PISA 2015

DRAFT SCIENCE FRAMEWORK

MARCH 2013

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INTRODUCTION: SCIENTIFIC LITERACY & WHY IT MATTERS

1. This document provides a description and rationale for the framework that forms the basis of the instrument to assess *scientific literacy* – the major domain for PISA 2015. Previous PISA frameworks for the science assessment (OECD, 1999, OECD, 2003, OECD, 2006) have elaborated a conception of scientific literacy as the central construct for science assessment. These documents have established a broad consensus among science educators of the concept of scientific literacy. This framework for PISA 2015 refines and extends the previous construct – in particular by drawing on the PISA 2006 framework that was used as the basis for assessment in 2006, 2009 and 2012.

2. Scientific literacy matters at both the national and international level as humanity faces major challenges in providing sufficient water and food, controlling diseases, generating sufficient energy and adapting to climate change (UNEP, 2012). Many of these issues arise, however, at the local level where individuals may be faced with decisions about practices that affect their own health and food supplies, the appropriate use of materials and new technologies, and decisions about energy use. Dealing with all of these challenges will require a major contribution from science and technology. Yet, as argued by the European Commission, the solutions to political and ethical dilemmas involving science and technology 'cannot be the subject of informed debate unless young people possess certain scientific awareness' (European Commission, 1995, p.28). Moreover, 'this does not mean turning everyone into a scientific expert, but enabling them to fulfil an enlightened role in making choices which affect their environment and to understand in broad terms the social implications of debates between experts' (*ibid*. p.28). Given that knowledge of science and science-based technology contributes significantly to individuals' personal, social, and professional lives an understanding of science and technology is thus central to a young person's 'preparedness for life'.

3. Becoming scientifically literate embodies the idea that the purposes of science education should be both broad and applied. Thus, within this framework, the concept of scientific literacy *refers both to a knowledge of science and science-based technology*. It should be noted, however, that science and technology do differ in their purposes, processes, and products. Technology seeks the optimal solution to a human problem and there may be more than one optimal solution. In contrast, science seeks the answer to a specific question about the natural material world. Nevertheless, the two are closely related. For instance, new scientific knowledge enables new technologies such as the advances in material science that led to the development of the transistor in 1948. Likewise new technologies can lead to new scientific knowledge such as the transformation of our knowledge of the universe through the development of better telescopes. As individuals, we make decisions and choices that influence the directions of new technologies *e.g.*, to drive smaller, more fuel-efficient cars. The scientifically literate individual should therefore be able to make more informed choices. They should also be able to recognise that, whilst science and technology are often a source of solutions, paradoxically, they can also be seen as a source of risk, generating new problems which, in turn, may require science and technology to resolve. Therefore, individuals need to be able to consider the implications of the application of scientific knowledge and the issues it might pose for themselves or the wider society.

4. Scientific literacy also requires not just knowledge of the concepts and theories of science but also a knowledge of the common procedures and practices associated with scientific enquiry and how these

enable science to advance. Therefore, individuals who are scientifically literate have a knowledge of the major conceptions and ideas that form the foundation of scientific and technological thought; how such knowledge has been derived; and the degree to which such knowledge is justified by evidence or theoretical explanations.

5. Undoubtedly, many of the challenges of the 21st century will require innovative solutions that have a basis in scientific thinking and scientific discovery. Societies will therefore require a cadre of well-educated scientists to undertake the research and the scientific and technological innovation that will be essential to meet the economic, social and environmental challenges which the world will face. To engage with the wider society, such scientists will also need to be both knowledgeable about science and highly scientifically literate with a deep understanding of the nature of science, its limitations and the consequences of its application.

6. For all of these reasons, scientific literacy is perceived to be a key competency (Rychen & Salganik, 2003) and defined in terms of the ability to use knowledge and information interactively – that is 'an understanding of how it [a knowledge of science] changes the way one can interact with the world and how it can be used to accomplish broader goals' (p.10). As such it represents a major goal for science education for *all* students. Therefore the view of scientific literacy which forms the basis for the 2015 international assessment of 15-year-olds is a response to the question: *What is important for young people to know, value, and be able to do in situations involving science and technology?*

7. This framework offers a rationale and elaborated description of what is meant by the term *scientific literacy*. It is this construct that forms the foundation of the PISA science assessments. Within this document, the construct of scientific literacy is defined in terms of a set of competencies that a scientifically literate individual would be expected to display. These competencies form the basis of the construct to be tested (Wiliam, 2010).

SCIENTIFIC LITERACY: TOWARDS A DEFINITION

8. Current thinking about the desired outcomes of science education is rooted strongly in a belief that an understanding of science is so important that it should be a feature of every young person's education (American Association for the Advancement of Science, 1989; Confederacion de Sociedades Cientificas de España, 2011; Fensham, 1985; Millar & Osborne, 1998; National Research Council, 2012 Sekretariat der Ständigen Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland (KMK), 2005; Taiwan Ministry of Education, 1999). Indeed, in many countries science is an obligatory element of the school curriculum from kindergarten until the completion of compulsory education.

9. Many of the documents and policy statements cited above give pre-eminence to an education for citizenship. However, internationally many of the curricula for school science are based on a view that the primary goal of science education should be the preparation of the next generation of scientists (Millar & Osborne, 1998). These two goals are not always compatible. Attempts to resolve the tension between the needs of the majority of students who *will not* become scientists and the needs of the minority who *will* have led to an emphasis on teaching science through enquiry (National Academy of Science, 1995; National Research Council, 2000), and new curriculum models (Millar, 2006) that address the needs of both groups. The emphasis in these frameworks and their associated curricula lies not on producing individuals who will be producers of scientific knowledge. Rather, it is on educating young people to become informed critical consumers of scientific knowledge – a competency that all individuals are expected to need during their lifetimes.

10. To understand and engage in critical discussion about issues that involve science and technology requires three domain-specific competencies. The first is the ability to provide explanatory accounts of natural phenomena, technical artefacts and technologies and their implications for society. Such an ability requires a knowledge of the major explanatory ideas of science and the questions that frame the practice and goals of science. The second is the competency to use a knowledge and understanding of scientific enquiry to: identify questions that can be answered by scientific enquiry; identify whether appropriate procedures have been used; and propose ways in which such questions might possibly be addressed. The third is the competency to interpret and evaluate data and evidence scientifically and evaluate whether the conclusions are warranted. Thus, scientific literacy in PISA 2015 is defined by the three competencies to:

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

11. All of these competencies require knowledge. Explaining scientific and technological phenomena, for instance, demands a knowledge of the content of science – referred to hereinafter as **content knowledge**. The second and third competencies, however, require more than a knowledge of what we know. Rather, they depend on an understanding of how scientific knowledge is established and the degree of confidence with which it is held. Specific calls, therefore, have been made for teaching about what has variously been called 'the nature of science' (Lederman, 2006), 'ideas about science' (Millar &

Osborne, 1998) or 'scientific practices' (National Research Council, 2012). Recognising and identifying the features that characterise scientific enquiry requires a knowledge of the standard procedures that are the foundation of the diverse methods and practices used to establish scientific knowledge – referred to here as **procedural knowledge**. Finally, the competencies require **epistemic knowledge –** an understanding of the rationale for the common practices of scientific enquiry, the status of the knowledge claims that are generated, and the meaning of foundational terms such as theory, hypothesis and data.

12. Both procedural and epistemic knowledge are necessary to identify questions that are amenable to scientific enquiry, to judge whether appropriate procedures have been used to ensure that the claims are justified, and to distinguish scientific issues from matters of values or economic considerations. Of significance in developing this definition of scientific literacy is that, in their lifetimes individuals will need to acquire knowledge, not through scientific investigations, but through the use of resources such as libraries and the Internet. Procedural and epistemic knowledge are essential to deciding whether the many claims to knowledge that pervade contemporary media have been derived using appropriate procedures and are warranted.

Scientific Knowledge: PISA 2015 Terminology

This document is based upon a view of scientific knowledge as consisting of three distinguishable but related elements. The first of these and the most familiar is a knowledge of the facts, concepts, ideas and theories about the natural world that science has established. For instance, how plants synthesise complex molecules using light and carbon dioxide or the particulate nature of matter. This kind of knowledge is referred to as "**content knowledge**" or "knowledge of the content of science".

Knowledge of the procedures that scientists use to establish scientific knowledge is referred to as "**procedural knowledge**". This is a knowledge of the practices and concepts on which empirical enquiry is based such as repeating measurements to minimise error and reduce uncertainty, the control of variables, and standard procedures for representing and communicating data (Millar, Lubben, Gott, & Duggan, 1995). More recently these have been elaborated as a set of "concepts of evidence" (Gott, Duggan, & Roberts, 2008).

Furthermore, understanding science as a practice also requires "**epistemic knowledge**" which refers to an understanding of the role of specific constructs and defining features essential to the process of knowledge building in science (Duschl, 2007). Epistemic knowledge includes an understanding of the function that questions, observations, theories, hypotheses, models, and arguments play in science, a recognition of the variety of forms of scientific enquiry, and the role peer review plays in establishing knowledge that can be trusted.

A more detailed discussion of these three forms of knowledge is provided in the later section on *Scientific Knowledge* and in Figures 4, 5 & 6.

13. People need all three forms of scientific knowledge to perform the three competencies of scientific literacy. Therefore PISA 2015 will focus on assessing the extent to which 15-year-olds are capable of displaying these competencies appropriately within in a range of personal, local, national and global contexts. This perspective differs from that of many school science programmes which are often dominated by content knowledge. Instead, the framework is based on a broader view of the kind of knowledge of science required by participating members of contemporary society.

14. In addition, the competency-based perspective also recognises that there is an affective element to a student's display of these competencies – that is that their attitudes or disposition towards science will determine their level of interest, sustain their engagement, and may motivate them to take action (Schibeci, 1984). Thus, commonly the scientifically literate person would have an interest in

scientific topics; engage with science-related issues; have a concern for issues of technology, resources, and the environment; and reflect on the importance of science from a personal and social perspective. This requirement does not mean that such individuals are necessarily disposed towards science itself. Rather, such individuals recognise that science, technology and research in this domain are an essential element of contemporary culture that frames much of our thinking.

15. It is such considerations that have led to the following definition of scientific literacy for PISA 2015:

The 2015 Definition of Scientific Literacy

Scientific Literacy is the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen.

A scientifically literate person, therefore, is willing to engage in reasoned discourse about science and technology which requires the competencies to:

1. **Explain phenomena scientifically:**
   - Recognise, offer and evaluate explanations for a range of natural and technological phenomena.
2. **Evaluate and design scientific enquiry:**
   - Describe and appraise scientific investigations and propose ways of addressing questions scientifically.
3. **Interpret data and evidence scientifically:**
   - Analyse and evaluate data, claims and arguments in a variety of representations and draw appropriate scientific conclusions.

Explanatory Notes

16. The following remarks are offered to clarify the meaning and use of this definition of scientific literacy for the purposes of the PISA 2015 assessment.

a) The term “scientific literacy” rather than “science” underscores the importance that the PISA science assessment places on the application of scientific knowledge in the context of life situations.

b) For the purposes of the PISA assessment, it should be noted that these competencies will only be tested using the knowledge that 15-year-old students can reasonably be expected to have of the concepts and ideas of science (**content knowledge**), the procedures and strategies used in all forms of scientific enquiry (**procedural knowledge**), and the manner in which ideas are justified and warranted in science (**epistemic knowledge**).

c) Finally, throughout this document, the term ‘natural world’ is used to refer to phenomena associated with any object or phenomenon occurring in the living or the material world.

The Competencies Required for Scientific Literacy

Competency 1: Explain Phenomena Scientifically

17. The cultural achievement of science has been to develop a set of explanatory theories that have transformed our understanding of the natural world, such as the idea that day and night is caused by a spinning Earth, or the idea that diseases can be caused by invisible micro-organisms. Moreover, such knowledge has enabled us to develop technologies that support human life enabling such things as the prevention of disease and rapid human communication across the globe. The competency to explain scientific and technological phenomena is thus dependent on a knowledge of these major explanatory ideas of science.

18. Explaining scientific phenomena, however, requires more than the ability to recall and use theories, explanatory ideas, information, and facts (**content knowledge**). Offering scientific explanation also requires an understanding of how such knowledge has been derived and the level of confidence we might hold about any scientific claims. For this competency, the individual requires a knowledge of the standard forms and procedures used in scientific enquiry to obtain such knowledge **(procedural knowledge)** and an understanding of their role and function in justifying the knowledge produced by science (**epistemic knowledge**).

Competency 2: Evaluate and Design Scientific Enquiry

19. Scientific literacy implies that students should have some understanding of the goal of scientific enquiry which is to generate reliable knowledge about the natural world (Ziman, 1979). Data collected and obtained by observation and experiment, either in the laboratory or in the field, lead to the development of models and explanatory hypotheses that enable predictions that can then be tested experimentally. New ideas, however, commonly build on previous knowledge. Scientists themselves rarely work in isolation and are members of research groups or teams that engage in extensive collaboration with colleagues both nationally and internationally. New knowledge claims are always perceived to be provisional and may lack justification when subjected to critical peer review – the mechanism which the scientific community has established to ensure the objectivity of scientific knowledge (Longino, 1990). Hence scientists have a commitment to publish or report their findings and the methods used in obtaining the evidence. Doing so enables empirical studies, at least in principle, to be replicated and results confirmed or challenged. Measurements, however, can never be absolutely precise. Rather, they all contain a degree of error. Much of the work of the experimental scientist is, therefore, devoted to the resolution of uncertainty by repeating measurements, collecting larger samples, building instruments that are more accurate, and using statistical techniques that assess the degree of confidence in any result.

