NATIONAL ASSESSMENT PROGRAM
SCIENCE LITERACY, YEAR 6, 2009

ASSESSMENT DOMAIN AND PROGRESS MAP

Assessment Domain: Science literacy

The national review of the status and quality of teaching and learning of science in Australian schools (Goodrum, Hackling, & Rennie, 2001) argued that the broad purpose of science in the compulsory years of schooling is to develop science literacy for all students.

Scientific literacy is a high priority for all citizens, helping them

- to be interested in, and understand the world around them,
- to engage in the discourses of and about science,
- to be sceptical and questioning of claims made by others about scientific matters,
- to be able to identify questions, investigate and draw evidence-based conclusions, and
- to make informed decisions about the environment and their own health and well-being

(Hackling, Goodrum, & Rennie, 2001, p. 7).

Science literacy is important as it contributes to the economic and social well-being of the nation, and improved decision-making at public and personal levels (Laugksch, 2000). The Organisation of Economic Cooperation and Development (OECD) Program for International Student Assessment (PISA) assessments focus on aspects of preparedness for adult life in terms of functional knowledge and skills that allow citizens to participate actively in society. It is argued that scientifically literate persons are “able to use scientific knowledge and processes not just to understand the natural world but (also) to participate in decisions that affect it” (OECD Programme for International Student Assessment, 1999, p. 13).

The OECD PISA (1999) has defined scientific literacy as:

> *…the capacity to use scientific knowledge, to identify questions (investigate)*[1] *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 (p. 60)*

This definition has been adopted for the National Assessment Program — Science Literacy (NAP — SL) in accord with the Ball, Rae and Tognolini (2000) Report recommendation.

Science literacy: Progress Map

A science literacy progress map (Appendix 1) has been developed based on the construct of science literacy and on an analysis of State and Territory curriculum and assessment frameworks. The progress map describes the development of science literacy across three strands of knowledge which are inclusive of Ball et al.’s concepts and processes and the elements of the OECD PISA definition.

The five elements of scientific literacy, including concepts and processes, used in PISA 2000 (OECD PISA 1999) include:

- demonstrating understanding of scientific concepts,
- recognising scientifically investigable questions,
- identifying evidence needed in a scientific investigation
- drawing or evaluating conclusions, and
- communicating valid conclusions.

1 Due to the constraints of large scale testing, PISA is not able to include performance tasks such as conducting investigations. Consequently, the PISA definition has omitted reference to investigating. The word ‘investigate’ has been inserted into the definition for the purpose of the National Assessment Program: Science Literacy (NAP-SL) as the sample testing methodology to be used allows for performance assessments of conducting investigations.

These elements have been clustered into three more holistic strands, which are described below. Elements 2 and 3 and conducting investigations to collect data are encompassed in Strand A; Elements 4 and 5, and conducting investigations to collect data are included in Strand B; and, Element 1 is included in Strand C.

A. Formulating or identifying investigable questions and hypotheses, planning investigations and collecting evidence.

This process strand includes: posing questions or hypotheses for investigation or recognising scientifically investigable questions; planning investigations by identifying variables and devising procedures where variables are controlled; gathering evidence through measurement and observation; and making records of data in the form of descriptions, drawings, tables and graphs using a range of information and communication technologies.

B. Interpreting evidence and drawing conclusions, critiquing the trustworthiness of evidence and claims made by others, and communicating findings.

This process strand includes: identifying, describing and explaining the patterns and relationships between variables in scientific data; drawing conclusions that are evidence-based and related to the questions or hypotheses posed; critiquing the trustworthiness of evidence and claims made by others; and, communicating findings using a range of scientific genres and information and communication technologies.

C. Using science understandings for describing and explaining natural phenomena, making sense of reports about phenomena, and for decision making.

This conceptual strand includes demonstrating conceptual understandings by being able to: describe, explain and make sense of natural phenomena; understand and interpret reports (eg TV documentaries, newspaper or magazine articles or conversations) related to scientific matters; and, make decisions about scientific matters in students' own lives which may involve some consideration of social, environmental and economic costs and benefits.

