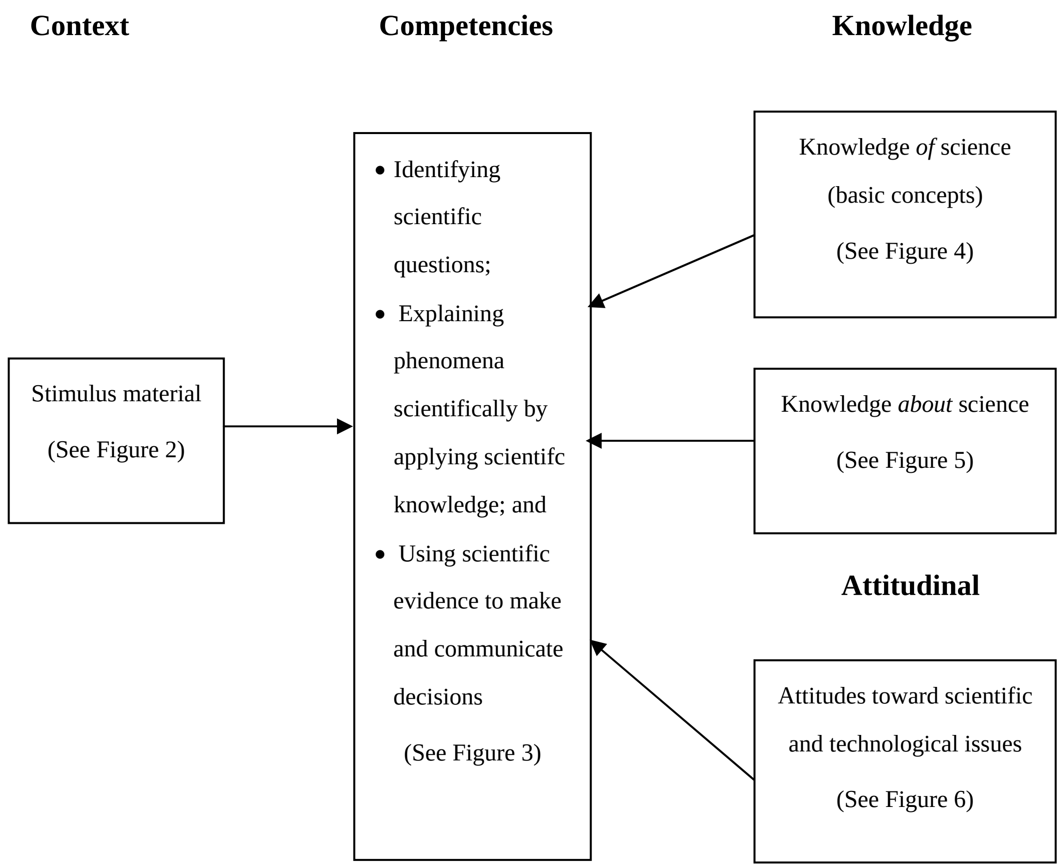

Figure 7. A tool for constructing and analysing assessment units and items.

52. A test unit is defined by a particular stimulus material, which may be a brief written passage, or writing accompanying a table, chart, graph, or diagram. The items are a set of independently scored questions requiring selection of a response in a multiple-choice format, a short constructed-response, or an open constructed-response. They may require review and analysis of drawings, schemes, or graphs.

53. There are several reasons for the PISA test design. One reason for this structure is to make the units as realistic as possible and to reflect in them the complexity of life situations. Another reason relates to the efficient use of testing time, reducing the time required for a student to "get into" the subject matter of the unit, by having fewer situations about which several questions can be posed rather than

separate questions about a larger number of different situations. The need to make each scored point independent of others within a unit must be taken into account, however. It is also necessary to recognise that, as this approach reduces the number of different assessment contexts, it is important to ensure an adequate range of materials so that there is a minimisation of bias that may be due to the choice of contexts for the units.

Item review guidelines

All items are distributed to the National Project Managers, and to the Science Expert Group, for feedback before being considered for inclusion in the Field Trial. Respondents are asked to give a rating from 1 (low) to 5 (high) on each of the following criteria:

- How closely does the item content correspond with material that would be dealt with in your country's typical school curriculum up to the stage that 15-year-olds should have reached?
- How relevant is the task for student's "preparedness for life"?
- How interesting (in a motivational sense) is the task for students?
- Will students regard the task as an authentic application of science or technology?