20. In addition, science has well established procedures such as the use of controls that are the foundations of a logical argument to establish cause and effect. The use of controls enables the scientist to claim that any change in a perceived outcome can be attributed to a change in one specific feature. Failure to use such techniques leads to results where effects are confounded and cannot be trusted. Likewise, double-blind trials enable scientists to claim that the results have not been influenced either by the subjects of the experiment, or by the experimenter themselves. Other scientists such as taxonomists and ecologists are engaged in the process of identifying underlying patterns and interactions in the natural world that warrant a search for an explanation. In other cases, such as evolution, plate tectonics or climate change, science relies on arguments that are an inference to the best explanation examining a range of hypotheses and eliminating those which do not fit with the evidence.

21. Facility with this competency draws on **content** knowledge, a knowledge of the common procedures used in science (**procedural knowledge**), and the function of these procedures in justifying any

claims advanced by science (**epistemic knowledge**). Procedural and epistemic knowledge serve two functions. First, such knowledge is required by individuals to appraise scientific investigations and decide whether they have followed appropriate procedures and whether the conclusions are warranted. Second, individuals who have this knowledge should be able to propose, at least in broad terms, how a scientific question might be investigated appropriately.

Competency 3: Interpret Data and Evidence Scientifically

22. Interpreting data is such a core activity of all scientists that some rudimentary understanding of the process is essential for scientific literacy. Initially data interpretation begins with looking for patterns, constructing simple tables and graphical visualisations such as pie charts, bar graphs, scatterplots or Venn diagrams. At the higher level, it requires the use of more complex data sets and the use of the analytical tools offered by spreadsheets and statistical packages. It would be wrong, however, to conceive of this competency as merely a skill. A substantial body of knowledge is required to recognise what constitutes reliable and valid evidence and how to present data appropriately. Scientists make choices about how to represent the data in graphs, charts or, increasingly, in complex simulations or 3D visualisations. Any relationships or patterns must then be read using a knowledge of standard patterns. Whether uncertainty has been minimised by standard statistical techniques must also be considered. All of this draws on a body of **procedural knowledge**. The scientifically literate individual can also be expected to understand that uncertainty is an inherent feature of all measurement, and that one criterion for expressing our confidence in a finding is in terms of the probability that it might have occurred by chance.

23. It is not sufficient, however, to understand the procedures that have been applied to obtain any data set. The scientifically literate individual needs to be able to judge whether they are appropriate and the ensuing claims are justified (**epistemic knowledge**). For instance, many sets of data can be interpreted in multiple ways. Argumentation and critique, therefore are essential to determining which is the most appropriate conclusion. Whether it is new theories, novel ways of collecting data, or fresh interpretations of old data, argumentation is the means that scientists and technologists use to make their case for new ideas. Disagreement amongst scientists is therefore normal rather than extraordinary. Resolution of which interpretation is the best requires a knowledge of science (**content knowledge**) and critique. Through this process science has managed to achieve consensus about key explanatory ideas and concepts (Longino, 1990). Indeed, it is a critical and sceptical disposition towards all empirical evidence that many would see as the hallmark of the professional scientist. The scientifically literate individual would understand the function and purpose of argument and critique and why it is essential to the construction of knowledge in science. In addition, they should have the competency both to construct claims that are justified by data and to identify any flaws in the arguments of others.

The Evolution of the Definition of Scientific Literacy in PISA

24. In PISA 2000 and 2003, 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." (OECD, 2000, 2003)

25. In 2000 and 2003 the definition embedded knowledge *of* science and understandings *about* science within the one term 'scientific knowledge'. The 2006 definition separated and elaborated the term 'scientific knowledge' by resolving it into two components 'knowledge *of* science' and 'knowledge *about* science' (OECD, 2006). Both definitions, however, referred to the application of scientific knowledge to understanding, and making informed decisions about, the natural world. In PISA 2006, the definition was

enhanced by the addition of knowledge of the relationship between science and technology – an aspect that was assumed but not elaborated in the 2003 definition.

26. The PISA 2015 definition of scientific literacy is an evolution of these ideas. The major difference is that the notion of "knowledge *about* science" has been specified more clearly and split into two components – **procedural** knowledge and **epistemic** knowledge.

27. In 2006 the PISA framework was also expanded to include attitudinal aspects of students' responses to scientific and technological issues within the construct of scientific literacy. In 2006, attitudes were measured in two ways – through the student questionnaire and through items embedded in the student test. Discrepancies were found between the results from the embedded questions and those from the background questionnaire with respect to 'interest in science' for all students and the gender difference on these issues (OECD, 2009; see also: Drechsel, Carstensen & Prenzel, 2011). More importantly, embedded items extended the length of the test. Hence for the 2015 framework attitudinal aspects will only be measured through the student questionnaire and there will be no embedded attitudinal items. As to the constructs measured within this domain, the first ('Interest in science') and third ('Environmental awareness') remain the same as in 2006. The second 'Support for scientific enquiry', however, has been changed to a measure of 'Valuing scientific approaches to enquiry' – which is essentially a change in terminology to better reflect what is measured.

28. Finally, the contexts for assessment in PISA 2015 have been changed from 'Personal, Social and Global' in the 2006 Assessment to 'Personal, Local/National and Global' to make the headings more coherent.

29. In summary, the 2015 definition builds on and develops the 2006 definition. Other changes, for example elaborating the concepts of procedural and epistemic knowledge, represent a more detailed specification of particular aspects that were embedded or assumed in earlier definitions.

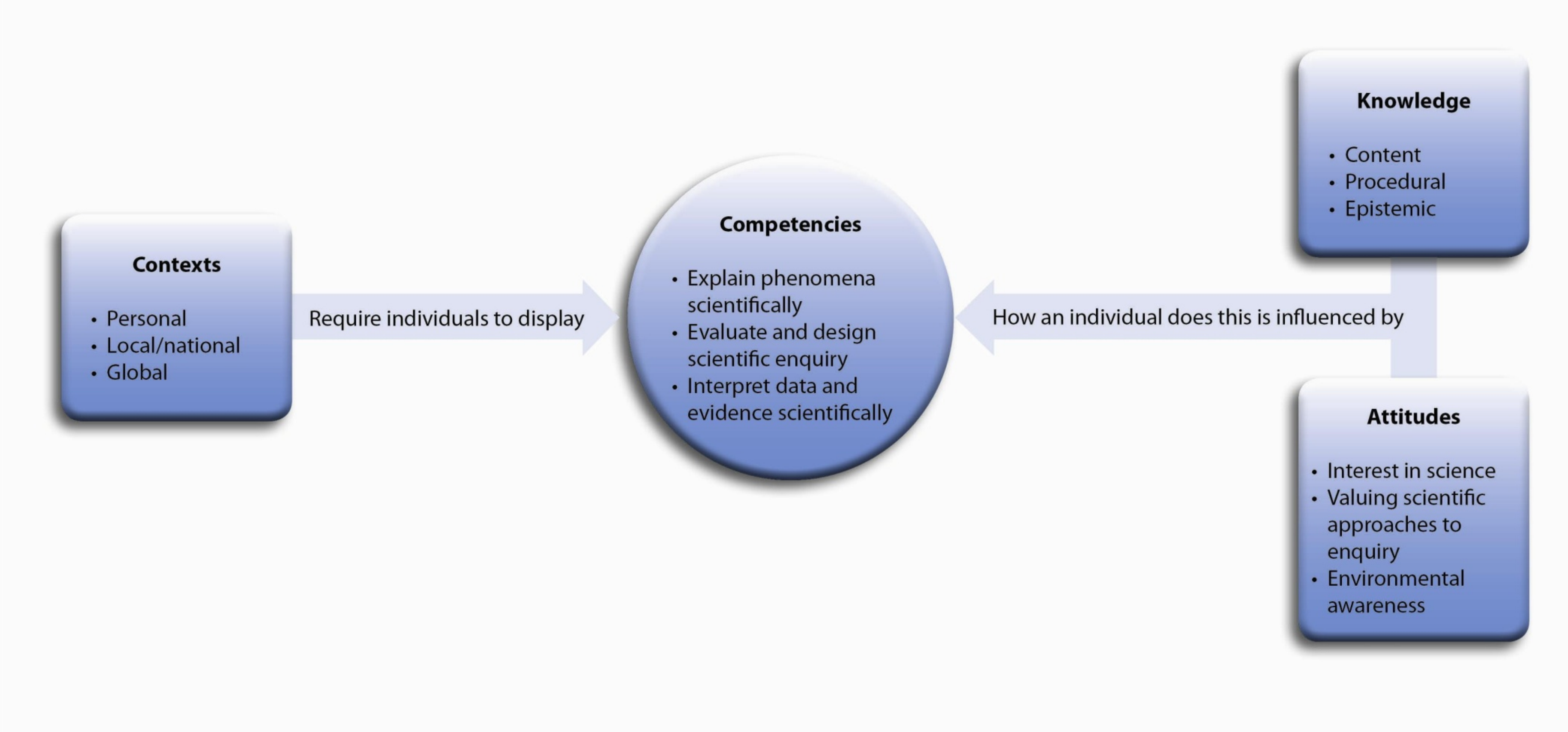
ORGANISATION OF THE DOMAIN

30. For purposes of assessment, the PISA 2015 definition of scientific literacy may be characterised as consisting of four interrelated aspects (see Figure 1).

Contexts	Personal, local, national and global issues, both current and historical, which demand some understanding of science and technology.
Knowledge	An understanding of the major facts, concepts and explanatory theories that form the basis of scientific knowledge. Such knowledge includes both knowledge of the natural world and technological artefacts (**content knowledge**), knowledge of how such ideas are produced (**procedural knowledge**) and an understanding of the underlying rationale for these procedures and the justification for their use (**epistemic knowledge**).
Competencies	The ability to explain phenomena scientifically, evaluate and design scientific enquiry, and interpret data and evidence scientifically.
Attitudes	A set of attitudes towards science indicated by an interest in science and technology; valuing of scientific approaches to enquiry, where appropriate, and a perception and awareness of environmental issues.

31. Each of these aspects is now discussed further below.

Figure 1. Framework for PISA 2015 Scientific Literacy Assessment



Contexts for Assessment Items

32. PISA 2015 will assess important scientific knowledge using contexts that raise issues and choices that are relevant to the science education curricula of participating countries. Such contexts will not, however, be restricted to the common aspects of participants' national curricula. Rather, the assessment will require evidence of the successful use of the three competencies required for scientific literacy in important situations reflecting personal, local, national and global contexts.

33. Assessment items will not be limited to school science contexts. In the PISA 2015 scientific literacy assessment, the focus of the items will be on situations relating to the self, family and peer groups (personal), to the community (local and national), and to life across the world (global). Technology based topics may be used as a common context. Also, appropriate to some topics are historical contexts which may be used to assess students' understanding of the processes and practices that are involved in advancing scientific knowledge.

34. Figure 2 lists the applications of science and technology, within personal, local, national and global settings that are primarily used as the contexts for assessment items. The applications will be drawn from a wide variety of life situations and will be generally consistent with the areas of application for scientific literacy in the previous PISA frameworks. The contexts will also be chosen in light of their relevance to students' interests and lives. The areas of application are: health and disease, 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.

Figure 2. Contexts for the PISA 2015 Scientific Literacy Assessment

	Personal	**Local/National**	**Global**
Health & Disease	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 actions, use and disposal of materials and devices	Population distribution, disposal of waste, environmental impact	Biodiversity, ecological sustainability, control of pollution, production and loss of soil/biomass
Hazards	Risk assessments of lifestyle choices	Rapid changes [*e.g.*, earthquakes, severe weather], slow and progressive changes [*e.g.*, coastal erosion, sedimentation], risk assessment	Climate change, impact of modern communication
Frontiers of Science and Technology	Scientific aspects of hobbies, personal technology, music and sporting activities	New materials, devices and processes, genetic modifications, health technology, transport	Extinction of species, exploration of space, origin and structure of the Universe

35. The PISA science assessment, however, is *not* an assessment of contexts. Rather, it assesses competencies and knowledge *in* specific contexts. The selection of these contexts, however, will be chosen on the basis of the knowledge and understanding that students are likely to have acquired by the age of fifteen.

36. Sensitivity to linguistic and cultural differences will be a priority in item development and selection, not only for the sake of the validity of the assessment, but also to respect these differences in participating countries. In developing any international test it is not possible, however, to include the differences in traditional and local knowledge about natural phenomena that exists between participating countries. This is not to deny, however, the contribution such knowledge can and has made to their respective cultures.

Scientific Competencies

37. Figure 3a-c provides an elaborated description of the kinds of performance expected for a display of the three competencies required for scientific literacy. The set of scientific competencies in Figure 3a-c reflects a view that science is best seen as an ensemble of social and epistemic practices which are common across all sciences (National Research Council, 2012). Hence, all these competencies are framed

as actions. They are written in this manner to convey the idea of what the scientifically literate person both understands and is capable of doing. Fluency with these practices is, in part, what distinguishes the expert scientist from the novice. Whilst it would be unreasonable to expect a 15-year-old student to have the expertise of a scientist, a scientifically literate student can be expected to appreciate their role and significance and undertake an approximation of the practice described.

Figure 3a. PISA 2015 Scientific Competencies

Explain phenomena scientifically
Recognise, 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.

38. Demonstrating the competency of *explaining phenomena scientifically* requires students to recall the appropriate content knowledge in a given situation and use it to interpret and provide an explanation for the phenomenon of interest. Such knowledge can also be used to generate tentative explanatory hypotheses in contexts where there is a lack of knowledge or data. A scientifically literate person should be expected to draw on standard scientific models to construct simple representations to explain everyday phenomena such as why antibiotics do not kill viruses, how a microwave oven works, or why gases are compressible but liquids are not and use these to make predictions. This competency includes the ability to describe or interpret phenomena and predict possible changes. In addition, it may involve recognising or identifying appropriate descriptions, explanations, and predictions.

Figure 3b. PISA 2015 Scientific Competencies

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 generalisability of explanations.