Science literacy has been described here in three strands to facilitate the interpretation of student responses to assessment tasks. However, authentic tasks should require students to apply concepts and processes together to address problems set in real-world contexts. These tasks may involve ethical decision-making about scientific matters in students' own lives and some consideration of social, environmental and economic costs and benefits.

The science literacy progress map (Appendix 1) describes progression in six levels from levels 1 to 6 in terms of three aspects:

- increasing complexity, from explanations that involve one aspect, to several aspects, and then through to relationships between aspects of a phenomenon;
- progression from explanations that refer to and are limited to directly experienced phenomena (concrete) to explanations that go beyond that which can be directly observed and involve abstract scientific concepts (abstract); and
- progression from descriptions of 'what' happened in terms of the objects and events, in explanations of 'how' it happened in terms of processes, to explanations of 'why' it happened in terms of science concepts.

The process strands, (Strands A and B) are based on the Western Australian and Victorian assessment profiles, as these most clearly describe these learning outcomes.

The conceptual strand (Strand C) has been abstracted across conceptual strands and makes no reference to particular concepts or contexts. As the progression in the conceptual strand is based on increasing complexity and abstraction, links have been made to the Structure of Observed Learning Outcomes (SOLO) taxonomy (Biggs & Collis, 1982).

The taxonomy was written to describe levels of student responses to assessment tasks. The basic SOLO categories include:

- prestructural — no logical response;
- unistructural — refers to only one aspect;
- multistructural — refers to several independent aspects;
- relational — can generalise (describe relationships between aspects) within the given or experienced context; and
- extended abstract — can generalise to situations not experienced.

The three main categories of unistructural, multistructural and relational can also be applied, as cycles of learning, to the four modes of representation:

- sensorimotor — the world is understood and represented through motor activity;
- ikonic — the world is represented as internal images;
- concrete — writing and other symbols are used to represent and describe the experienced world; and
- formal — the world is represented and explained using abstract conceptual systems.

The conceptual stand, Strand C, of the progress map therefore makes links to the SOLO categories of concrete unistructural (level 1), concrete multistructural (level 2), concrete relational (level 3), abstract unistructural (level 4), abstract multistructural (level 5) and abstract relational (level 6).

The SOLO levels of performance should not be confused with Piagetian levels of cognitive development. Biggs and Collis (1982, p. 22) explain that the relationship between Piagetian stages and SOLO levels "is exactly analogous to that between ability and attainment" and that level of performance depends on quality of instruction, the student's motivation to perform, prior knowledge and familiarity with the context. Consequently performance is highly variable for a given individual and is often sub-optimal.

The progress map elaborates proficiency standards for science literacy that have been established as part of the first cycle of national assessments in 2003. A 'proficient' standard is a challenging level of performance, with students needing to demonstrate more than minimal or elementary skills. In the 2003 assessment of science literacy approximately 58% of students achieved or bettered the proficient standard.

Scientific Concepts Appropriate to National Assessment Program — Science Literacy, Year 6

A table of the major scientific concepts (Appendix 2) found most widely in the various State and Territory documents has been developed to accompany the Science Literacy Progress Map. These major concepts are broad statements of scientific understandings Year 6 students would be expected to demonstrate and provide item writers with a specific context in which science literacy would be assessed. An illustrative list of examples for each of the major concepts provides elaboration of these broad conceptual statements, and in conjunction with the Science Literacy Progress Map, which describes the developmental stages for science literacy, would be used as a guide in the development of assessment items.

It should be noted that given the NAP — SL test instruments are constructed within constraints of test length, it may not be practical to include all listed concepts in the instruments constructed for any particular testing cycle.

References

Ball, S., Rae, I., & Tognolini, J. (2000). Options for the assessment and reporting of primary students in the key learning area of science to be used for the reporting of nationally comparable outcomes of schooling within the context of the National Goals for Schooling in the Twenty-First Century: National Education Performance Monitoring Taskforce.