Respondents are also asked to identify any cultural concerns, anticipated translation difficulties, or apparent scientific errors.

54. PISA 2006 test units will incorporate up to five cognitive items. Each item will involve the use of one of the scientific competencies *and* require either knowledge *of* science or knowledge *about* science. In most cases, more than one competency and more than one knowledge category will be assessed within a unit.

55. Most of the new units included in the Field Trial will also contain an assessment of students' attitudes. Two types of items are being piloted: "match the opinion" items, and items consisting of a set of Likert-style questions. Question 7 in the sample unit "Solar Tower" is an example of the first type of item. Four ordered opinions about an issue, representing different levels of commitment to

sustainable development, are given and students have to choose the one that best matches their opinion. This item has a similar "look and feel" to other items in the unit.

56. Question 6 in the sample unit "Catching the Killer" is an example of the second type of item. In this question, students are asked to indicate their agreement to three statements assessing their interest in this area of application of science. The statements operationalise, in this scientific context, the criteria used to define "interest in science" (see Figure 6). A unipolar response format (High interest, Medium interest, Low interest, No interest), rather than the conventional bipolar one (Strongly agree, Agree, Disagree, Strongly disagree), is used to reduce the influence of "social desirability" on responses. This item has a different "look and feel" to the other items in the unit, but this is an advantage when affective items are included in a predominantly cognitive test.

Example of a "match the opinion" item

Question 7: SOLAR TOWER

Here is what four people said in response to the question: "Do you support the building of solar towers?"

Circle the letter beside the response that is most like your own opinion. There is no "correct" response.

A. No. We need electric power at the lowest possible cost. Greenhouse effects are too far into the future to worry about now.

Key: Little in the way of commitment to sustainable development is shown as exemplified by an emphasis on human utilisation of resources at the expense of sustainability and natural environment. The world is seen by the individual in terms of his/her position in relation to others rather than in terms of his/her place in a fragile environment.

B. No. Greenhouse gases should be reduced but I would prefer to wait until scientists find other, cheaper ways of producing renewable energy.

Key: When faced with alternative options for action enhancing the preservation of resources, or for action not leading to such an enhancement, the individual indicates some recognition of behaviours leading to sustainable outcomes but opts for short to medium-term outcomes at the expense of longer-term *sustainability. The world-view expressed is relatively short-term.*

C. Yes. Although electricity would cost more, I would be willing to pay the increased price provided everyone shared the cost of reducing greenhouse gases.

Key: Individuals indicate some knowledge of behaviours likely to enhance the preservation of resources for future generations but their support for (investment in) those behaviours is limited in extent – e.g., the behaviour is readily or easily facilitated at a personal level or is conditional on a shared relationship with others.

D. Yes. I would pay more for electricity, even if others would not. In fact, I'd actively encourage others to do something to reduce greenhouse gases.

Key: Individuals demonstrate a personal sense of responsibility for sustainable development as exemplified by their stated intention to engage in behaviours likely to enhance the possibility of preserving resources for the long-term future (including support for groups with sustainable development missions). The intention to act in this way is generally independent of the actions of others i.e. it is not conditional on the actions or views of others.

Example of a "Likert-style" item

How interested are you in the following tasks?

Tick only one box in each row.

		High interest	*Medium interest*	*Low interest*	*No interest*
a)	Knowing more about the use of DNA in solving crime.	□1	□2	□3	□4
b)	Learning more about how DNA profiling works.	□1	□2	□3	□4
c)	Understanding better how crime can be solved using science.	□1	□2	□3	□4

57. A range of item response formats and lengths will be required to cover the cognitive abilities and scientific knowledge identified in this framework. Multiple-choice items can be produced that validly assess the first competency (which involves identification and formulation of questions), but to assess the ability to communicate, an open-response format likely will provide more validity and

authenticity. In many cases, however, the most appropriate format will depend on the particular content of the item. For example, it may be necessary to provide formats and response options that require reasoning from data, brief writing based on images, drawings, tables, charts, graphs, or symbolic representations.

“Likert-style” items versus “Match the opinion” items

“Likert-style” items are easily distinguishable from cognitive items and are very efficient in that they minimise demands on student response time. Their potential disadvantage is cultural variation in response behaviour to the graded adjectives that are used as options. “Match the opinion” items may not have this disadvantage with the options being opinions that correspond to points on the underlying scale. This feature is a strength in itself and compensates, at least in part, for the fewer student responses that can be obtained in the same amount of time in comparison with “Likert-style” items. The fact that “match the opinion” items have a similar “look and feel” to other PISA items will be addressed with distinctive formatting and appropriate student instructions.