39. The competency of *evaluating and designing scientific enquiry* is required to evaluate reports of scientific findings and investigations critically. It is reliant on the ability to discriminate scientific questions

from other forms of enquiry or recognise questions that could be investigated scientifically in a given context. This competency requires a knowledge of the key features of a scientific investigation, for example, what things should be measured, what variables should be changed or controlled, or what action should be taken so that accurate and precise data can be collected. It requires an ability to evaluate the quality of data, which in turn depends on recognising that data are not always completely accurate. It also requires the competency to identify if an investigation is driven by an underlying theoretical premise or, alternatively, whether it seeks to determine identifiable patterns.

40. A scientifically literate person should also be able to recognise the significance of previous research in judging the value of any given scientific enquiry. Such knowledge is needed to situate the work and judge the importance of any possible outcomes. For instance, that the search for a malaria vaccine has been an on-going programme of scientific research for several decades. Hence, given the number of people who are killed by malarial infections, any findings that suggested a vaccine would be achievable would be of substantial significance. Moreover, students need to understand the importance of developing a sceptical disposition to all media reports in science recognising that all research builds on previous work, that the findings of any one study are always subject to uncertainty, and that the study may be biased by the sources of funding. This competency requires students to possess both procedural and epistemic knowledge but may also draw, to varying degrees, on their content knowledge of science.

Figure 3c. PISA 2015 Scientific Competencies

Interpret data and evidence scientifically
Analyse 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; • Analyse 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).

41. A scientifically literate person should be able to interpret and make sense of basic forms of scientific data and evidence that are used to make claims and draw conclusions. The display of such competency can require all three forms of knowledge of science.

42. Those who possess this competency should be able to interpret the meaning of scientific evidence and its implications to a specified audience in their own words, using diagrams or other representations as appropriate. This competency requires the use of mathematical tools to analyse or summarise data, and the ability to use standard methods to transform data to different representations.

43. This competency also includes accessing scientific information and producing and evaluating arguments and conclusions based on scientific evidence (Kuhn, 2010; Osborne, 2010). It may also involve evaluating alternative conclusions using evidence; giving reasons for or against a given conclusion using procedural or epistemic knowledge; and identifying the assumptions made in reaching a conclusion. In

short, the scientifically literate individual should be able to identify logical or flawed connections between evidence and conclusions.

Scientific Knowledge

44. The three competencies required for scientific literacy require three forms of knowledge that are discussed below.

Content Knowledge

45. Only a *sample* of the content domain of science can be assessed in the PISA 2015 scientific literacy assessment. Hence, it is important that clear criteria are used to guide the selection of knowledge that is assessed. These are that knowledge to be assessed will be selected from the major fields of physics, chemistry, biology, earth and space sciences such that the knowledge:

- has relevance to real-life situations;
- represents an important scientific concept or major explanatory theory that has enduring utility;
- is appropriate to the developmental level of 15-year-olds.

46. Therefore it will be assumed that students have some knowledge and understanding of the major explanatory ideas and theories of science such as our understanding of the history and scale of the Universe, the particle model of matter, and the theory of evolution by natural selection. These examples of major explanatory ideas are provided for illustrative purposes and there has been no attempt to list comprehensively all the ideas and theories that might be seen to be fundamental for a scientifically literate individual.

47. Figure 4 shows the content knowledge categories and examples selected by applying these criteria. Such knowledge is required for understanding the natural world and for making sense of experiences in personal, local, national, and global contexts. The framework uses the term "systems" instead of "sciences" in the descriptors of the content knowledge. The intention is to convey the idea that citizens have to understand concepts from the physical and life sciences, earth and space sciences, and their application in contexts where the elements of knowledge are interdependent or interdisciplinary. Things viewed as subsystems at one scale may themselves be viewed as whole systems at a smaller scale. For example, the circulatory system can be seen as an entity in itself or as a subsystem of the human body; a molecule can be studied as a stable configuration of atoms but also as a subsystem of a cell or a gas. Hence, applying scientific knowledge and deploying scientific competencies requires consideration of which system and which boundaries apply to any particular context.

Figure 4. Knowledge of the Content of Science in PISA 2015

Physical Systems that require knowledge of:
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.*, chemical reactions, energy transfer, acids/bases)
Motion and forces (*e.g.*, velocity, friction) and action at a distance (*e.g.*, magnetic, gravitational and electrostatic forces)
Energy and its transformation (*e.g.*, conservation, dissipation, chemical reactions)
Interactions between energy and matter (*e.g.*, light and radio waves, sound and seismic waves)
Living Systems that require knowledge of:
Cells (*e.g.*, structures and function, DNA, plant and animal)
The concept of an organism (*e.g.*, unicellular and multicellular)
Humans (*e.g.*, health, nutrition, subsystems such as digestion, respiration, circulation, excretion, reproduction and their relationship)
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 that require knowledge of:
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, galaxies)
The history and scale of the Universe and its history (*e.g.*, light year, Big Bang theory)

Procedural Knowledge

48. A fundamental goal of science is to generate explanatory accounts of the material world. Tentative explanatory accounts are first developed and then tested through empirical enquiry. Empirical enquiry is reliant on certain well-established concepts such as the notion of dependent and independent variables, the control of variables, types of measurement, forms of error, methods for minimising error, common patterns observed in data, and methods of presenting data. It is this knowledge of the concepts and procedures that are essential for scientific enquiry that underpins the collection, analysis and interpretation of scientific data. Such ideas form a body of procedural knowledge which has also been called 'concepts of evidence' (Gott, Duggan, & Roberts, 2008; Millar, Lubben, Gott, & Duggan, 1995). One can think of procedural knowledge as knowledge of the standard procedures scientists use to obtain reliable and valid data. Such knowledge is needed both to undertake scientific enquiry and engage in critical review of the evidence that might be used to support particular claims. It is expected, for instance, that students will know that scientific knowledge has differing degrees of certainty associated with it and can explain why, for instance, that there is a difference between the confidence associated with measurements of the speed of light (which has been measured many times with ever more accurate instrumentation) and measurements of fish stocks in the North Atlantic or the mountain lion population in California. The examples listed in Figure 5 convey the general features of procedural knowledge that may be tested.

Figure 5. PISA 2015 Procedural Knowledge

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 minimising 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 randomised 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

49. Epistemic knowledge is a knowledge of the constructs and defining features essential to the process of knowledge building in science and *their role in justifying* the knowledge produced by science *e.g.*, a hypothesis, a theory or an observation *and* its role in contributing to how we know what we know (Duschl, 2007). Those who have such knowledge can explain, with examples, the distinction between a scientific theory and a hypothesis or a scientific fact and an observation. They would know that the construction of models, be they directly representational, abstract or mathematical, is a key feature of science and that such models are akin to maps rather than accurate pictures of the material world. They would, for instance, recognise that any particle model of matter is an idealised representation of matter and be able to explain how the Bohr model is a limited model of what we know about the atom and its constituent parts. They will recognise that the conception of a 'theory' as used in science is not the same as the notion of a 'theory' in everyday language where it is used as a synonym for a 'guess' or a 'hunch'. Whereas procedural knowledge is required to explain what is meant by the control of variables strategy, being able to explain *why* the use of the control of variables strategy or replication of measurements is central to establishing knowledge in science is epistemic knowledge.

50. Scientifically literate individuals will also understand that scientists draw on data to advance claims to knowledge and that argument is a commonplace feature of science. In particular, they will know that some arguments in science are hypothetico-deductive (*e.g.*, Copernicus' argument for the heliocentric system), some are inductive (the conservation of energy), and some are an inference to the best explanation (Darwin's theory of evolution or Wegener's argument for moving continents). Also understood would be the role and significance of peer review as the mechanism that the scientific community has established for testing claims to new knowledge. As such, epistemic knowledge provides a rationale for the procedures and practices in which scientists engage, a knowledge of the structures and defining features which guide scientific enquiry, and the foundation for the basis of belief in the claims that science makes about the natural world.

51. Figure 6 represents what are considered to be the major features of epistemic knowledge necessary for scientific literacy.

Figure 6. PISA 2015 Epistemic Knowledge

Epistemic Knowledge
The constructs and defining features of science. That is: 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. That is: 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.

52. Epistemic knowledge is most likely to be tested in a pragmatic fashion in a context where a student is required to interpret and answer a question that requires some epistemic knowledge rather than assessing directly whether they understand the features in Figure 6. For instance, students may be asked to identify whether the conclusions are justified by the data or what piece of evidence best supports the hypothesis advanced in an item and explain why.

Sample Items

53. In this section, three examples of science units are presented. The first is from PISA 2006, and is included to demonstrate the linkage between the 2006 and the 2015 framework. Questions from the unit are shown in the original paper based format and also how they might be transposed and presented

onscreen. The second example is a new onscreen unit illustrating the 2015 scientific literacy framework. The third example illustrates an interactive simulated scientific enquiry environment enabling assessment within a rich contextual setting.

Science example 1: Greenhouse

54. Science example 1 is titled GREENHOUSE and deals with the increase of the average temperature of the Earth's atmosphere. The stimulus material consists of a short text introducing the term "Greenhouse effect" and includes graphical information on the average temperature of the Earth's atmosphere and the carbon dioxide emission on the Earth over time.

55. The area of application is Environment Quality within a global setting.

SCIENCE EXAMPLE 1: GREENHOUSE

Read the texts and answer the questions that follow.

THE GREENHOUSE EFFECT: FACT OR FICTION?

Living things need energy to survive. The energy that sustains life on the Earth comes from the Sun, which radiates energy into space because it is so hot. A tiny proportion of this energy reaches the Earth.

The Earth's atmosphere acts like a protective blanket over the surface of our planet, preventing the variations in temperature that would exist in an airless world.

Most of the radiated energy coming from the Sun passes through the Earth's atmosphere. The Earth absorbs some of this energy, and some is reflected back from the Earth's surface. Part of this reflected energy is absorbed by the atmosphere.

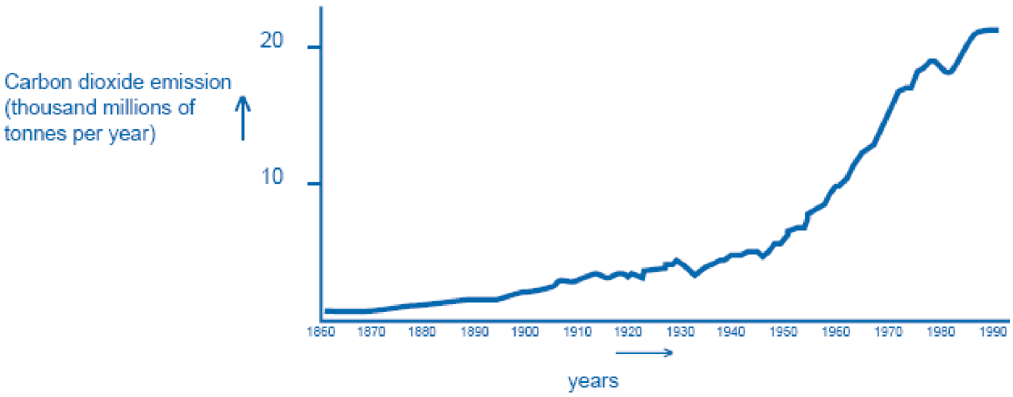
As a result of this the average temperature above the Earth's surface is higher than it would be if there were no atmosphere. The Earth's atmosphere has the same effect as a greenhouse, hence the term greenhouse effect.

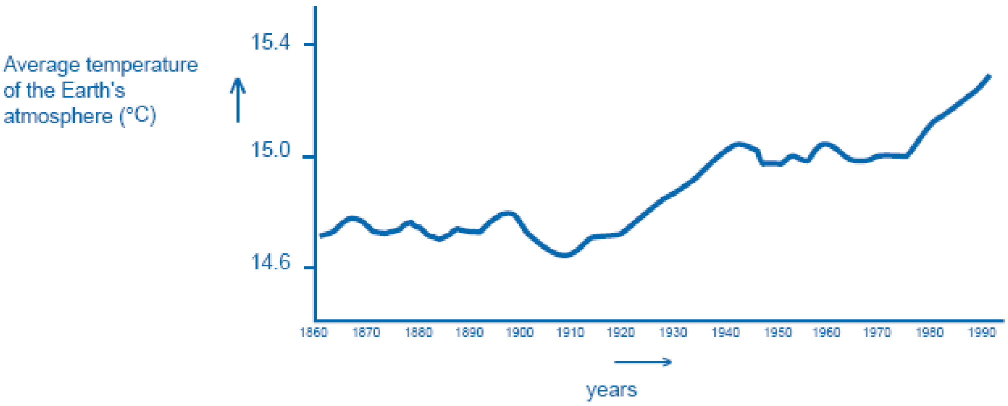
The greenhouse effect is said to have become more pronounced during the twentieth century.

It is a fact that the average temperature of the Earth's atmosphere has increased. In newspapers and periodicals the increased carbon dioxide emission is often stated as the main source of the temperature rise in the twentieth century.

A student named André becomes interested in the possible relationship between the average temperature of the Earth's atmosphere and the carbon dioxide emission on the Earth.

In a library he comes across the following two graphs.





André concludes from these two graphs that it is certain that the increase in the average temperature of the Earth's atmosphere is due to the increase in the carbon dioxide emission.

Question 1: GREENHOUSE

What is it about the graphs that supports André's conclusion?

....
....

