PAT Science

Assessment framework

Australian Council *for* Educational Research

ACER

Contents

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Introduction

The ACER Progressive Assessment Tests in Science, commonly known as PAT Science, are a set of science assessments that allow teachers to accurately and efficiently measure students' abilities in science, to diagnose strengths, weaknesses, and gaps in student learning, and monitor student progress over time. The assessments have been developed especially, but not exclusively, for use in Australian schools and results can be compared to a representative Australian norm at each year level. The PAT Science construct is appropriate for broad international use.

PAT Science assesses students' science knowledge, science inquiry skills, and how these relate to the real world. The assessments are designed to be engaging and to encourage students to interact with the content to the best of their ability.

PAT Science 2nd Edition

PAT Science 2nd Edition (2023) stimulus materials and test items include colour, interactivity, videos and animations, and a wide range of item types that better allow for assessment of higher-level concepts and scientific skills. The assessment comprises tests ranging from Test 1 to Test 8 that are likely to suit students from year 3 to year 10. These can be administered according to student ability, based on previous scale scores and the educator's professional judgement.

PAT Science

PAT Science (2009), referred to as *PAT Science 1st Edition* within ACER's Online Assessment and Reporting System (OARS), comprises tests ranging from Test 1 to Test 8. For more information, please refer to the T*eacher Manual, Progressive Achievement Tests in Science* (ACER Press, 2009).

Rationale for PAT Science

Science is a core subject that allows students to understand the world around them, gain an appreciation of the benefits of science, and engage in the broader research areas of humanities, arts, and social sciences (Australia's National Science Statement, 2017; Harlen, 2015) and, if students choose to, gain the prerequisite skills to pursue a career in the sciences. PAT Science enables teachers to monitor and evaluate these skills so that they can improve student learning.

Progressive Achievement approach

The Progressive Achievement approach provides a framework for integrating student assessment, resources that support teaching practice, and professional learning. PAT assessments allow teachers to collect evidence of student learning, to identify where students are in their learning at a given point in time, to monitor growth over time, and to reflect on student attainment. They provide reliable measures that enable a variety of interpretations about attainment and progress, such as:

- what students attaining specific levels of progression are likely to know, understand and be able to do;
- how much students have improved over time and what skills, knowledge and abilities they have been able to develop; and
- how a student's level of attainment compares with other students'.

The value of an integrated approach to assessment and student learning has become widely acknowledged. There is now a wide variety of formative, diagnostic assessment tools used in Australian classrooms. Summative assessments, such as NAPLAN, are also often used to inform teaching and learning. As Wiliam (2011) makes clear, 'any assessment is formative to the extent that evidence about student achievement is elicited, interpreted, and used by teachers, learners, or their peers to make decisions about the next steps in instruction'. In their report, Finding 7, Gonski et al., (2018) refers to the compelling evidence that 'tailored teaching based on ongoing formative assessment and feedback is the key to enabling students to progress to higher levels of achievement.'

ACER's PAT tests provide indicators of student achievement via scale scores and the accompanying achievement band descriptions. Upon completing their assessments, students are allocated a scale score that represents their ability in science. The PAT scale is divided into achievement bands from which the skills and understanding represented at each level are described. The achievement bands provide valuable evidence-based information about the concepts and skills students have achieved, are consolidating, and are working towards. As the Gonski report recommends, reporting on assessment should have an emphasis on achievement and growth and that growth should be measured against learning progressions (Gonski et al., 2018, Recommendation 4). Masters (2013) also expresses the idea that learning should be assessed by measuring growth over time and against empirically derived learning progressions.

The PAT reports provide targeted formative feedback, allowing students' data to be sorted and analysed in a variety of ways. Using the PAT data and the achievement band descriptions, teachers can structure learning specifically to students' needs, rather than where they are expected to be.

Progressive Achievement in Science

The PAT Science assessment is designed to target the key skills and concepts that underpin growth, and to assist teachers in understanding the progression of science understanding through the PAT reports. Items cover content strands (Science understanding, Science as a human endeavour and Science inquiry) and cognitive skills (Knowing, Applying, and Reasoning). The assessment includes items that vary in difficulty and feedback is provided immediately through a series of reports that allow teachers to analyse group and individual performance by content strand, cognitive skill, and item difficulty.

While growth indicators are available for many formative assessment tools, the PAT Science achievement band descriptions are evidence-based, developed from valid and reliable assessment data that has identified a 'typical' trajectory of development. This can provide teachers with confidence in the data they are using to target areas of learning, and to identify how students' progress over time.

PAT Science and curricula

The Australian Curriculum, and all state curricula, describe expected levels of performance in science based on year or stage level. Science curricula consist of three strands – Science understanding, Science as a human endeavour and Science inquiry, all of which are supported by content descriptors.

PAT Science items are not explicitly developed according to the Australian Curriculum, as the PAT construct is based on a Progressive Achievement approach, rather than year-based expectations. PAT Science results do not directly align with curriculum-based year or stage level outcomes, but items are mapped to the Australian Curriculum and some state curricula, with content codes and descriptions provided in the online reports and the PAT Teaching Resources Centre.

PAT Science assesses scientific concepts and skills in more depth than curricula, which generally describe the skills in broader terms. For this reason, there is often a single content description aligned to many test items at similar levels of difficulty. A single assessment is likely to be aligned to curriculum descriptions across a range of year levels.