58. While the majority of the items will be dichotomously scored a number of the open-responses items may allow partial credit scoring. For each partial credit item a detailed scoring rubric that allows for “full credit”, “partial credit” and “no credit” will be provided. The categories “full credit”, “partial credit” and “no credit” divide students’ responses into three groups in terms of the extent to which the students demonstrate ability to answer the question. A “full credit” response, although not necessarily “absolutely scientifically correct”, will exhibit a level of understanding of the topic appropriate for a scientifically literate 15-year-old. Less sophisticated or correct responses may qualify for “partial credit”, with completely incorrect, irrelevant or missing responses being assigned “no credit”.

59. The need for students to have a degree of reading literacy in order to understand and answer questions on scientific literacy raises an issue of the level of that reading literacy. Stimulus material and questions will use language that is as clear, simple and brief as possible while still conveying the appropriate meaning. The number of concepts introduced per paragraph will be limited and, generally,

care will be taken to achieve a reading age no higher than that of the average 15-year-old. Questions that predominantly assess reading literacy, or mathematical literacy, will be avoided.

60. Countries may elect to participate in the optional Computer-Based Assessment of Scientific Literacy as part of the PISA 2006 assessment. The addition of a supplementary computer-based assessment of scientific literacy will increase the overall diversity of the assessment tasks and improve the coverage of the scientific literacy domain. Importantly, it will reduce the impact that reading literacy skills have on the outcomes of the science assessment.

ASSESSMENT STRUCTURE

61. The desired balance between the two knowledge components, knowledge *of* science and knowledge *about* science is shown in Figure 8 in terms of percentages of score points. Figure 8 also shows the desired distribution of score points among the various knowledge *of* science and knowledge *about* science categories.

Knowledge *of* Science	**Per cent of score points**
Physical systems	20–25
Living systems	25–30
Earth and space systems	15–20
Subtotal	*60–65*
Knowledge *about* Science	
Scientific enquiry	10–15
Scientific explanations	10–15
Science and technology in society	10–15
Subtotal	*35–40*
Total	100

Figure 8. Desired distribution of score points for knowledge

Rationale for "scientific knowledge" framework weights

- The definition of "scientific literacy" places almost as much emphasis on "knowledge *about* science" as it does on "knowledge *of* science" and this is reflected in their respective weightings. Approximately 40% of the new units included in the Field Trial will assess "knowledge *about* science", but this proportion will drop to about 35% in the Main Study given the nature of the available link items.
- The desired distribution of score points across the "knowledge *of* science" categories, expressed as percentages of the "knowledge *of* science" subtotal, is about 35% for "physical systems", 40% for "living systems", and 25% for "earth and space systems". The corresponding TIMSS (eighth grade) percentages are 40%, 30% and 15%, with the remaining 15% assigned to "environmental science". PISA's increased emphasis on "living systems" reflects the fact that a major proportion of the contexts that are relevant and interesting to 15-year-olds, and that are encountered in later life, involve the life sciences.
- The distribution of score points across the "knowledge *about* science" categories reflects the fact that they are regarded as equally important and ensures sufficient coverage of each category whilst allowing some flexibility.

62. The desired balance for scientific competencies is given in Figure 9.

Scientific Competencies	Per cent of score points
Identifying scientific questions	25–30
Explaining phenomena scientifically	35–40
Using scientific evidence	35–40
Total	100

Figure 9. Desired distribution of score points for scientific competencies

Rationale for "scientific competencies" framework weights

The weightings assigned to the three scientific competencies were determined by the following factors:

- the need to have enough items targeting each competency to ensure that a reliable scale can be prepared for **each** of the competencies;
- their relative importance in the conception of a scientifically literate 15-year-old; and

- experience in developing items for the PISA 2000 and 2003 science assessments.

The lower weighting assigned to the first competency is in keeping with its narrower definition and reduced importance, but will be sufficient to produce a reliable scale.

63. Item contexts will be spread fairly evenly across personal, social and global settings. A wide a selection of applications will be used for units, subject to satisfying as far as possible the various constraints imposed throughout the Framework

Distribution of items across the contexts

It is not possible to be more prescriptive about the distribution of items across contexts. In addition to satisfying the weightings of Figures 8 and 9 for knowledge and competency score points, item format must be taken into account (at least half of the items must be able to be marked automatically), the items must have sound psychometric properties, and they need to have an appropriate difficulty distribution. Experience has shown that it is virtually impossible to satisfy all of these conditions simultaneously, let alone adding another one.