Figure 7. Framework Categorisation for GREENHOUSE Question 1

Framework categories	2006 Framework	2015 Framework
Knowledge type	Knowledge about science	Epistemic
Competency	Explaining phenomena scientifically	Explaining phenomena scientifically
Context	Environmental, Global	Environmental, Global
Cognitive demand	Not applicable	Medium

56. Question 1 demonstrates how the 2015 framework largely maps onto the same categories as the 2006 framework, using the same competency and context categorisations. The 2006 framework included two categorisations of scientific knowledge; knowledge *of* science (referring to knowledge of the natural world across the major fields of science) and knowledge *about* science (referring to the means and goals of science). The 2015 framework elaborates on these two aspects, subdividing knowledge *about* science into procedural and epistemic knowledge. Question 1 requires students to understand not only how the data is represented in the two graphs, but also to consider whether this evidence scientifically justifies a given conclusion. This is one of the features of epistemic knowledge in the 2015 framework. The context categorisation is Environmental – global. A new feature of the 2015 framework is consideration of cognitive demand (see figure 23). This question requires an interpretation of graphs involving a few linked steps, and is therefore, using the descriptors from the framework, categorised as medium cognitive demand.

Question 2: GREENHOUSE

Another student, Jeanne, disagrees with André's conclusion. She compares the two graphs and says that some parts of the graphs do not support his conclusion.

Give an example of a part of the graphs that does not support André's conclusion. Explain your answer.

....
....
....

Figure 8. Framework Categorisation for GREENHOUSE Question 2

Framework categories	2006 Framework	2015 Framework
Knowledge type	Knowledge about science	Epistemic
Competency	Explaining phenomena scientifically	Explaining phenomena scientifically
Context	Environmental, Global	Environmental, Global
Cognitive demand	Not applicable	Medium

57. Question 2 requires students to interrogate the two graphs in detail. The knowledge, competency, context and cognitive demand are in the same categories as question 1.

Question 3: GREENHOUSE

André persists in his conclusion that the average temperature rise of the Earth's atmosphere is caused by the increase in the carbon dioxide emission. But Jeanne thinks that his conclusion is premature. She says: "Before accepting this conclusion you must be sure that other factors that could influence the greenhouse effect are constant".

Name one of the factors that Jeanne means.

....

Figure 9. Framework Categorisation for GREENHOUSE Question 3

Framework categories	**2006 Framework**	**2015 Framework**
Knowledge type	Knowledge about science	Procedural
Competency	Explaining phenomena scientifically	Explaining phenomena scientifically
Context	Environmental, Global	Environmental, Global
Cognitive demand	Not applicable	Medium

58. Question 3 requires students to consider control variables in terms of the critical review of evidence used to support claims. This is categorised as procedural knowledge in the 2015 framework.

59. The screenshots below illustrate how the Greenhouse question would be presented in an onscreen environment. The text and graphs are essentially unchanged, with students using page turners on the top right of the screen to view graphs and text as required. As the original questions were open responses, the onscreen version also necessitates an open response format in order to replicate the paper version as closely as possible, ensuring comparability between delivery modes and therefore protecting trend.

Figure 10. GREENHOUSE Presented Onscreen: Stimulus Page 1

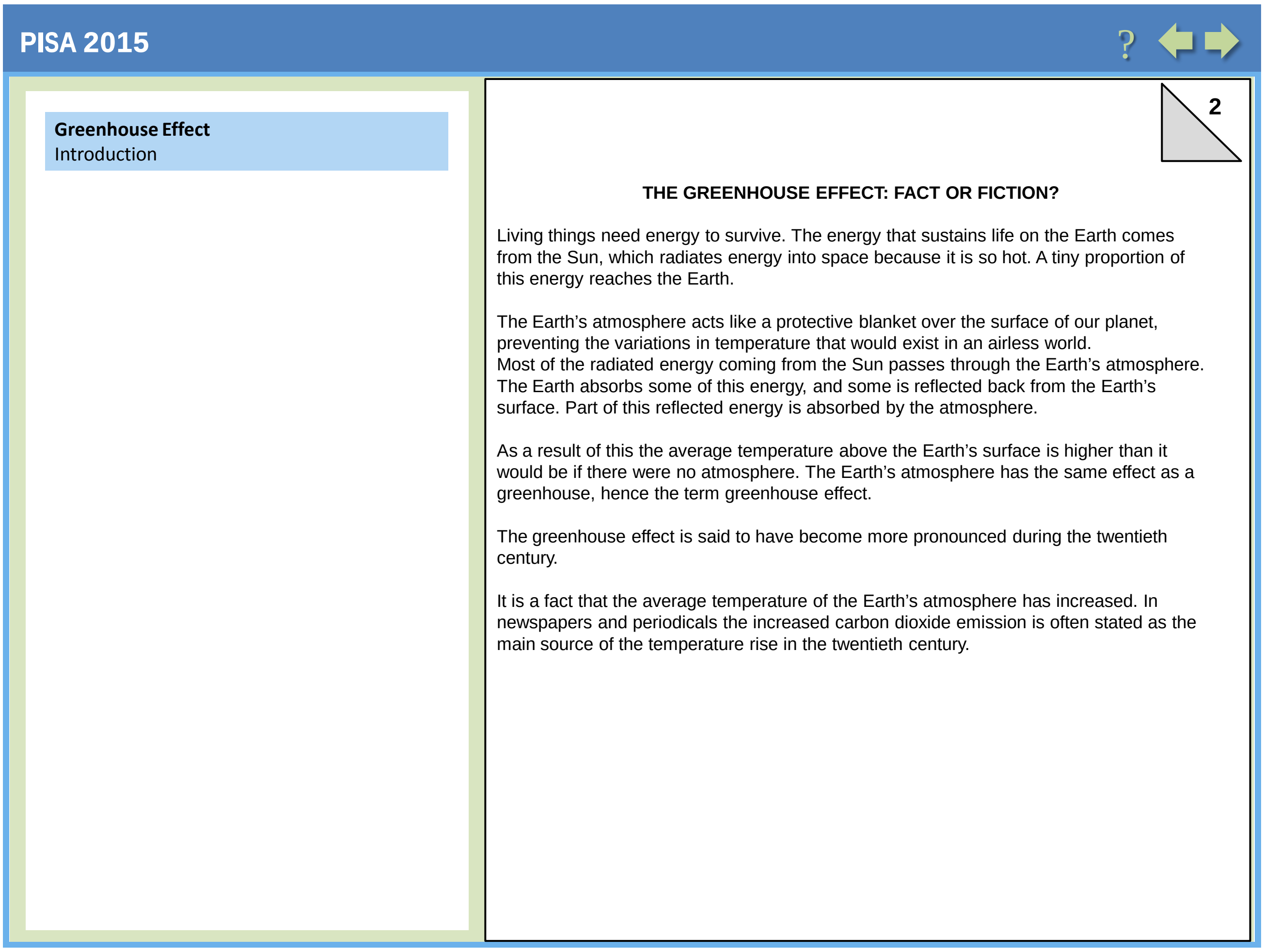


Figure 11. GREENHOUSE Presented Onscreen: Stimulus Page 2

PISA 2015

Greenhouse Effect
Introduction

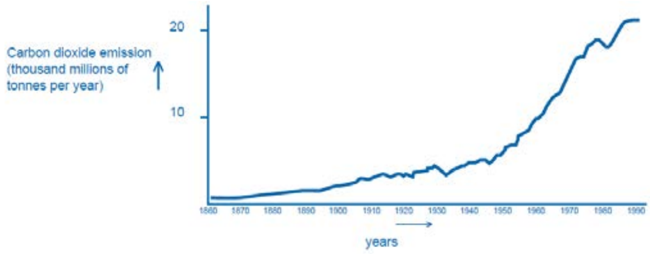
*Now click on **Next** to view the first question.*

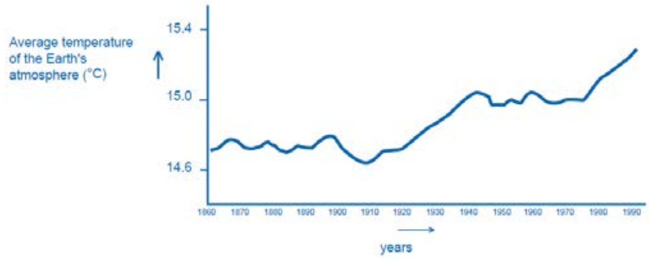
1

2

A student named André becomes interested in the possible relationship between the average temperature of the Earth's atmosphere and the carbon dioxide emission on the Earth.

In a library he comes across the following two graphs.





André concludes from these two graphs that it is certain that the increase in the average temperature of the Earth's atmosphere is due to the increase in the carbon dioxide emission.

Figure 12. GREENHOUSE Presented Onscreen: Question 1

PISA 2015

Greenhouse Effect
Question 1/3

Type your answer to the question below.

What is it about the graphs that supports André's conclusion?

2

THE GREENHOUSE EFFECT: FACT OR FICTION?

Living things need energy to survive. The energy that sustains life on the Earth comes from the Sun, which radiates energy into space because it is so hot. A tiny proportion of this energy reaches the Earth.

The Earth's atmosphere acts like a protective blanket over the surface of our planet, preventing the variations in temperature that would exist in an airless world.
Most of the radiated energy coming from the Sun passes through the Earth's atmosphere. The Earth absorbs some of this energy, and some is reflected back from the Earth's surface. Part of this reflected energy is absorbed by the atmosphere.

As a result of this the average temperature above the Earth's surface is higher than it would be if there were no atmosphere. The Earth's atmosphere has the same effect as a greenhouse, hence the term greenhouse effect.

The greenhouse effect is said to have become more pronounced during the twentieth century.

It is a fact that the average temperature of the Earth's atmosphere has increased. In newspapers and periodicals the increased carbon dioxide emission is often stated as the main source of the temperature rise in the twentieth century.

Figure 13. GREENHOUSE Presented Onscreen: Question 2

PISA 2015

Greenhouse Effect
Question 2/3

Type your answer to the question below.

Another student, Jeanne, disagrees with André's conclusion. She compares the two graphs and says that some parts of the graphs do not support his conclusion.

Give an example of a part of the graphs that does not support André's conclusion. Explain your answer.

2

THE GREENHOUSE EFFECT: FACT OR FICTION?

Living things need energy to survive. The energy that sustains life on the Earth comes from the Sun, which radiates energy into space because it is so hot. A tiny proportion of this energy reaches the Earth.

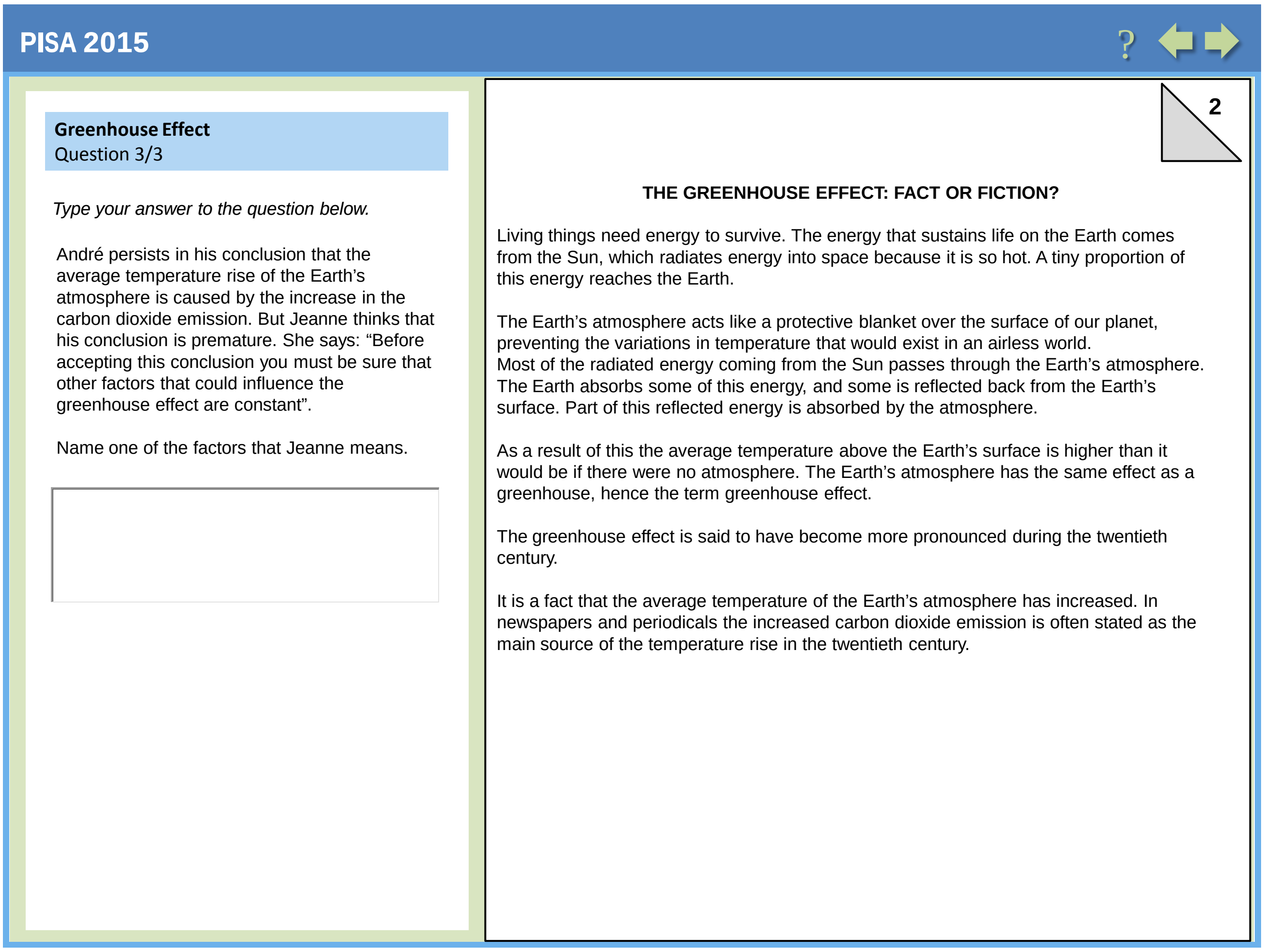
The Earth's atmosphere acts like a protective blanket over the surface of our planet, preventing the variations in temperature that would exist in an airless world.
Most of the radiated energy coming from the Sun passes through the Earth's atmosphere. The Earth absorbs some of this energy, and some is reflected back from the Earth's surface. Part of this reflected energy is absorbed by the atmosphere.