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Appendix 1

Science Literacy Progress Map

Level	Year level at which 50% of the population would be expected to reach the standard	Solo Taxonomy	Strands of Science Literacy		
			Strand A Formulating or identifying investigable questions and hypotheses, planning investigations and collecting evidence Process Strand: experimental design and data gathering	Strand B Interpreting evidence and drawing conclusions from their own or others' data, critiquing the trustworthiness of evidence and claims made by others, and communicating findings Process Strand: interpreting experimental data	Strand C Using understandings for describing and explaining natural phenomena, and for interpreting reports about phenomena Conceptual Strand: applies conceptual understanding
1	2	C – U	Responds to the teacher's questions and suggestions, manipulates materials and observes what happens	Shares observations; tells, acts out or draws what happened Focuses on one aspect of the data	Describes (or recognises) one aspect or property of an individual object or event that has been experienced or reported SOLO: Concrete unistructural
2	4	C – M	Given a question in a familiar context, identifies that one variable/factor is to be changed (but does not necessarily use the term 'variable' to describe the changed variable) Demonstrates intuitive level of awareness of fair testing Observes and describes or makes non-standard measurements and limited records of data	Makes comparisons between objects or events observed Compares aspects of data in a simple supplied table of results Can complete simple tables and bar graphs given table column headings or prepared graph axes	Describes changes to, differences between or properties of objects or events that have been experienced or reported SOLO: Concrete multistructural
3	6	C – R	Formulates simple scientific questions for testing and makes predictions Demonstrates awareness of the need for fair testing and appreciates scientific meaning of 'fair testing' Identifies variable to be changed and/or measured but does not indicate variables to be controlled Makes simple standard measurements Records data as tables, diagrams or descriptions	Displays data as tables or constructs bar graphs when given the variables for each axis Identifies and summarises patterns in science data in the form of a rule. Recognises the need for improvement to the method. Applies the rule by extrapolating and predicting.	Describes the relationships between individual events (including cause and effect relationships) that have been experienced or reported Can generalise and apply the rule by predicting future events SOLO: Concrete relational
4	8	A – U	Formulates scientific questions, identifies the variable to be changed, the variable to be measured and in addition identifies at least one variable to be controlled Uses repeated trials or replicates Collects and records data involving two or more variables	Calculates averages from repeat trials or replicates, plots line graphs where appropriate. Interprets data from line graph or bar graph Conclusions summarise and explain the patterns in the science data Able to make general suggestions for improving an investigation (e.g. make more measurements)	Explains interactions, processes or effects, that have been experienced or reported, in terms of a non-observable property or abstract science concept SOLO: Abstract unistructural

5	10	A – M	Formulates scientific questions or hypotheses for testing and plans experiments in which most variables are controlled Selects equipment that is appropriate and trials measurement procedure to improve techniques and ensure safety When provided with an experimental design involving multiple independent variables, can identify the questions being investigated	Conclusions explain the patterns in the data using science concepts, and are consistent with the data Makes specific suggestions for improving/extending the existing methodology (e.g. controlling an additional variable, changing an aspect of measurement technique) Interprets/compares data from two or more sources Critiques reports of investigations noting any major flaw in design or inconsistencies in data	Explains phenomena, or interprets reports about phenomena, using several abstract scientific concepts SOLO: Abstract multistructural
6	12	A - R	Uses scientific knowledge to formulate questions, hypotheses and predictions and to identify the variables to be changed, measured and controlled Trials and modifies techniques to enhance reliability of data collection	Selects graph type and scales that display the data effectively Conclusions are consistent with the data, explain the patterns and relationships in terms of scientific concepts and principles, and relate to the question, hypothesis or prediction Critiques the trustworthiness of reported data (e.g. adequate control of variables, sample or consistency of measurements, assumptions made in formulating the methodology), and consistency between data and claims	Explains complex interactions, systems or relationships using several abstract scientific concepts or principles and the relationships between them SOLO: Abstract relational