Construct

Definition

A construct is a description of an ability that can be measured on a single dimension with a single numeric variable. In the context of educational assessment, a test's construct often refers to 'what students know and can do.' A carefully defined construct enables the transformation of observations (in other words, student responses to test items) into measurements of ability/proficiency using a mathematical model. This approach helps ensure that both assessment and reporting are consistent and legitimate.

PAT Science's overarching construct definition is based on the Australian Curriculum: Science. The curriculum outlines what students need to understand in terms of scientific concepts and processes and what they need to do to develop inquiry practices and how these apply to our lives and decision-making processes. The curriculum provides the means for students to develop the scientific knowledge, understandings, and skills to become global citizens that will enable them to make contributions to the social wellbeing of Australians, understand technology and pressing issues such as climate change and, if they choose, pursue a Science related career.

By studying science, students learn process skills such as observing, classifying, predicting, and making inferences and integrated process skills such as interpreting data, variables, and developing hypotheses (Turiman et al., 2012). Through learning these skills a person becomes scientifically literate and can apply scientific concepts and scientific knowledge to provide insights to societal and environmental issues using inquiry, critical thinking, and problem solving (Turiman et al., 2012). With this in mind, a simple definition of science literacy that is used for PAT Science is as follows:

Scientific literacy is the facility with which a person can utilise process skills and apply these to science and scientific knowledge to gather and interpret data, make evidence-based conclusions, solve problems, and understand the world around us.

PAT Science aims to measure these essential skills of science within a broad range of contexts. The assessments require students to use a variety of these skills across a wide range of subject matter, as reflected by the variety of both written and animated stimulus in an online platform.

Structure

The PAT Science construct is the organising principle of the assessments; it is used to guide test development and structure the PAT reports. This structure is also part of the Progressive Achievement approach because the knowledge, skills and understanding represented in the tests are designed to support educators in identifying student needs.

The construct for PAT Science has been framed by the Australian Curriculum: Science and references the cognitive skills as defined in the Trends in Mathematics and Science Study (TIMSS) for year 4 and year 8. The TIMSS Cognitive skills of Knowing, Applying, and Reasoning provide another aspect to which items are aligned.

Four overarching elements guide assessment development:

- Strands
- Cognitive skills
- Key ideas
- Content progressions

Strands

The two key aspects of the construct (what students know and can do) are evident in the three interrelated strands of the Australian Curriculum: Science. These strands are Science understanding, Science as a human endeavour, and Science inquiry. All items are aligned to a content description (with its Australian Curriculum code) at the content description level.

When developing test items, each is usually targeted to one Science understanding strand and can also be associated with an additional strand. The PAT Science strands are an organising component of the PAT reports, so that educators can analyse the performance of students according to these different skill areas.

Science understanding

The Science understanding strand is concerned with the scientific knowledge (facts, concepts, principles, laws, theories, and models) that students need to acquire in order for them to explain and predict phenomena and be able to apply to new situations. Science understanding consists of four sub-strands, divided by year level:

Biological sciences focus on understanding living things, their interdependence and interactions within the environment. The sub-strand considers the form and features of living things and how these are passed on to their offspring and their evolution over time.

Chemical sciences examine how atomic structure determines the properties of substances, the formation of new substances, and how to classify these substances. It explores the differences between physical and chemical change and the energy requirements for these changes.

Earth and space sciences explore the formation and dynamic structure of Earth, its position within the cosmos, and how its movement affects day, night, and the seasons. It considers the range of timescales required for processes to occur, including the formation of natural resources and the effect that collecting and using these resources has on the environment.

Physical sciences consider how energy is transferred and transformed and how forces such as friction, magnetism, and gravity affect the behaviour of objects.

Science as a human endeavour

The Science as a human endeavour strand provides contexts for science's contribution to our culture and society, and its applications, as well as considerations of global issues. This strand has two sub-strands:

Nature and development of science acknowledges the processes involved with the acquirement of scientific knowledge through the efforts of many people throughout time.

Use and influence of science considers the importance of science knowledge and applications within society and how this can be used in decision-making.

Science inquiry

The Science inquiry strand follows the scientific investigation pathway so that ideas and predictions can be made, tested, analysed and represented to gain in an in-depth understanding of scientific understandings and concepts. It is broken down into five sub-strands:

Questioning and predicting provides opportunities for the identification of questions, hypotheses and making predictions.

Planning and conducting covers the decisions required to investigate or solve a problem.

Processing, modelling, and analysing focuses on how data can be represented in meaningful ways and how to use this data to make conclusions.

Evaluating examines the validity of data gathered from investigations and research when used to support claims.

Communicating considers the various means of communicating scientific research based on the audience.

Cognitive skills

A second aspect of the construct is the cognitive skill that students need to use to engage with and respond to items. The PAT Science cognitive skills are based on the classifications used in the Trends in Mathematics and Science Study (TIMSS) and are elaborated below (Mullis et al., 2017).

Knowing

Items in this domain assess students' knowledge of facts, relationships, processes, concepts, and equipment. Accurate and broad-based factual knowledge enables students to successfully engage in the more complex cognitive activities essential to the scientific enterprise.