As a result of this the average temperature above the Earth's surface is higher than it would be if there were no atmosphere. The Earth's atmosphere has the same effect as a greenhouse, hence the term greenhouse effect.

The greenhouse effect is said to have become more pronounced during the twentieth century.

It is a fact that the average temperature of the Earth's atmosphere has increased. In newspapers and periodicals the increased carbon dioxide emission is often stated as the main source of the temperature rise in the twentieth century.

Figure 14. GREENHOUSE Presented Onscreen: Question 3



Science Example 2: Smoking

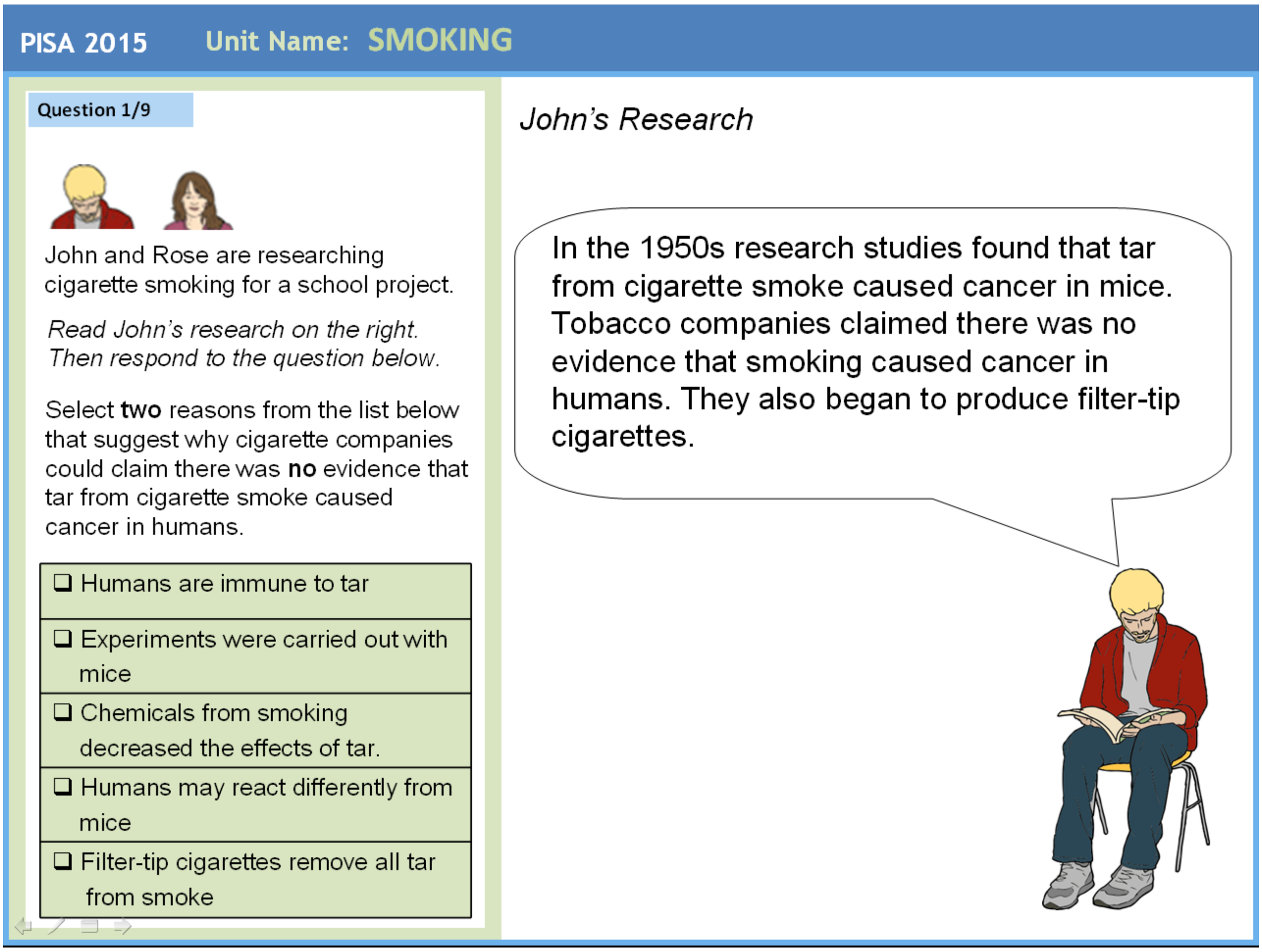
60. This new 2015 exemplar unit explores various forms of evidence linked to the harmful effects of smoking and the methods used to help people to stop smoking. New Scientific Literacy items for 2015 will only be developed for computer-based delivery and therefore this exemplar is only shown in an onscreen format.

61. All onscreen standard question types in the PISA 2015 computer platform have a vertical split screen with the stimuli presented on the right hand side and the questions and answer mechanisms on the left hand side.

Question 1: SMOKING

62. This question requires students to interpret given evidence using their knowledge of scientific concepts. They need to read the information in the stimulus about early research into the potential harmful effects of smoking, and then select two options from the menu to answer the question.

Figure 15. SMOKING: Question 1



63. In this question, students have to apply content knowledge using the competency of explaining phenomena scientifically. The context is categorised as health and disease in a local/national setting. The cognitive demand requires the use and application of conceptual knowledge and is therefore categorised as a medium level of demand.

Figure 16. Framework Categorisation for SMOKING Question 1

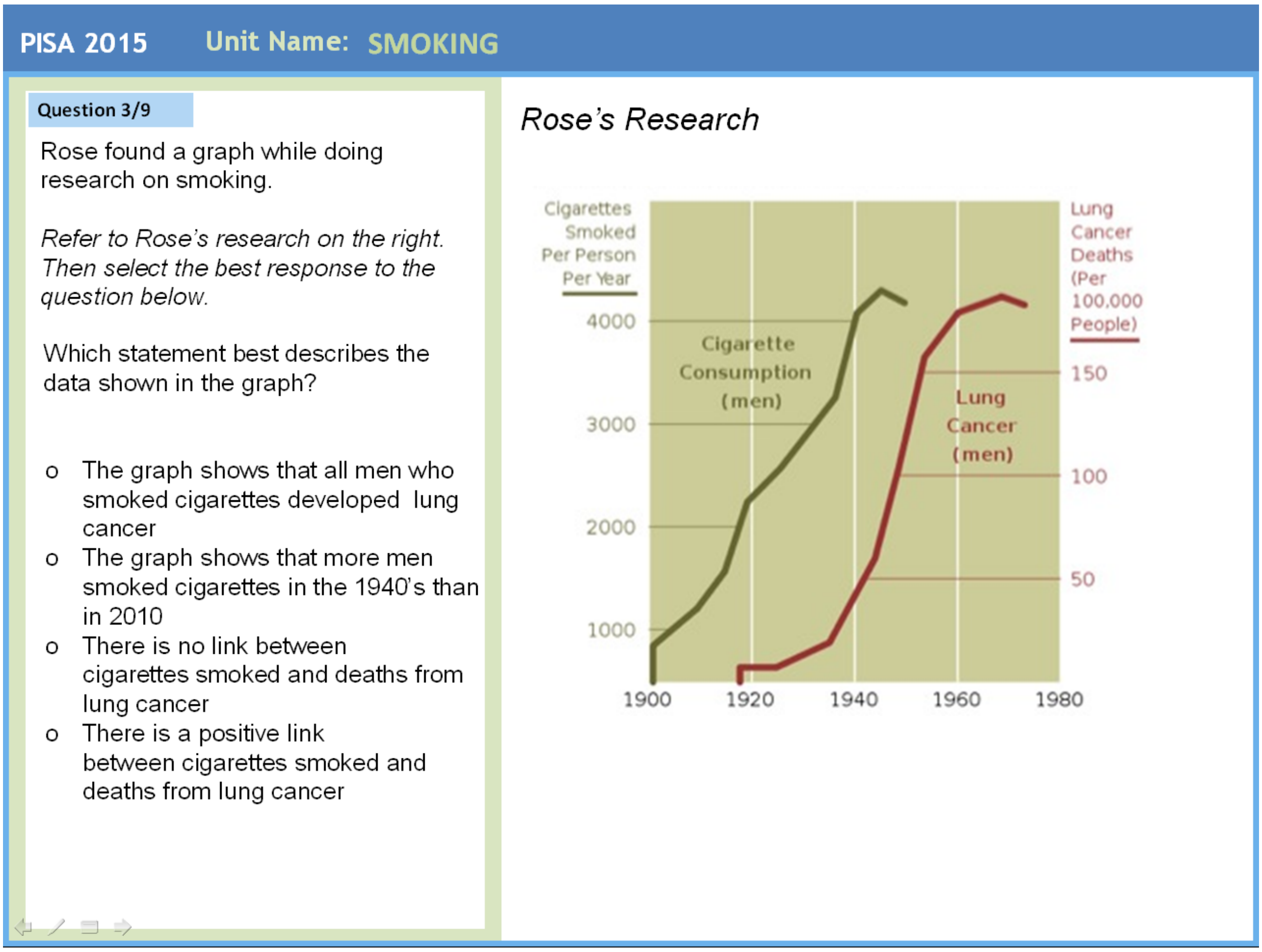
Framework categories	2015 Framework
Knowledge type	Content
Competency	Explain phenomena scientifically
Context	Health and Disease, Local/National
Cognitive demand	Medium

Question 2: SMOKING

64. This question explores students' understanding of data.

65. The right hand side of the screen shows authentic data of cigarette consumption and deaths from lung cancer in men over an extended period of time. Students are asked to select the best descriptor of the data by clicking on one of the radio buttons next to answer statements on the left hand side of the screen.

Figure 17. SMOKING: Question 2



66. This unit tests content knowledge using the competency of interpreting data and evidence scientifically.

67. The context is health and disease applied to a local/national setting. As students need to interpret the relationship between two graphs, the cognitive demand is categorised as medium.

Figure 18. Framework Categorisation for SMOKING Question 2

Framework categories	2015 Framework
Knowledge type	Content
Competency	Interpret data and evidence scientifically
Context	Health and Disease, Local/National
Cognitive demand	Medium

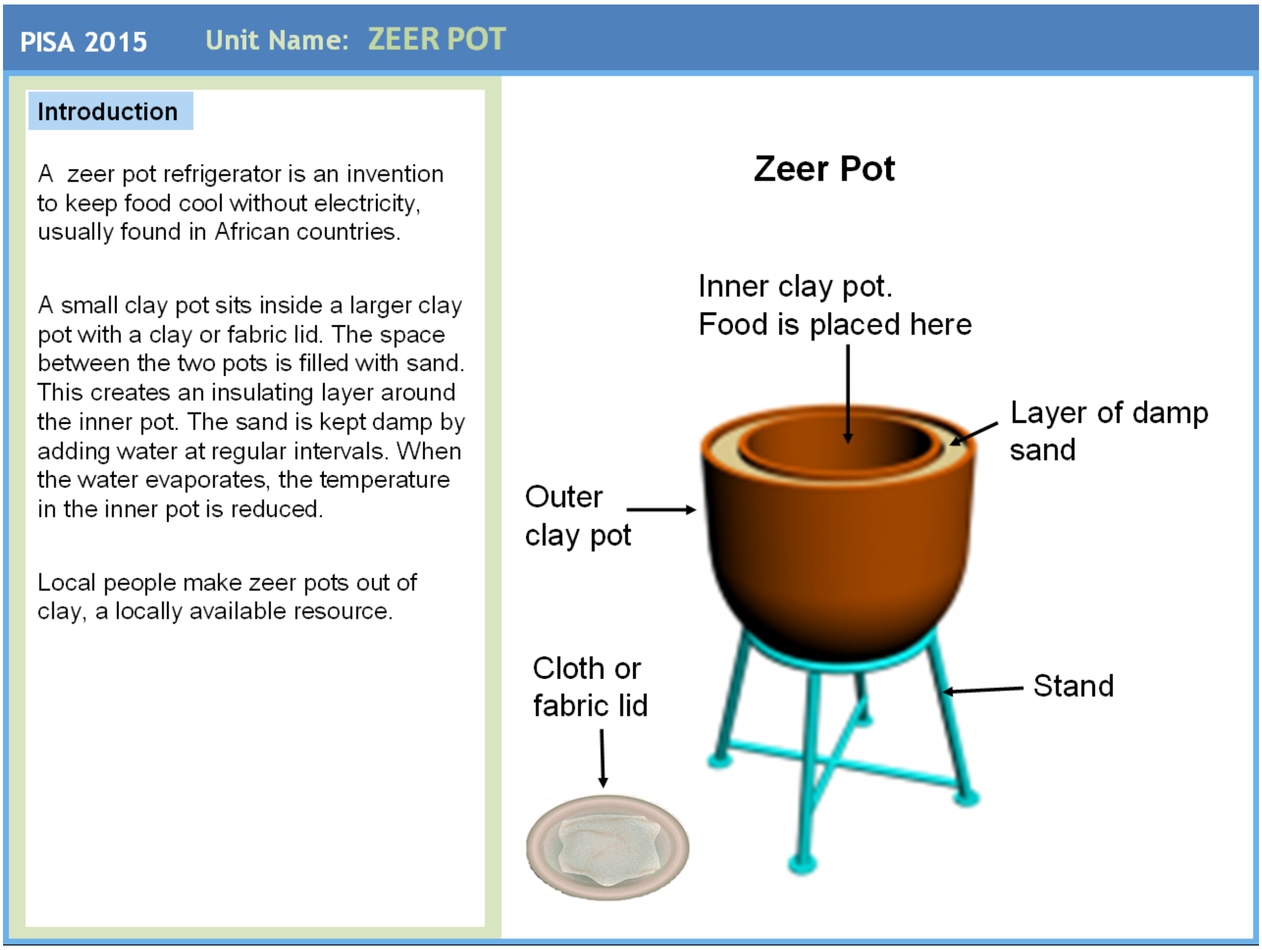
Science Example 3: Zeer pot

68. This new 2015 exemplar unit demonstrates a new feature of science assessment for 2015; the use of interactive tasks using simulations of scientific enquiry to explore and assess scientific literacy knowledge and competencies.