64. At least half of the cognitive test items will be of types that can be marked without the involvement of trained markers – i.e., multiple-choice, complex multiple-choice (e.g., “Catching the Killer”, question 4), or closed constructed-response items.

65. About 80 per cent of the units included in the Field Trial will contain either one “match the opinion” attitude item or two “Likert-style” items (each comprising three score points). It is estimated that responding to these items will occupy 15–20 per cent of the total test time. The proportion of units in the Main Study that will include attitude items will be decided after analysis of the Field Trial results. To ensure comparability of performance over time, link items from the two previous PISA science assessments that are used in the Main Study will not contain attitude items.

REPORTING SCALES

66. To meet the aims of PISA, the development of scales of student achievement is essential. The process of arriving at a scale has to be iterative. Initial descriptions, based on the results of the trials and the PISA 2000 and 2003 surveys – and informed by past experience of assessing science achievement and findings from research into learning and cognitive development in science – are likely to be modified as more data are accumulated in future trials and surveys.

67. For PISA 2000, when science was a minor domain thus having limited information, scientific literacy was reported in terms of a proficiency scale with a mean of 500 and a standard deviation of 100. Although no proficiency levels were identified, it was possible to describe what processes (i.e., scientific competencies) students can perform at three points in this scale:

- Towards the top end of the scientific literacy scale (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.
- At around 550 points, students are typically able to use scientific knowledge 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.
- Towards the lower end of the scale (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.

68. For PISA 2003, the reporting of scientific literacy results is likely to follow a similar format to that of 2000. However, for PISA 2006, when the testing time available will enable a wider coverage of competencies, experience in constructing the 2000 and 2003 scales suggests that it **will** be possible to construct *separate* scales, and described proficiency levels, for the three scientific competencies of Figure 3.

Example of a competency-based reporting scale

Proficiency levels on the PISA 2000 scientific literacy scale are described in terms of the scientific processes (i.e., the PISA 2006 scientific competencies). By examining the descriptions we can derive the skeleton of each PISA 2006 competency scale. For example, for “Using scientific evidence” we obtain the following:

High	Can compare data in order to evaluate alternative viewpoints or differing perspectives; can communicate scientific arguments and/or descriptions in detail and with precision.
	Able to select relevant information from competing data or chains of reasoning in drawing or evaluating conclusions.
Low	Able to use common scientific knowledge in drawing or evaluating conclusions.

69. Alternatively, it should be possible to report separate scales for the two knowledge components, knowledge *of* science and knowledge *about* science. The competencies would then be central to describing the proficiency levels for these two knowledge scales (as is proposed for the PISA 2003 mathematics assessment).

Competency-based versus knowledge-based reporting scales

Reporting PISA 2006 scientific literacy achievement using competency-based scales follows directly from the central role of the scientific competencies in the PISA 2006 definition of scientific literacy. Reporting via knowledge-based scales would not be as appropriate since the aim of the assessment is not to assess the extent of students’ knowledge, but whether students can *apply* their knowledge.

Nevertheless, sufficient items are being developed for the Field Trial to cover both possibilities. A final decision on reporting scales will be made after analysis of the Field Trial results, in time to influence the selection of items for the Main Study.

70. There will be sufficient attitude items to prepare reliable scales for the three attitudes of Figure 6 (Interest in science, Support for scientific enquiry, and Responsibility for sustainable development). Depending on the relationships observed, "shadow" data obtained from the student questionnaire will be combined with the test data or used to form three "corresponding" scales.

71. To the degree possible, attitudinal responses will be linked to student performance. However, the "scores" on attitude items will not be included in an index (or overall score) of scientific literacy; rather, the three attitude scores will form a component of a profile of student scientific literacy.

Example of an attitudinal response scale

The following example scale for "responsibility for sustainable development" is based on Bogner and Wiseman (1999).

High	Demonstrates a personal sense of responsibility for sustainable development, independent of the actions of others.
	Demonstrates some commitment but support is limited in extent or conditional on the cooperation of others.
	Recognises actions that could be taken but opts for short-term solutions at the expense of long-term sustainability.
Low	Shows little commitment to sustainable development; favours development at the expense of sustainability and natural environment.