Recall / Recognise	Identify or state facts, relationships, and concepts; identify the characteristics or properties of specific organisms, materials, and processes; identify the appropriate uses for scientific equipment and procedures; and recognise and use scientific vocabulary, symbols, abbreviations, units, and scales.
Describe	Describe or identify descriptions of properties, structures, and functions of organisms and materials, and relationships among organisms, materials, and processes and phenomena.
Provide Examples	Provide or identify examples of organisms, materials, and processes that possess certain specified characteristics; and clarify statements of facts or concepts with appropriate examples.

Applying

Items in this domain require students to engage in applying knowledge of facts, relationships, processes, concepts, equipment, and methods in contexts likely to be familiar in the teaching and learning of science.

Compare / Contrast / Classify	Identify or describe similarities and differences between groups of organisms, materials, or processes; and distinguish, classify, or sort individual objects, materials, organisms, and processes based on characteristics and properties.
Relate	Relate knowledge of an underlying science concept to an observed or inferred property, behaviour, or use of objects, organisms, or materials.
Use Models	Use a diagram or other model to demonstrate knowledge of science concepts, to illustrate a process, cycle, relationship, or system, or to find solutions to science problems.
Interpret Information	Use knowledge of science concepts to interpret relevant textual, tabular, pictorial, and graphical information.
Explain	Provide or identify an explanation for an observation or a natural phenomenon using a science concept or principle.

Reasoning

Items in this domain require students to engage in reasoning to analyse data and other information, draw conclusions, and extend their understandings to new situations. In contrast to the more direct applications of science facts and concepts exemplified in the applying domain, items in the reasoning domain involve unfamiliar or more complicated contexts. Answering such items can involve more than one approach or strategy. Scientific reasoning also encompasses developing hypotheses and designing scientific investigations.

Analyse	Identify the elements of a scientific problem and use relevant information, concepts, relationships, and data patterns to answer questions and solve problems.
Synthesise	Answer questions that require consideration of a number of different factors or related concepts.
Formulate Questions / Hypothesise / Predict	Formulate questions that can be answered by investigation and predict results of an investigation given information about the design; formulate testable assumptions based on conceptual understanding and knowledge from experience, observation, and/or analysis of scientific information; and use evidence and conceptual understanding to make predictions about the effects of changes in biological or physical conditions.
Design Investigations	Plan investigations or procedures appropriate for answering scientific questions or testing hypotheses; and describe or recognise the characteristics of well-designed investigations in terms of variables to be measured and controlled and cause-and-effect relationships.
Evaluate	Evaluate alternative explanations; weigh advantages and disadvantages to make decisions about alternative processes and materials; and evaluate results of investigations with respect to sufficiency of data to support conclusions.
Draw Conclusions	Make valid inferences on the basis of observations, evidence, and/or understanding of science concepts; and draw appropriate conclusions that address questions or hypotheses, and demonstrate understanding of cause and effect.
Generalise	Make general conclusions that go beyond the experimental or given conditions; apply conclusions to new situations.
Justify	Use evidence and science understanding to support the reasonableness of explanations, solutions to problems, and conclusions from investigations.

Key ideas

The Australian Curriculum: Science is framed by six key ideas (Table 1, page 8) that are considered during item development for PAT Science.

The inclusion of these key ideas in the Australian Curriculum is designed to support the coherence and developmental sequence of science knowledge across disciplines and year levels (Australian Curriculum: Science, Key Ideas, 2010). The key ideas assist in 'seeing' the progress students are likely to make across year levels with respect to each of these ideas.

Table 1 *Summary of key ideas within the Australian Curriculum: Science*

Key ideas	Summary
Patterns, order and organisation	Recognising patterns in the world around us, and ordering and organising phenomena at different scales.
Form and function	Aspects of science concerned with the relationships between form (the nature or make-up of an aspect of an object or organism) and function (the use of that aspect).
Stability and change	The recognition, description and prediction of stability and change.
Scale and measurement	Quantification of time and spatial scale is critical to the development of science understanding as it enables the comparison of observations.
Matter and energy	Identifying, describing and measuring transfers of energy and/or matter.
Systems	This key idea involves thinking, modelling and analysing in terms of systems in order to understand, explain and predict events and phenomena.

The Australian Curriculum: Science provides an overview of the typical progress students are anticipated to make in their understanding and application of each of these key ideas as they progress through the years of schooling.

Content progressions

The scope of the Australian Curriculum: Science is such that not all material can be assessed adequately in the time allotted to testing across eight tests. Therefore 'mini-progressions' of learning were identified and aligned with the overarching key ideas of the Australian Curriculum. These mini-progressions focus on the development of major concepts that are progressively advanced as the tests move to higher levels. The term mini-progression encapsulates the idea that we can drill down in the literature to find out more about conceptual and process skills development at a fine level to support item writing. Whilst the Australian Curriculum: Science provides a good scaffold for progression across major concepts (and connections to the inquiry skills that support their development), it sometimes 'jumps' across several year levels without referencing a specific concept. Test developers used the mini-progressions to write 'up' or 'down' a progression to ensure cohesion within content (conceptual understanding or skill development) of the Australian Curriculum. The mini-progressions informed test developers where these gaps are (for example, Table 2, page 9, illustrates a specific learning mini-progression focused on the relationship between the Earth, Sun, and Moon) and were 'back-mapped' to the Australian Curriculum content descriptions to ensure items complemented the Australian Curriculum (Table 3, page 10). The mini-progressions were modelled on the progressions in Science understanding outlined by Harlen & Winter (2004) and also the Systems Thinking Hierarchal Model (STH Model) outlined by Assaraf & Orion (2005).