69. This unit is focussed on an authentic low cost cooling container called a Zeer pot, developed for localised needs in Africa, using readily available local resources. Cost and lack of electricity limit the use of refrigerators in these regions, while the hot climate necessitates food to be kept cool to prolong the length of time food can be kept before bacterial growth renders it a risk to health.

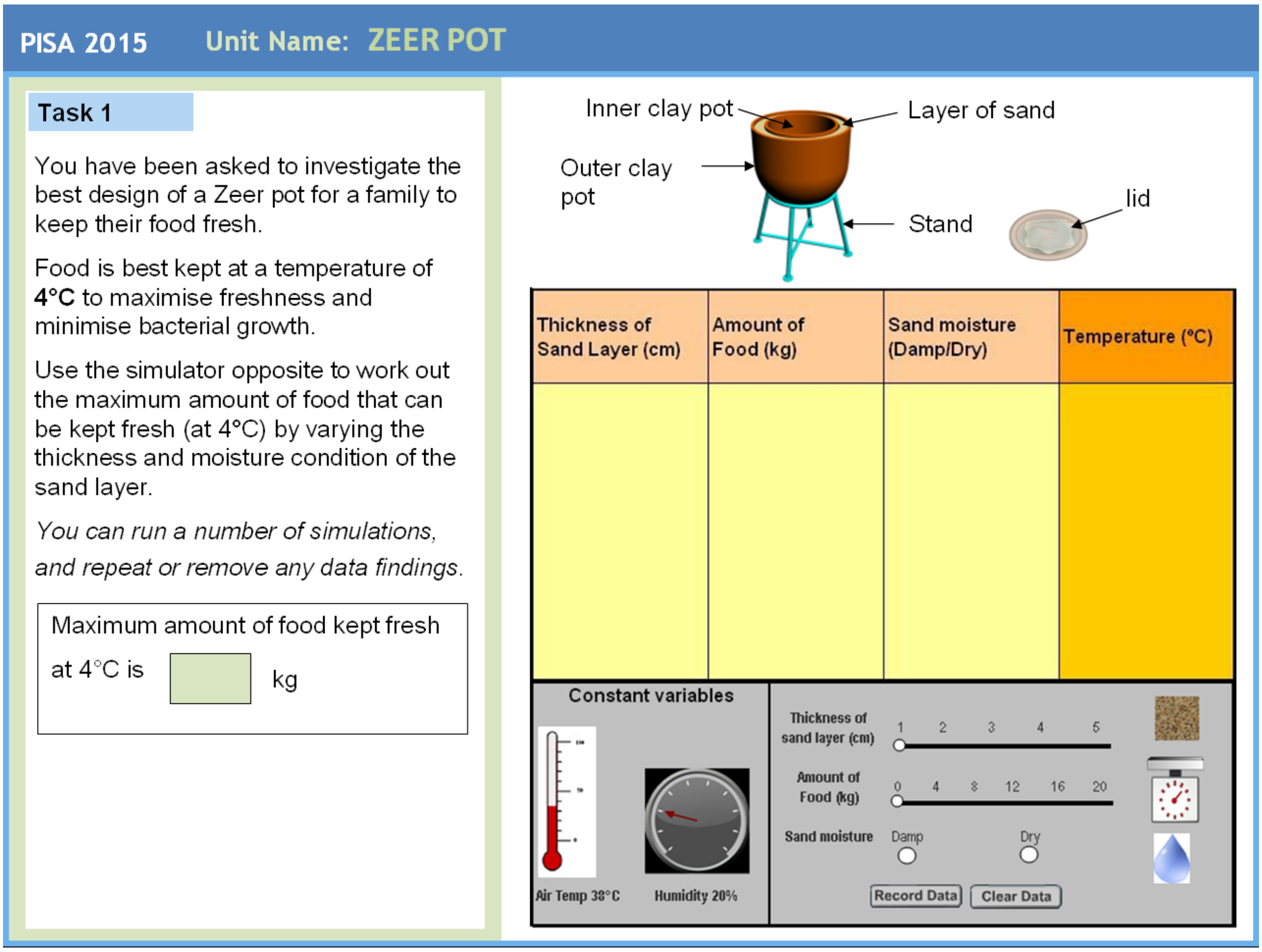
70. The first screen shot of this simulation introduces what a Zeer pot looks like and how it works. Students are not expected to have an understanding of how the process of evaporation causes cooling, just that it does.

Figure 19. ZEER POT: Stimulus



71. Using this simulation, students are asked to investigate the conditions that will produce the most effective cooling effects (4 ^{0}C) for keeping food fresh in the Zeer pot. The simulator keeps certain conditions constant (the air temperature and the humidity), but includes this information to enhance the authentic contextual setting. In the first question, students are asked to investigate the optimum conditions to keep the maximum amount of food fresh in the Zeer pot by altering the thickness of the sand layer and the moisture conditions.

Figure 20. ZEER POT: Question 1



72. When students have set their conditions (which also alter the visual display of the on screen Zeer pot), they press the record data button which then runs the simulation and populates the data chart. They need to run a number of data simulations, and can remove data or repeat any simulations as required. This screen then records their response to the maximum amount of food kept fresh at 4°C. Their approaches to the design and evaluation of this form of scientific enquiry can be assessed in subsequent questions.

73. The knowledge categorisation for this item is procedural and the competence is Evaluate and design scientific enquiry. The context categorisation is Natural Resources, although it also has links to Health and Disease. The cognitive demand of this question is categorised as high because students are given a complex situation, and they need to develop a systematic sequence of investigations to answer the question.

Figure 21. Framework Categorisation for ZEERPOT Question 1

Framework categories	2015 Framework
Knowledge type	Procedural
Competency	Evaluate and design scientific enquiry
Context	Natural Resources
Cognitive demand	High

Attitudes

Why attitudes matter

74. Peoples' attitudes towards science play a significant role in their interest, attention, and response to science and technology, and to issues that affect them in particular. One goal of science education is to develop attitudes that lead students to engage with scientific issues. Such attitudes also support the subsequent acquisition and application of scientific and technological knowledge for personal, local, national, and global benefit and lead to the development of self-efficacy (Bandura, 1997).

75. Attitudes form part of the construct of scientific literacy. That is, a person's scientific literacy includes certain attitudes, beliefs, motivational orientations, self-efficacy, and values. The construct of attitudes used in PISA draws upon Klopfer's (1976) structure for the affective domain in science education and reviews of attitudinal research (Gardner, 1975; Osborne, Simon, & Collins, 2003; Schibeci, 1984). A major distinction made in these reviews is between attitudes towards science and scientific attitudes. While the former is measured by the level of interest displayed in scientific issues and activities, the latter is a measure of a disposition to value empirical evidence as the basis of belief.

Defining attitudes towards science for PISA 2015

76. The PISA 2015 assessment will evaluate students' attitudes towards science in three areas: *Interest in science and technology, Environmental awareness* and *Valuing scientific approaches to enquiry* (see Figure 22) that are considered core to the construct of scientific literacy. These three areas were selected for measurement because a positive attitude towards science, a concern for the environment and an environmentally sustainable way of life, and a disposition to value the scientific approach to enquiry are features of a scientifically literate individual. Thus the extents to which individual students are, or are not interested in science and recognise its value and implications are considered important measures of the outcome of compulsory education. Moreover, in 2006, in 52 of the participating countries (including all OECD countries) students with a higher general interest in science performed better in science (OECD, 2007, p143).

77. *Interest in science and technology* was selected because of its established relationships with achievement, course selection, career choice, and lifelong learning. For instance, there is a considerable body of literature which shows that interest in science is established by age 14 for the majority of students (Ormerod & Duckworth, 1975; Tai, Qi Liu, Maltese, & Fan, 2006). Moreover, students with such an interest are more likely to pursue scientific careers. Policy concerns in many OECD countries about the number of students, particularly female students, choosing to pursue the study of science make the

measurement of attitudes towards science an important aspect of the PISA assessment and the results may provide information about a perceived declining interest in the study of science among young people (Bøe *et al*, 2011). This measure, when correlated with the large body of other information collected by PISA through the student, teacher and school questionnaires, may provide insights into the causes of any decline in interest.

78. *Valuing scientific approaches to enquiry* was chosen because scientific approaches to enquiry have been highly successful at generating new knowledge – not only within science itself, but also in the social sciences, and even finance and sports. Moreover, the core value of scientific enquiry and the Enlightenment is the belief in empirical evidence as the basis of rational belief. Recognising the *value of the scientific approach to enquiry* is, therefore, widely regarded as a fundamental objective of science education that warrants assessing. Appreciation of, and support for scientific enquiry implies that students can identify and also value scientific ways of gathering evidence, thinking creatively, reasoning rationally, responding critically, and communicating conclusions, as they confront life situations related to science and technology. Students should understand how scientific approaches to enquiry function, and why they have been more successful than other methods in most cases. Valuing scientific approaches to enquiry, however, does not mean that an individual has to be positively disposed towards all aspects of science or even use such methods themselves. Thus, the construct is a measure of students' attitudes towards the use of a scientific method to investigate material and social phenomenon and the insights that are derived from such methods.

79. *Environmental awareness* 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 and Wiseman, 1999; Eagles & Demare, 1999; Rickinson, 2001; Weaver, 2002). 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 (UNESCO, 2003). The International Implementation Scheme (UNESCO, September 2005) identifies the environment as one of the three spheres of sustainability (along with society (including culture) and economy) that should be included in all education for sustainable development programmes.

80. Given the importance of environmental issues to the continuation of life on Earth and the survival of humanity, the youth of today need to understand the basic principles of ecology and the need to organise their lives accordingly. This means that developing an environmental awareness and a responsible disposition towards the environment is an important element of contemporary science education.

81. In PISA 2015 these specific attitudes toward science will be measured by the student questionnaire. For each of these attitudes, Figure 22 provides the details of the specific sub-constructs that it is intended to measure in 2015.

Figure 22. PISA 2015 Areas for Assessment of Attitudes

Interest in Science
This is an attitude that is indicated by: • A curiosity in science and science-related issues and endeavours; • A willingness to acquire additional scientific knowledge and skills, using a variety of resources and methods; • An on-going interest in science, including consideration of science-related careers.

These dimensions of interest in science will be measured through the following constructs:

Interest in Learning Science: A measure of how much interest students have in learning about physics, human biology, geology and the processes and products of scientific enquiry.

Enjoyment of Science: A measure of how much students like learning about science both in and out of school.

Future Orientated Science Activities: A measure of the level of interest students have in pursuing scientific careers or the study of science after school.

Instrumental Motivation to Learn: A measure of the extent to which a students' motivation to learn science is extrinsically motivated by the opportunities science offers for employment.

General Value of Science: A measure of how much prestige the student holds about a range of different careers including scientific ones.

Self-Efficacy in Science: A measure of how able the student perceives they are at science.

The Occupational Prestige of Specific Careers: A measure of how valuable the student sees science to be for him or herself.

Use of Technology: A scale that measures how adolescents approach and use new technology.

Out-of-School Science Experiences: A measure of the range of extra-curricular and out-of-school science activities that students engage in.

Career Aspirations: A broad measure of the disposition that students have towards scientific careers.

School Preparation for Science Career: A measure of how well the student feels that their formal science education and school has provided them with the knowledge and skills needed for a scientific career.

Student Information on Science Career: A measure of how well-informed the student feels that they area about possible science careers.

Valuing Scientific Approaches to Enquiry

This is an attitude that is indicated by:

- A commitment to evidence as the basis of belief for explanations of the material world;
- A commitment to the scientific approach to enquiry when appropriate;
- A valuing of criticism as a means of establishing the validity of any idea.

Environmental Awareness
This is an attitude indicated by: • A concern for the environment and sustainable living; • A disposition to take and promote environmentally sustainable behaviours. These elements of environmental awareness will be measured using the following constructs: • Awareness of environmental issues: A measure of how informed students are about current environmental issues. • Perception of environmental issues: A measure of how concerned students are about environmental issues. • Environmental optimism: A measure of students' belief that their or human actions can contribute to sustaining and improving the environment.

82. Further detail of these constructs can be found in the Questionnaire Framework.

ASSESSMENT OF THE DOMAIN

Cognitive Demand

83. A key new feature of the 2015 PISA framework is the definition of levels of cognitive demand within the assessment of scientific literacy and across all three competences of the framework. In assessment frameworks, item difficulty, which is empirically derived, is often confused with cognitive demand. Empirical item difficulty is estimated from the proportion of the test taker population that is successful in solving the item correctly and thus assesses the amount of knowledge held by the test taker population, whereas cognitive demand refers to the type of mental processing required (Davis & Buckendahl, 2011). Care needs to be taken to ensure that the depth of knowledge required, i.e., the cognitive demand test items set to students, is understood explicitly by the item developers and users of the PISA framework. For instance, an item can have high difficulty because the knowledge it is testing is not well known but the cognitive demand is simply recall. Conversely, an item can be cognitively demanding because it requires the individual to relate and evaluate many items of knowledge – each of which are easily recalled. Thus, not only should the PISA test instrument discriminate in terms of performance between easier and harder test items, the test also needs to provide information on how students across the ability range can deal with problems at different levels of cognitive demand (Brookhart & Nitko, 2011).