For Glossary of terms used see (Appendix 3)

Appendix 2

Major Scientific Concepts for the National Yr 6 Primary Science Sample Assessment

Major Scientific Concepts	Examples
Earth and space Earth, sky and people: Our lives depend on air, water and materials from the ground; the ways we live depend on landscape, weather and climate. The changing Earth: The Earth is composed of materials that are altered by forces within and upon its surface. Our place in space: The Earth and life on Earth are part of an immense system called the universe.	- Features of weather, soil and sky and affects on me. - Changes in weather, weather data, seasons, soil landscape and sky (e.g. moon phases), weathering and erosion, movement of the Sun and shadows, bush fires, land clearing. - People use resources from the earth; need to use them wisely. - Rotation of the Earth and night/day, spatial relationships between Sun, Earth and Moon. - Planets of our solar system and their characteristics.
Energy and force Energy and us: Energy is vital to our existence and our quality of life as individuals and as a society. Transferring energy: Interaction and change involve energy transfers; control of energy transfer enables particular changes to be achieved. Energy sources and receivers: Observed change in an object or system is indicated by the form and amount of energy transferred to or from it.	- Uses of energy, patterns of energy use and variations with time of day and season. - Sources, transfers, carriers and receivers of energy, energy and change. - Types of energy, energy of motion – toys and other simple machines – light, sound. - Forces as pushes and pulls, magnetic attraction and repulsion.
Living things Living together: Organisms in a particular environment are interdependent. Structure and function: Living things can be understood in terms of functional units and systems. Biodiversity, change and continuity: Life on Earth has a history of change and disruption, yet continues generation to generation.	- Living vs non-living. - Plant vs animal and major groups. - Major structures and systems and their functions. - Dependence on the environment: Survival needs – food, space and shelter. - Change over lifetime, reproductions and lifecycles. - Interactions between organisms and interdependence e.g. simple food chains. - Adaptation to physical environment.

Matter

Materials and their uses: The properties of materials determine their uses; properties can be modified.

Structure and properties: The substructure of materials determines their behaviour and properties.

Reactions and change: Patterns of interaction of materials enable us to understand and control those interactions.

- Materials have different properties and uses
- The properties of materials can be explained in terms of their visible substructure such as fibres.
- Materials can change their state and properties.
- Solids, liquids and gases

Appendix 3

Glossary of Terms

Variable: A factor that can be changed, kept the same or measured in an investigation.

Independent variable: The variable that is changed in an investigation to see what effect it has on the dependent variable.

Dependent variable: The variable that changes in response to changes in the independent variable. Often the variable that is measured in an investigation.

Controlled variable: A variable that is kept the same in all treatments to be sure that it is change in the independent variable that is causing the change in the dependent variable.

Hypothesis: A tentative idea to be tested in an investigation stated as the relationship between the independent and dependent variables.

Preliminary trials: These represent a 'dry run' of the procedure used to fine-tune the procedure and measurement techniques before doing the experiment and collecting the data.

Repeat trials: These are conducted to repeat data collections for a given trial to increase the sample space. Discrepancies between results for repeat trials provide information about the extent of measurement error.

Replication: In experiments such as germination tests it is useful to set up duplicate dishes of seeds for each set of conditions. This increases the sample space. Discrepancies in results for replicates gives information about the extent of control of variables and sampling error.

Rule: A generalised statement that summarises the pattern within a set of data as a relationship between variables (e.g. the longer the pendulum the slower the swing).

Discrete variables and data: Data for a given variable that is collected in categories, e.g. hot and cold, tall and short, high and low, heavy and light.

Continuous variables and data: Data for a given variable that is collected using a continuous scale of measurement, e.g. 10, 20, 30, 40 and 50 degrees Celsius; 10, 20, 30, 40 and 50 grams; 0, 30, 60, 90, 120 and 180 seconds.