Table 2 *A learning/assessment mini-progression for understanding the Earth, Sun, and Moon in Space.*

Developmental progress (progression)	
↓	**Observations:** the Sun appears to move across the sky each day the Moon changes shape over a month shadows change length and shape with the movement of the Sun in the sky
	Models: the Earth orbits the Sun the Moon orbits the Earth the Earth rotates on its axis Does not ascribe understanding to the apparent motions.
	Coordinates the apparent and actual motion of objects in the sky. Knows that: Earth orbits the Sun once a year Earth rotates on its axis once a day (day/night cycle) Earth is both orbiting the Sun and rotating on its axis the Moon orbits the Earth once a month
	Models: the phases of the Moon Earth seasons
	Models: eclipses of the Sun by the Moon eclipses of the Moon by the Earth
	Complex ideas: perturbations in the Earth's orbit about the Sun historical causes of changes in the Earth's temperature rotation of the Moon and its effects
At each stage of this progression students are expected to use procedural knowledge and make records of observations.	

__Table 3__ Earth, Sun, and Moon in Space learning/assessment progression mapped to the Australian Curriculum

Year level	Science understanding	Science inquiry	Science as a human endeavour
Year 1	describe daily and seasonal changes in the environment and explore how these changes affect everyday life **AC9S1U02**	pose questions to explore observed simple patterns and relationships and make predictions based on experiences **AC9S1I01** sort and order data and information and represent patterns, including with provided tables and visual or physical models **AC9S1I04** compare observations with predictions and others' observations, consider if investigations are fair and identify further questions with guidance **AC9S1I05** write and create texts to communicate observations, findings and ideas, using everyday and scientific vocabulary **AC9S1I06**	describe how people use science in their daily lives, including using patterns to make scientific predictions **AC9S1H01**
Year 2	recognise Earth is a planet in the solar system and identify patterns in the changing position of the sun, moon, planets and stars in the sky **AC9S2U01**	pose questions to explore observed simple patterns and relationships and make predictions based on experiences **AC9S2I01** sort and order data and information and represent patterns, including with provided tables and visual or physical models **AC9S2I04** compare observations with predictions and others' observations, consider if investigations are fair and identify further questions with guidance **AC9S2I05** write and create texts to communicate observations, findings and ideas, using everyday and scientific vocabulary **AC9S2I06**	describe how people use science in their daily lives, including using patterns to make scientific predictions **AC9S1H01**

Table 3 Cont.

Year level	Science understanding	Science inquiry	Science as a human endeavour
Year 6	describe the movement of Earth and other planets relative to the sun and model how Earth's tilt, rotation on its axis and revolution around the sun relate to cyclic observable phenomena, including variable day and night length **AC9S6U02**	pose investigable questions to identify patterns and test relationships and make reasoned predictions **AC9S6I01** construct and use appropriate representations, including tables, graphs and visual or physical models, to organise and process data and information and describe patterns, trends and relationships **AC9S6I04** compare methods and findings with those of others, recognise possible sources of error, pose questions for further investigation and select evidence to draw reasoned conclusions **AC9S6I05**	examine why advances in science are often the result of collaboration or build on the work of others **AC9S6H01**

Table 3 Cont.

Year level	Science understanding	Science inquiry	Science as a human endeavour
Year 7	model cyclic changes in the relative positions of the Earth, sun and moon and explain how these cycles cause eclipses and influence predictable phenomena on Earth, including seasons and tides **AC9S7U03** investigate and represent balanced and unbalanced forces, including gravitational force, acting on objects, and relate changes in an object's motion to its mass and the magnitude and direction of forces acting on it **AC9S7U04 (Physics)**	develop investigable questions, reasoned predictions and hypotheses to explore scientific models, identify patterns and test relationships **AC9S7I01** select and construct appropriate representations, including tables, graphs, models and mathematical relationships, to organise and process data and information **AC9S7I04** analyse methods, conclusions and claims for assumptions, possible sources of error, conflicting evidence and unanswered questions **AC9S7I06** construct evidence-based arguments to support conclusions or evaluate claims and consider any ethical issues and cultural protocols associated with using or citing secondary data or information **AC9S7I07** write and create texts to communicate ideas, findings and arguments for specific purposes and audiences, including selection of appropriate language and text features, using digital tools as appropriate **AC9S7I08**	different perspectives can lead to changes in scientific knowledge **AC9S7H01** investigate how cultural perspectives and world views influence the development of scientific knowledge **AC9S7H02**

Table 3 Cont.