84, The competencies are articulated using a range of terms defining cognitive demand through the use of verbs such as ‘recognise’, ‘interpret’, ‘analyse’ and ‘evaluate’. However, in themselves these verbs do not necessarily indicate a hierarchical order of difficulty which is dependent on the level of knowledge required to answer any item. Various classifications of cognitive demand schemes have been developed and evaluated since Bloom's Taxonomy was first published (Bloom, 1956). These have been largely based on categorisations of knowledge types and associated cognitive processes that are used to describe educational objectives or assessment tasks.

85. Bloom’s revised Taxonomy (Anderson & Krathwohl, 2001) identifies four categories of knowledge – factual, conceptual, procedural and meta-cognitive. This categorisation considers these forms of knowledge to be hierarchical and distinct from the six categories of performance used in Bloom’s first taxonomy – remembering, understanding, applying, analysing, evaluating and creating. In Anderson and Krathwohl’s framework, these two dimensions are now seen to be independent of each other allowing for lower levels of knowledge to be crossed with higher order skills and vice versa.

86. A similar framework is offered by Marzano and Kendall's Taxonomy (2007) which also provides a two dimensional framework based on the relationship between how mental processes are ordered and the type of knowledge required. The use of mental processes is seen as a consequence of a need to engage with a task with meta-cognitive strategies which define potential approaches to solving problems. The cognitive system then uses either retrieval, comprehension, analysis or knowledge utilisation. Marzano and Kendall divide the knowledge domain into three types of knowledge, information, mental procedures and psychomotor, compared to the four categories in Bloom's revised Taxonomy. Marzano and Kendall argue that their taxonomy is an improvement upon Bloom’s Taxonomy because it offers a model of how humans actually think rather than simply an organising framework.

87. A different approach is offered by Ford and Wargo, (2012) who offer a framework for scaffolding dialogue as a way of considering cognitive demand. Their framework utilises four levels that build on each other: recall, explain, juxtapose and evaluate. Although this framework has not been specifically designed for assessment purposes it has many similarities to the PISA 2015 definition of scientific literacy and the need to make more explicit references to such demands in the knowledge and competencies.

88. Another schema can be found in the framework based on “Depth of Knowledge” developed by Webb (1997) specifically to address the disparity between assessments and the expectations of student learning. For Webb, levels of depth can be determined by taking into account the complexity of both the content and the task required. His schema consists of four major categories: level 1 (recall), level 2 (using skills and/or conceptual knowledge), level 3 (strategic thinking), and level 4 (extended thinking). Each category is populated with a large number of verbs that can be used to describe cognitive processes. Some of these appear at more than one level. This framework offers a more holistic view of learning and assessment tasks and requires an analysis of both the content and cognitive process demanded by any task. Webb’s depth of knowledge (DOK) approach is a simpler but more operational version of the SOLO Taxonomy (Biggs & Collis, 1982) which describes a continuum of student understanding through five distinct stages of pre-structural, unistructural, multistructural, relational and extended abstract understanding.

89. All the frameworks described briefly above have served to develop the knowledge and competencies in the 2015 PISA Framework. In drawing up such a framework it is recognised that there are challenges in developing test items based on a cognitive hierarchy. The three main challenges are that:

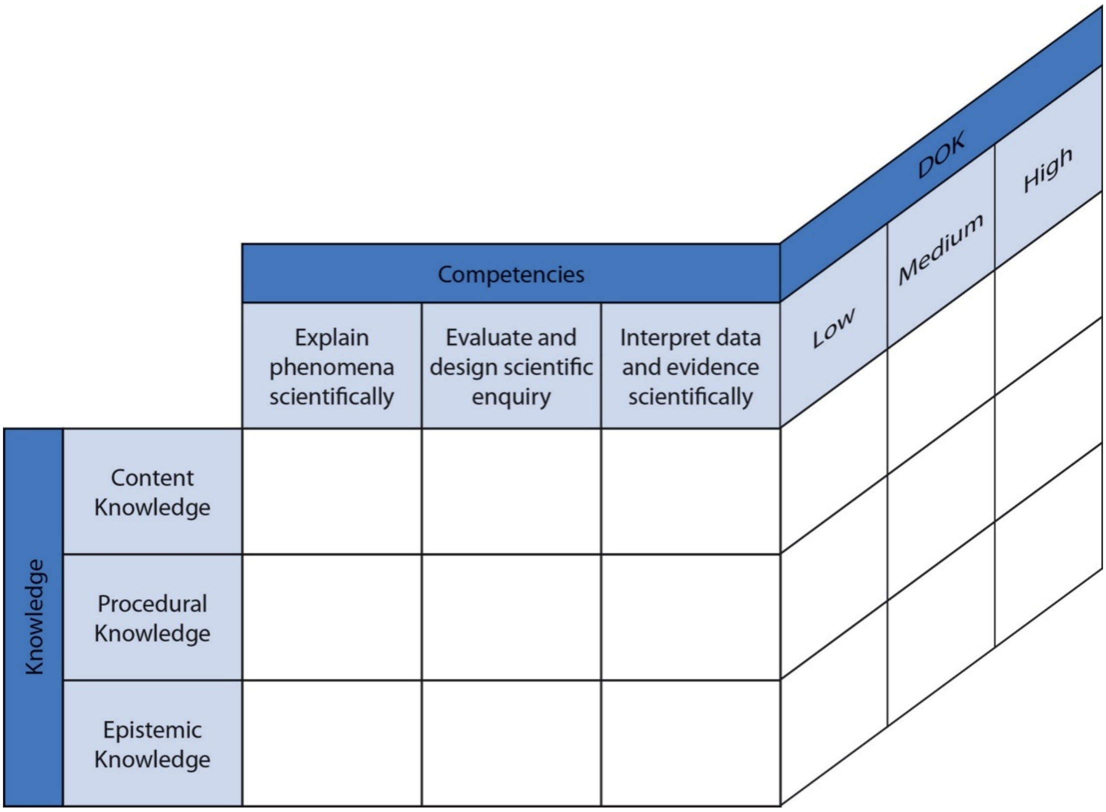
a) Too much effort is made to fit test items into particular cognitive frameworks which can lead to poorly developed items;

b) Misclassification between intended and actual demand with frameworks defining rigorous, cognitively demanding goals, and items which may operationalise the standard in a much less cognitively demanding way;

c) Without a well-defined and understood cognitive framework, item writing and development often focuses on item difficulty and uses a limited range of cognitive processes and knowledge types, which are then only described and interpreted post hoc, rather than building from a theory of increasing competency.

90. The approach taken for the 2015 Framework is to use an adapted version of Webb’s Depth of Knowledge grid (Webb, 1997) alongside the desired knowledge and competencies. As the competencies are the central feature of the framework, the cognitive framework needs to assess and report on them across the student ability range. Webb’s Depth of Knowledge Levels offer a taxonomy for cognitive demand that requires items to identify both the cognitive demand from the verbal cues that are used, *e.g.*, analyse, arrange, compare, and the expectations of the depth of knowledge required.

Figure 23. PISA 2015 Framework for Cognitive Demand



91. The grid above in Figure 23 provides a framework for mapping items against the two dimensions of knowledge and competencies. In addition, each item can also be mapped using a third dimension based on a depth of knowledge taxonomy. This provides a means of operationalising cognitive demand as each item can be categorised as making demands that are:

- **Low (L)**

  Carrying out a one-step procedure, for example recall of a fact, term, principle or concept or locating a single point of information from a graph or table.

- **Medium (M)**

  Use and application of conceptual knowledge to describe or explain phenomena, select appropriate procedures involving two or more steps, organise/display data, interpret or use simple data sets or graphs.

- **High (H)**

  Analyse complex information or data, synthesise or evaluate evidence, justify, reason given various sources, develop a plan or sequence of steps to approach a problem.

92. Thus items that merely require recall of one piece of information make low cognitive demands, even if the knowledge itself might be quite complex. In contrast, items that require recall of more than one piece of knowledge and require a comparison and evaluation made of the competing merits of their relevance would be seen as having high cognitive demand. The difficulty of any item, therefore, is a combination both of the degree of complexity and range of knowledge it requires and the cognitive operations that are required to process the item.

93. Therefore the factors that determine the demand of items assessing science achievement include:

- The number and degree of complexity of elements of knowledge demanded by the item;
- The level of familiarity and prior knowledge that students may have of the content, procedural and epistemic knowledge involved;
- The cognitive operation required by the item *e.g.*, recall, analysis, evaluation;
- The extent to which forming a response is dependent on models or abstract scientific ideas.

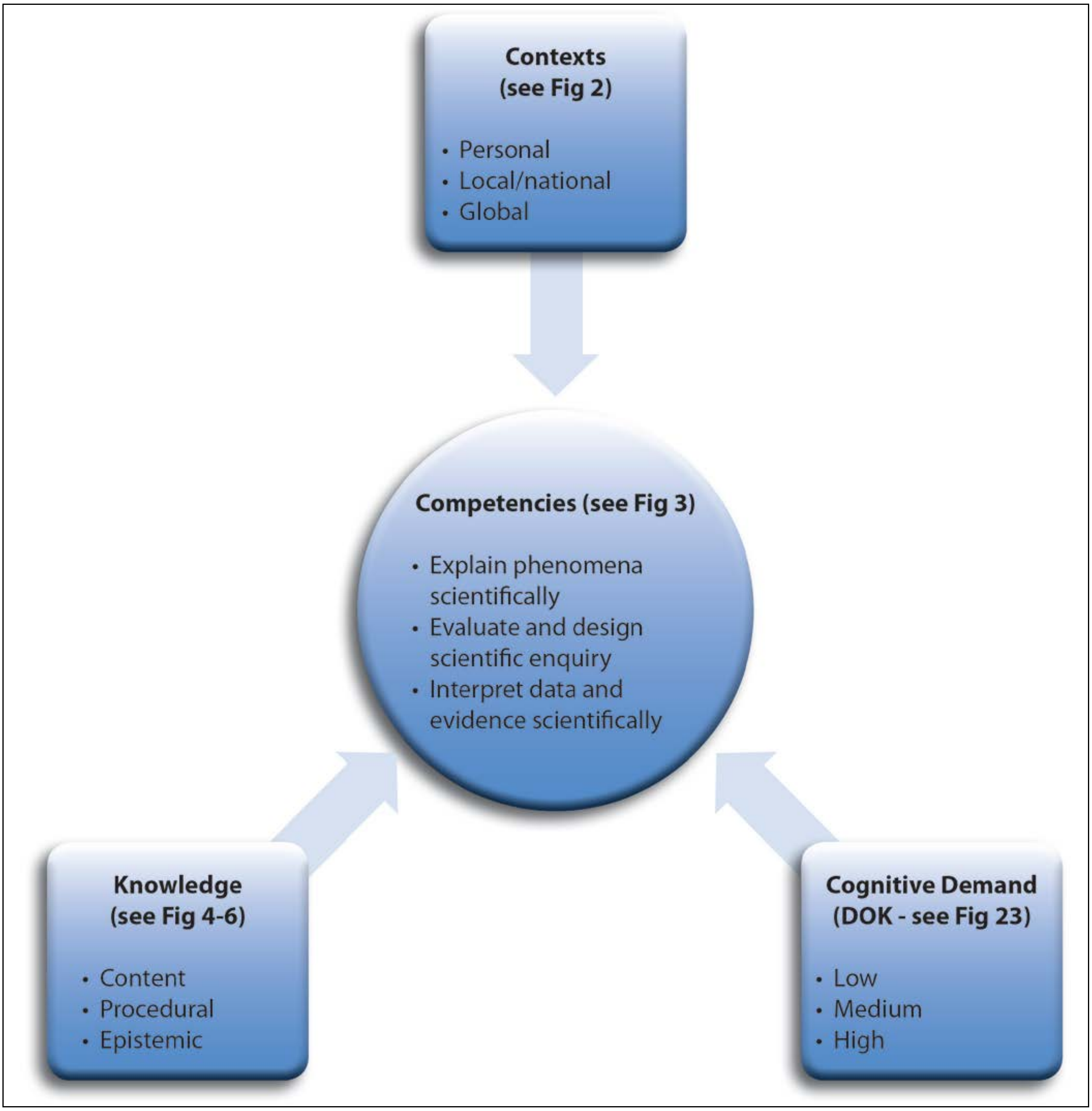
94. This four-factor approach allows for a broader measure of scientific literacy across a wider range of student ability. Categorising the cognitive processes required for the competencies that form the basis of scientific literacy together with a consideration of the depth of knowledge required offers a model for assessing the level of demand of individual items. In addition, its relative simplicity offers a framework for minimising the problems encountered in applying such frameworks. The use of this cognitive framework will also facilitate the development of an a priori definition of the descriptive parameters of the reporting proficiency scales (see Fig 27).

Test Characteristics

95. In accordance with the PISA definition of scientific literacy, test questions (items) will require the use and application of the scientific competencies and knowledge within a context.

96. Figure 24 is a variation of Figure 1 that presents the basic components of the PISA framework for the 2015 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, it shows the need to consider the contexts that will serve as stimulus material, the competencies required to respond to the questions or issues, the knowledge central to the exercise, and the cognitive demand.

Figure 24. A Tool for Constructing and Analysing Assessment Units and Items



97. A test unit is defined by specific stimulus material, which may be a brief written passage, or text accompanying a table, chart, graph, or diagram. In units created for PISA 2015, the stimulus material may also include non-static stimulus material, such as animations and interactive simulations. The items are a set of independently scored questions of various types, as illustrated by the examples already discussed. Further examples can be found at *[WEB REFERENCE TO BE INSERTED AFTER FIELD TRIAL]*

98. The reason PISA employs this unit structure is to facilitate the employment of contexts that are as realistic as possible, reflecting the complexity of real situations, while making efficient use of testing time.