Year level	Science understanding	Science inquiry	Science as a human endeavour
Year 10	describe how the big bang theory models the origin and evolution of the universe and analyse the supporting evidence for the theory **AC9S10U03**	develop investigable questions, reasoned predictions and hypotheses to test relationships and develop explanatory models **AC9S10I01** analyse and connect a variety of data and information to identify and explain patterns, trends, relationships and anomalies **AC9S10I05** assess the validity and reproducibility of methods and evaluate the validity of conclusions and claims, including by identifying assumptions, conflicting evidence and areas of uncertainty **AC9S10I06** write and create texts to communicate ideas, findings and arguments effectively for identified purposes and audiences, including selection of appropriate content, language and text features, using digital tools as appropriate **AC9S10I08**	explain how scientific knowledge is validated and refined, including the role of publication and peer review **AC9S10H01**

Assessment design

Measuring the construct

In developing items and designing the tests, the major criteria considered are as follows:

- distribution of items across strands
- distribution of items across cognitive skills
- distribution of item difficulty
- curriculum appropriateness

Distribution by strand

It is necessary to assess students on an appropriate distribution of strands so that the assessment encompasses a range of scientific skill and knowledge. This approach ensures that the formative data gained provide insight into possible strengths, gaps, and weaknesses in different areas. Items are written to include the primary focus of the Australian Curriculum: Science strands. Table 4 shows the distribution of items by strand in each of the *PAT Science 2nd Edition* tests. The Science as a human endeavour content descriptions are targeted to a particular year level and therefore often provide a useful starting point for real-world and authentic contexts, within which Science understanding and Science inquiry assessment items can be situated. A small number of items address Science as a human endeavour outcomes, with the majority of items addressing Science understanding and Science inquiry outcomes directly, often set within a real-world context.

Table 4 *Percentages of PAT Science 2nd Edition items by strand for each test*

	Strand %		
Test level	Science understanding	Science as a human endeavour	Science inquiry
Test 1	60	4	36
Test 2	60	8	32
Test 3	47	7	47
Test 4	47	7	47
Test 5	49	3	49
Test 6	49	6	46
Test 7	40	3	58
Test 8	55	3	43

Distribution by cognitive skill

The TIMSS cognitive skills are an important component to assess as they describe the thinking processes that students should be using when answering science-based items. Items that are classified as Knowing are assessing a fundamental cognitive ability that highlights a student's ability to recall information accurately (Mullis et al., 2017). Applying items assess students on their ability to use knowledge whilst Reasoning assesses students to draw conclusions and extend their knowledge into unfamiliar contexts (Mullis et al., 2017). Therefore, students are exposed to range of cognitive skills within the PAT Science construct (Table 5, page 15).

Table 5 *Percentages of PAT Science 2nd Edition items by cognitive skill for each test*

	Cognitive skill %		
Test level	Knowing	Applying	Reasoning
Test 1	40	32	28
Test 2	24	44	32
Test 3	17	47	37
Test 4	37	27	37
Test 5	26	40	34
Test 6	34	34	31
Test 7	25	33	43
Test 8	23	50	28

Distribution of item difficulty

It is important to have a spread of item difficulties that match the abilities of the students.

Table 6 shows the mean difficulty of the items in each of the *PAT Science 2nd Edition* tests in scale score units, with their standard deviations. Standard deviation measures the amount of variation in item difficulty for a set of items.

Table 6 *Mean difficulty and standard deviation of each PAT Science 2nd Edition test*

Test level	No. of items	Mean item difficulty (scale score)	Standard deviation (scale score)
Test 1	25	111.2	9.1
Test 2	25	112.8	8.0
Test 3	30	116.6	9.6
Test 4	30	117.0	10.4
Test 5	35	124.1	7.5
Test 6	35	129.4	10.6
Test 7	40	131.2	8.9
Test 8	38	133.2	7.4

Appropriateness of context

The context for items within PAT Science is important as it provides the entry point for students to access and engage with items. Contexts were largely chosen to be relatable, modern (where appropriate), of interest to the students and able to be simplified (where necessary) to provide items that related back to the curriculum. Where a topic may be relatively new to students at that test level, contexts are simple and are familiar to most students (for example organisms and objects that are usually seen or heard about in their daily life). Similarly, where a topic is more familiar, contexts tend to be more complex. The types of contexts are diversified within the tests to avoid repetition and keep students engaged.

Delivery

Choosing the right test

Planning and consistency are important in ensuring PAT Science is used effectively and that students' results are useful and meaningful. The difficulty of a test and the teacher's knowledge of a student should be taken into consideration when selecting an appropriate level. Curriculum appropriateness and the context of the classroom also need to be taken into account when making this decision. There is often a wide range of ability within the classroom and it is not necessary to provide all students in a class with the same test. Instead, the focus should always be each student's ability at the time of the assessment, not where they are expected to be.

Table 7 *Summary of test delivery details for PAT Science 2nd Edition*

<table>
<tr><th>Test level</th><th>Generally suitable for</th><th>No. of questions</th><th>Time allowed</th></tr>
<tr><td>Test 1</td><td>Year 2, year 3, year 4</td><td rowspan="2">25</td><td rowspan="8">60 minutes</td></tr>
<tr><td>Test 2</td><td>Year 3, year 4, year 5</td></tr>
<tr><td>Test 3</td><td>Year 4, year 5, year 6</td><td rowspan="2">30</td></tr>
<tr><td>Test 4</td><td>Year 5, year 6, year 7</td></tr>
<tr><td>Test 5</td><td>Year 6, year 7, year 8</td><td rowspan="2">35</td></tr>
<tr><td>Test 6</td><td>Year 7, year 8, year 9</td></tr>
<tr><td>Test 7</td><td>Year 8, year 9, year 10</td><td>40</td></tr>
<tr><td>Test 8</td><td>Year 9, year 10</td><td>38</td></tr>
</table>

Frequency

For the purpose of monitoring student progress, a gap of 9 to 12 months between PAT Science testing sessions is recommended. Learning progress may not be reflected in a student's PAT Science scale scores over a shorter period of time. Longitudinal growth should be measured over a minimum of two years of schooling, or three separate testing sessions, in most contexts. This will help account for possible scale score variation, for example where external factors may affect a student's performance on a particular testing occasion.

Test administration

Teachers are required to supervise test administration. Practice items are embedded to support administration of the tests. The recommended test administration time is 60 minutes, which should be sufficient for all students to complete their tests. Consistency in the time allowed to students will assist teachers in comparing the results of students.

Item response formats

Most items in *PAT Science 2nd Edition* use a selected response item format, either multiple-choice or complex multiple-choice. The remainder involve some form of student interaction within the stimulus or question. These are drag-and-drop, hotspot, cloze, animations and videos with play and pause capability. Questions with greater interactivity are an advantage as they allow for the assessment of concepts that are hard to measure, such as Science inquiry, and therefore a broader range of questions can be included. Items are accompanied by various texts or modes, including images and animations that are designed to allow students to visualise contexts. Examples of different response formats are provided in Appendix 3.

Reporting

The information provided by the PAT Science reports is intended to assist teachers in understanding their students' scientific abilities, diagnosing gaps, strengths, and weaknesses, and measuring learning progress over time.

PAT scale scores

A PAT scale score is a numerical value given to a student whose achievement has been measured by completing a PAT assessment. A student's scale score lies at a point somewhere on the specific PAT scale, and it indicates that student's level of achievement in that particular learning area — the higher the scale score, the more able the student.

Regardless of the test level or items administered to students, they will be placed on the same scale for the learning area. This makes it possible to directly compare students' achievement and to observe students' progress within a learning area by comparing their scale scores from multiple testing periods over time.

Item difficulty is a measure of the extent of skills and knowledge required to be successful on the item. This makes it possible to allocate each PAT Science test item a score on the same scale used to measure student achievement. An item with a high scale score is more difficult for students to answer correctly than a question with a low scale score. It could generally be expected that a student is able to successfully respond to more items located below their scale score than above.

By referencing the difficulty of an item, or a group of items, and the proportion of correct responses by a student or within a group, it may be possible to identify particular items, or types of items, which have challenged students.

A score on the PAT Science scale has no meaning on the PAT Maths scale or any other PAT scale. The units of the scale have different meanings for each scale. This is because these units are calculated based on the range of student levels of achievement, which vary widely between learning areas.

Achievement bands

While a scale score indicates a student's achievement level and can be used to quantitatively track a student's growth, it is only in understanding what the number represents that teachers can successfully inform their practice to support student learning. For this reason, the PAT scale has been divided into achievement bands that include written descriptions of what students are typically able to demonstrate at that band (band description). A student scoring within a particular band can be expected to have at least some proficiency as described in that band and be progressively more proficient with the Science knowledge, skills and understanding described in lower bands.

Two students whose test performance places them into the same achievement band are operating at approximately the same achievement level within a learning area, regardless of their respective school year levels. Viewing student achievement in terms of achievement bands may assist teachers to group students of similar abilities. By referencing the PAT achievement band descriptions, teachers can understand the types of skills typical of students according to their PAT band. For example, a PAT Science scale score of 129 could be considered to be at the upper end of achievement band 120–129 or at the lower end of achievement band 130–139. In cases like these, it is important to consult the descriptions of both achievement bands to understand the student's abilities.

The following extract from the PAT Science achievement band descriptions sets out how the descriptions can support teachers' understanding of progression in PAT Science and help to inform their teaching practices in a specific and targeted way

Students identify the difference in mass between subatomic particles, elements, and molecules.
Students apply their knowledge of the particle model
Using correct terminology students describe how matter changes state and apply information to determine how plasma is formed
Students recognise that materials change state due to changes in temperature, but their mass does not change.
Students relate the properties of materials to their use.
Students recall and identify the basic properties of materials.
Make general conclusions that go beyond the experimental or given conditions; apply conclusions to new situations.
Use evidence and science understanding to support the reasonableness of explanations, solutions to problems, and conclusions from investigations

The complete PAT Science achievement band descriptions are available as a separate document and within the online reporting.

Norms

PAT Science norms representing the achievement of students across Australia are available as reference groups against which student achievement can be compared. The comparison between a student's scale score achievement and the Australian norms can be expressed as a percentile rank.

The percentile rank of a score is the percentage of students who achieve less than that score. Percentiles are useful when measuring the performance of a student against the reference group for that year level. For example, a student with a percentile rank of 75th compared to the year 3 norms has a scale score that is higher than 75% of Australian year 3 students.

Appendixes

Appendix 1

Literature review: locating PAT Science in the broader research context

Science education is fundamental to helping all students make informed personal, family, community, and global decisions and to prepare and encourage those students who have an interest in science for their future careers. Science education attempts to teach students to be scientifically literate and learn the skills required for the changing employment opportunities technological advancements have brought and will bring (Rennie et al., 2001). With increased technology advancements it is projected that employers in the 21st century will require people with higher-order thinking skills to solve a range of problems and make evidence-based decisions (Glaze, 2018; Harlen et al., 2010; Hodson, 2003). Therefore, it is important that students learn not only about the world around us (Osborne & Dillon, 2008) but also learn relevant skills such as viewing data sources critically and being able to check the validity of those sources, particularly as new advancements rapidly change the way we work.