Using situations about which several questions can be posed, rather than asking separate questions about a larger number of different situations, reduces the overall time required for a student to become familiar with the material in each question. However, the need to make each score point independent of others within a unit needs to be taken into account. It is also necessary to recognise that, because this approach reduces the number of different assessment contexts, it is important to ensure that there is an adequate range of contexts so that bias due to the choice of contexts is minimised.

99. PISA 2015 test units will require the use of all three scientific competencies and draw on all three forms of science knowledge. In most cases, each test unit will assess multiple competencies and knowledge categories. Individual items, however, will assess only one form of knowledge and one competency.

100. The need for students to read texts in order to understand and answer written questions on scientific literacy raises an issue of the level of reading literacy that will be required. Stimulus material and questions will use language that is as clear, simple and brief, and as syntactically simplified as possible while still conveying the appropriate meaning. The number of concepts introduced per paragraph will be limited. Questions within the domain of science that assess reading or mathematical literacy will be avoided.

Item Response Formats

101. Three classes of items will be used to assess the competencies and scientific knowledge identified in the framework. About one-third of the items will be in each of the three classes:

Simple multiple-choice: Items calling for

- selection of a single response from four options
- selection of a "hot spot," an answer that is a selectable element within a graphic or text.

Complex multiple-choice: Items calling for

- responses to a series of related "Yes/No" questions that are treated for scoring as a single item (the typical format in 2006)
- selection of more than one response from a list
- completion of a sentence by selecting drop-down choices to fill multiple blanks
- "drag-and-drop" responses, allowing students to move elements on screen to complete a task of matching, ordering, or categorising.

Constructed response: Items calling for written or drawn responses.

- Constructed response items in scientific literacy typically call for a written responses ranging from a phrase to a short paragraph (*e.g.*, two to four sentences of explanation). A small number of constructed response items call for drawing (*e.g.*, of a graph or diagram). For computer delivery, any such items will be supported by simple drawing editors that are specific to the response required.

102. Also, in 2015, some responses will be captured by interactive tasks, for example, a student's choices for manipulating variables in a simulated scientific enquiry. Responses to these interactive tasks will likely be scored as complex multiple choice items. Some kinds of responses to interactive tasks may be sufficiently open-ended that they will be treated as constructed response.

Assessment Structure

103. For PISA 2015, computer-based assessment will be the primary mode of delivery for all domains, including scientific literacy. All new science literacy items will only be available in the computer-based assessment. However a paper-based assessment instrument will be provided for countries choosing not to test their students by computer which will consist only of the trend items.

104. Scientific literacy items will be organised into 30-minute sections called "clusters." Each cluster will include either only new units or only trend units. Overall for 2015, the target number of clusters to be included in the main survey is:

Target number of clusters	**6**	clusters of trend units in 2015 main survey	**9**	clusters of new units in 2015 main survey

105. Each student will be assigned one two-hour test form. A test form will be composed of four clusters, with each cluster designed to occupy thirty minutes of testing time. The clusters are placed in multiple computer–based test forms, according to a rotated test design.

106. Each student will spend one hour on scientific literacy, with the remaining time assigned to either one or two of the additional domains of reading, maths and collaborative problem solving. For any countries taking the paper-based assessment instrument, intact clusters of 2006 units will be formed into a number of test booklets. It is important to note that the paper-based assessment will be limited to trend items and will not include any newly developed material. In contrast, the computer-based instrument will include newly developed items as well as trend items. Care will be taken when transposing paper-based trend items to an on-screen format that the presentation, response format and cognitive demand remain comparable.

107. The desired balance between the three knowledge components, content, procedural and epistemic knowledge, is shown in Figure 25 in terms of percentages of score points. Figure 26 also shows the target distribution of score points among the various knowledge categories. These weightings are broadly consistent with the previous framework and reflect a consensus view amongst the experts consulted in the writing of this framework.

Figure 25. Target Distribution of Score Points for Knowledge

	Systems			
Knowledge types	**Physical**	**Living**	**Earth & Space**	**Total over systems**
Content	*20-24%*	*20-24%*	*14-18%*	**54-66%**
Procedural	*7-11%*	*7-11%*	*5-9%*	**19- 31%**
Epistemic	*4-8%*	*4-8%*	*2-6%*	**10-22%**
Total over knowledge types	**36%**	**36%**	**28%**	**100%**

108. The target balance for scientific competencies is given in Figure 26. These weightings have been chosen so that the assessment is evenly split between items that draw predominantly on content knowledge and items that draw predominantly on procedural and/or epistemic knowledge.

Figure 26. Target Distribution of Score Points for Scientific Competencies

Scientific Competencies	**% of score points**
Explaining phenomena scientifically	*40-50%*
Evaluating and designing scientific enquiry	*20-30%*
Interpreting data and evidence scientifically	*30-40%*
TOTAL	**100%**

109. Item contexts will be spread across personal, local/national and global settings roughly in the ratio 1:2:1 as was the case in 2006. A wide selection of areas of application will be used for units, subject to satisfying as far as possible the various constraints imposed by the distribution of score points shown in Figure 25 and Figure 26.

Reporting Scales

110. To meet the aims of PISA, the development of scales of student achievement is essential. A descriptive scale of levels of competence needs to be based on a theory of how the competence develops, not just on a post-hoc interpretation of what items of increasing difficulty seem to be measuring. The 2015 draft framework has therefore defined explicitly the parameters of increasing competence and progression, allowing item developers to design items representing this growth in ability (Kane, 2006; Mislevy and Haertel, 2006). Initial draft descriptions of the scales are offered below, though it is recognised that these may need to be modified as data are accumulated after field testing of the items. Although comparability with the 2006 scale descriptors (OECD, 2007) has been maximised in order to enable trend analyses, the new elements of the 2015 framework such as depth of knowledge have also been incorporated. The scales have also been extended by the addition of a level '1b' to specifically address and provide a description of students at the lowest level of ability who demonstrate very minimal evidence of scientific literacy and would previously not have been included in the reporting scales. The initial draft scales for 2015 Framework therefore propose more detailed and more specific descriptors of the levels of Scientific Literacy, and not an entirely different model.

Figure 27. Initial Draft Reporting Scale Proposed for PISA 2015

[Note: Currently these descriptors should be seen as a hypothesis. When the field trials have been conducted, the data will enable these descriptions to be refined]

Level	Descriptor
6	At Level 6, students are able to use content, procedural and epistemic knowledge to consistently provide explanations, evaluate and design scientific enquiries and interpret data in a variety of complex life situations that require a high level of cognitive demand. They can draw appropriate inferences from a range of different complex data sources, in a variety of contexts and provide explanations of multi-step causal relationships. They can consistently distinguish scientific and non-scientific questions, explain the purposes of enquiry, and control relevant variables in a given scientific enquiry or any experimental design of their own. They can transform data representations, interpret complex data and demonstrate an ability to make appropriate judgments about the reliability and accuracy of any scientific claims. Level 6 students consistently demonstrate advanced scientific thinking and reasoning requiring the use of models and abstract ideas and use such reasoning in unfamiliar and complex situations. They can develop arguments to critique and evaluate explanations, models, interpretations of data and proposed experimental designs in a range of personal, local and global contexts.
5	At Level 5, students are able to use content, procedural and epistemic knowledge to provide explanations, evaluate and design scientific enquiries and interpret data in a variety of life situations in some but not all cases of high cognitive demand. They draw inferences from complex data sources, in a variety of contexts and can explain some multi-step causal relationships. Generally, they can distinguish scientific and non-scientific questions, explain the purposes of enquiry, and control relevant variables in a given scientific enquiry or any experimental design of their own. They can transform some data representations, interpret complex data and demonstrate an ability to make appropriate judgments about the reliability and accuracy of any scientific claims. Level 5 students show evidence of advanced scientific thinking and reasoning requiring the use of models and abstract ideas and use such reasoning in unfamiliar and complex situations. They can develop arguments to critique and evaluate explanations, models, interpretations of data and proposed experimental designs in some but not all personal, local and global contexts.
4	At Level 4, students are able to use content, procedural and epistemic knowledge to provide explanations, evaluate and design scientific enquiries and interpret data in a variety of given life situations that require mostly a medium level of cognitive demand. They can draw inferences from different data sources, in a variety of contexts and can explain causal relationships. They can distinguish scientific and non-scientific questions, and control variables in some but not all scientific enquiry or in an experimental design of their own. They can transform and interpret data and have some understanding about the confidence held about any scientific claims. Level 4 students show evidence of linked scientific thinking and reasoning and can apply this to unfamiliar situations. Students can also develop simple arguments to question and critically analyse explanations, models, interpretations of data and proposed experimental designs in some personal, local and global contexts.
3	At Level 3, students are able to use content, procedural and epistemic knowledge to provide explanations, evaluate and design scientific enquiries and interpret data in some given life situations that require at most a medium level of cognitive demand. They are able to draw a few inferences from different data sources, in a variety of contexts, and can describe and partially explain simple causal relationships. They can distinguish some scientific and non-scientific questions, and control some variables in a given scientific enquiry or in an experimental design of their own. They can transform and interpret simple data and are able to comment on the confidence of scientific claims. Level 3 students show some evidence of linked scientific thinking and reasoning, usually applied to familiar situations. Students can develop partial arguments to question and critically analyse explanations, models, interpretations of data and proposed experimental designs in some personal, local and global contexts.
2	At Level 2, students are able to use content, procedural and epistemic knowledge to provide explanations, evaluate and design scientific enquiries and interpret data in some given familiar life situations that require mostly a low level of cognitive demand. They are able to

	make a few inferences from different sources of data, in few contexts, and can describe simple causal relationships. They can distinguish some simple scientific and non-scientific questions, and distinguish between independent and dependent variables in a given scientific enquiry or in a simple experimental design of their own. They can transform and describe simple data, identify straightforward errors, and make some valid comments on the trustworthiness of scientific claims. Students can develop partial arguments to question and comment on the merits of competing explanations, interpretations of data and proposed experimental designs in some personal, local and global contexts.
1a	At Level 1a, students are able to use a little content, procedural and epistemic knowledge to provide explanations, evaluate and design scientific enquiries and interpret data in a few familiar life situations that require a low level of cognitive demand. They are able to use a few simple sources of data, in a few contexts and can describe some very simple causal relationships. They can distinguish some simple scientific and non-scientific questions, and identify the independent variable in a given scientific enquiry or in a simple experimental design of their own. They can partially transform and describe simple data and apply them directly to a few familiar situations. Students can comment on the merits of competing explanations, interpretations of data and proposed experimental designs in some very familiar personal, local and global contexts.
1b	At Level 1b, students demonstrate a little evidence to use content, procedural and epistemic knowledge to provide explanations, evaluate and design scientific enquiries and interpret data in a few familiar life situations that require a low level of cognitive demand. They are able to identify straightforward patterns in simple sources of data in a few familiar contexts and can offer attempts at describing simple causal relationships. They can identify the independent variable in a given scientific enquiry or in a simple design of their own. They attempt to transform and describe simple data and apply them directly to a few familiar situations.

111. The proposed level descriptors are based on the 2015 framework described in this document and offer a qualitative description of the differences between levels of performance. The factors used to determine the demand of items assessing science achievement that have been incorporated into this outline of the proficiency scales include:

- The number and degree of complexity of elements of knowledge demanded by the item;
- The level of familiarity and prior knowledge that students may have of the content, procedural and epistemic knowledge involved;
- The cognitive operation required by the item *e.g.*, recall, analysis, evaluation;
- The extent to which forming a response is dependent on models or abstract scientific ideas.

SUMMARY

112. Science will be the major domain in PISA 2015 and the 2015 definition builds on and develops the 2006 definition. In particular, the competencies required for scientific literacy have been further elaborated and the concept of ‘knowledge about science’ has been defined as two forms of knowledge – procedural and epistemic. In addition, the 2015 framework has articulated a conception of the range of cognitive demand required of items. The 2015 framework therefore represents a more detailed specification of particular aspects of scientific literacy that were embedded or assumed in the earlier definitions.

113. The PISA 2006 definition of scientific literacy has its origin in the consideration of what 15-year-old students should know, value and be able to do as “preparedness for life” in modern society. Central to the definition and the assessment of scientific literacy are the competencies that are characteristic of science and scientific enquiry. The ability of students to make use of these competencies depends on their scientific knowledge, both their content knowledge of the natural world and their procedural and epistemic knowledge. In addition, it depends on a willingness to engage with science related topics. Their attitudes towards science-related issues are measured separately in the background questionnaire.

114. This framework describes and illustrates the scientific competencies and knowledge that will be assessed in PISA 2015 (see Figure 28), and the contexts for test items. Test items will be grouped into units with each unit beginning with stimulus material that establishes the context for items. A combination of item types will be used. Computer-based delivery for 2015 offers the opportunity for several novel item formats, including animations and interactive simulations. This will improve the validity of the test and the ease of scoring.

Figure 28. Major Components of the PISA 2015 Framework for Scientific Literacy

Competencies	Knowledge	Attitudes
• Explaining phenomena scientifically • Evaluating and designing scientific enquiry • Interpreting data and evidence scientifically	• Knowledge of the content of science: ➢ Physical systems ➢ Living systems ➢ Earth and space systems • Procedural knowledge • Epistemic knowledge	• Interest in science • Valuing scientific approaches to enquiry • Environmental awareness

115. The ratio of items assessing students’ content knowledge of science to items assessing procedural *and* epistemic knowledge of science will be about 3:2. Approximately 50 per cent of the items will test the competency to explain phenomena scientifically, 30 per cent the competency to interpret data and evidence scientifically, and 20 per cent their competency to evaluate and design scientific enquiry. The cognitive

demand of items will consist of a range of low, medium and hard. The combination of these weightings and a range of items of varying cognitive demand will enable proficiency levels to be constructed to describe performance in the three competencies that define scientific literacy.

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