Changes in science education

During the 20th century there has been significant changes to science and the education sector in technology, scientific practice, and the population of students. In the early half of the 20th century, only a small proportion of students completed their secondary education, which resulted in a largely academic focus in science education with the vision of preparing students for university courses (Fensham, 1986; Tytler, 2007). Currently, students stay in school longer, which results in educators catering for students with a wide range of needs. Science practice itself is changing with scientists often working with large national and/or international groups that depend on large funding bodies with a focus on technology to solve problems with significant societal impacts (Harlen et al., 2010; Tytler, 2007). Issues relating to health, stem cell research, climate change, and other environmental issues, combined with the technological advancement of society means that science is a consideration of the general public as well as experts (Tytler, 2007). Science educators must also consider the increasing impact of globalisation and the need to be inclusive of all people (eg First Nations) (Tytler, 2007).

Curriculum

Updates to science curricula have aimed to consolidate the competing factors in science education and the different levels of understanding between the public, science experts, and governments (Fensham, 2013; Harlen et al., 2010; Tytler, 2007). The Australian Curriculum: Science has also changed in response to the changing needs of society, basic foundational science concepts, and the 'big ideas' of science. The 'big ideas' of science include what science is and its applications, the scientific capabilities required to gather and use evidence, and the perception of science (Harlen et al., 2010). They also cover questions of why science is important, how and why knowledge is formed, and how these concepts connect to other events (Harlen et al., 2010; Osborne, 2007). Another motivator behind reforming the Australian Curriculum was the lack of student interest in science, which was attributed to teacher-focused rather than student-focused learning and a lack of science being taught in primary school (Rennie et al., 2001). Unfortunately there is still a decline in the uptake of science from year 11 upwards, a prevalence of non-science teachers teaching science (Gough, 2021), and Australian PISA and TIMSS science results (Thomson et al., 2017) showing a slight downturn.

The Australian Curriculum was published in 2010 and aspired to provide a unifying curriculum for states and territories. As part of this change the Australian Curriculum: Science aimed to address the 'big ideas' of science, increase student motivation and adapt to the changing demands of society. The key ideas overarch the concepts found within the three strands of the curriculum, providing connections between topics. The three strands are Science understanding, which covers the fundamental concepts of science including the dynamic nature of science, Science as a human endeavour, which attempts to relate the ethical considerations, benefits, and processes of scientific research to students and, Science inquiry skills (changed to Science inquiry in 2022) which covers experimental design (Shape of the Australian

Curriculum: Science, 2009). In 2022, the 9th version of the Australian Curriculum was published and aimed to clarify and refine the curriculum to align with current research, further refining knowledge so that only the 'big ideas' in Science are taught, improve alignment across the strands, and clarifying the depth and the breadth of the knowledge of Science that needs to be taught (ACARA, 2021).

The cognitive skills in TIMSS allows for a further refinement of curriculum and allows for specific skills to be targeted.

Progressions

Whilst the big ideas of Science are included within the Australian Curriculum: Science, there are approximately two-to-three year gaps between key concepts in Science understanding (Haeusler, 2013), which means that students lack some continuity in subject matter. To overcome this, a learning progression approach can be followed. Learning progressions are research-based and are considered to be a set of hypotheses that are tested to validate learning pathways (Corcoran et al., 2009). Student progress can be thought of as occurring along a continuum. At the lowest level this encompasses rudimentary skills and understandings of the curriculum content. As students develop, they increase their competence and skills and their understandings become more sophisticated (Masters and Forster, 1996). Harlen & Winter (2004) describe a generalised progression of students' conceptual understanding of science in the following steps, from a limited to a broader comprehension of scientific concepts:

Students:

- do no more than describe the situation rather than explaining it
- use their own preconceived ideas rather than the relevant scientific ones
- refer to relevant ideas without showing how they apply
- apply the relevant ideas only in situations similar to those already encountered
- apply the relevant ideas in situations different from those encountered before
- bring several relevant ideas together to give a reasoned explanation or prediction

Learning progressions were developed to focus on assessment and setting standards, but with more research, identifying progressions will also support teachers to scaffold their teaching of learning (Liu & Jackson, 2019), the main benefit being that educators can 'see' and consider what comes before and what comes after the specific content or skill that is being taught or assessed.

Science pedagogy

Science encourages a constructivist approach where students make their own discoveries through their own explorations and forming their own ideas. This approach is also supported by the recent expansion of scientific knowledge plus the introduction of the internet where students can gain specific information quickly as it changes the teacher from the knowledge giver to the student as the knowledge seeker (Tytler, 2007). This constructivist approach has changed from the more instructional approach and academic focus of earlier years where students were required to recall a range of facts. Part of the constructivist approach is the inquiry method in Science, whereby students are encouraged to develop their own ideas to solve problems using the scientific method under the guidance of the teacher, a method that has gradually been gaining support with science educators (Rennie et al., 2001; Tawfik et al., 2020).

When teaching science, teachers need to build on the prior knowledge of students, use a range of approaches to suit the students and match the cognitive abilities of learners with the specific content being taught (Lind, 1998). Making connections to prior student learning and to the real world using concrete examples combined with making connections between concepts is important to ensure greater understanding in science (Harlen, 1999). For example, when learning about photosynthesis and respiration students should not only be shown the equations, but where gas exchange takes place (the stomata), that photosynthesis occurs in the leaves, and the importance of this process for life (Näs, 2012).

Whilst Science is often broken down into different components (Physics, Chemistry, Biology, etc.), scientific literacy is one factor that draws all these elements together. Scientific literacy is the ability for a person to understand theories, conduct scientific experiments and investigations, reason and think inductively, and have fundamental literacy skills: how to read and interpret texts, make connections between concepts, consider the theories and certainty behind the text (Norris & Phillips, 2003). It is therefore important that teachers teach how to read scientific texts not just for decoding the language and finding information behind the text but also connecting ideas. Combined with this is the need for students to be numerate. Students need to be able to distinguish between scales, mathematical variables (for example, discrete, continuous, and categoric), interpret graphs, determine frequency of measurements, and the accuracy of their results (McMahon & Davies, 2013).

Science Assessment

Assessment is an important component of improving student progression in learning science. In order to improve student learning, results from assessments should be used to adapt and modify teaching and learning and should be shared with students along with constructive feedback so that they can improve their own learning (Harlen & Winter, 2004). The connection between curriculum, practice, and assessment must be strong for any one element to be effective (Phelps, 2014). Therefore it is also important that teachers create an environment where students are active learners, that they create and share goals for a particular assessment, and that they are involved in self- and peer-assessment (Harlen & Winter, 2004).

In the past, science assessments often only assessed the concepts students should know, overlooking inquiry (or science processing skills), and research skills students require to fully grasp science (Harlen, 1999). Whilst the concepts and theories of science are important, so are the processes of science, the common procedures, practices, and how these advance over time (Osborne & Dillon, 2008). Inquiry skills focus on the ability for students to carry out scientific investigations, develop research questions and hypotheses, collect evidence to test predictions and answer the questions, and interpret results, forming conclusions (Harlen, 1999). At times this can be challenging in traditional, multiple-choice tests, but with the advent of computer software and the ability to use different item formats in tests, additional skills can be assessed (Davenport & Quellmalz, 2017; Lawrenz et al., 2001).

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Appendix 2

Trial design and validity

The PAT Science tests are designed to assess the science construct, comprising the strands Science understanding, Science as a human endeavour, and Science inquiry, as well as the cognitive skills of Knowing, Applying, and Reasoning in a science context. Within each PAT Science test, care has been taken to curate a set of items balanced across all appropriate characteristics (for example, science context, item type, item difficulty, strand, and cognitive skill) to give students many opportunities to demonstrate their science knowledge and skills. All items have been equated to the PAT Science scale; the calibration of item difficulties and student abilities on the PAT Science scale allows for the monitoring of student progress over time.

Each PAT Science item has been rigorously trialled in Australia, providing empirical evidence of its suitability for inclusion in the PAT Science tests. This process started with potential test items being developed by a panel of experienced test developers with expertise in the assessment of science skills and knowledge and their development, who reviewed, scrutinised, and revised the items until they were judged ready for trial. A rigorous process of quality checking, proofreading, and formatting then took place to prepare the items for administration to students.

Psychometricians used the set of finalised items to construct a trial design that balanced the distributions of strands, item types, and science contexts across the trial test forms. In the *PAT Science 2nd Edition* trial design, items were organised into modules, and each trial test form was constructed from a set of modules. Some modules were made up exclusively of items from the first edition of PAT Science, and at least one such module was included in every trial form. This meant that approximately 25 per cent of the items in a trial form were from the first edition. These first edition modules had a dual role: first, the inclusion of items that were already calibrated onto the PAT Science scale facilitated the calibration of the remaining items onto the same scale; second, each first edition module was used in more than one trial form such that, for example, a trial form designed to be administered to year 5 students and a trial form designed to be administered to year 6 students would have some items in common. These common first edition items 'linked' trial forms and enabled accurate calibration of item difficulties along a wider section of the PAT Science scale than would be possible with any single trial form.

The modular design also allowed for a logistically straightforward way to control any item order effects during trialling. Within each test form, the order in which the constituent modules were administered to students was rotated, such that each module was administered first to approximately equal numbers of students. This rotated design meant that no single item would risk low response rates due to consistently being at the end of the trial form.

Response data from online sittings of the trial forms by participating schools was collected over 5 months in 2021. Schools using any of ACER's online PAT assessments may opt for their students to participate in test trials. This data was analysed by psychometricians to assess the performance of each trial item to inform its inclusion or exclusion in the final *PAT Science 2nd Edition* test forms. The item analysis procedures identified whether item performances conformed to the expectations of the Rasch measurement model; items found to 'misfit' the model were excluded. The Test Development Manager made final decisions about item performance and inclusion/exclusion. The result was a final set of items, calibrated to the PAT Science scale, which were (i) judged to be good measurements of the PAT Science construct based on their content and (ii) had been empirically demonstrated to contribute to the measurement of the PAT Science construct via the trialling process.

Appendix 3

PAT Science item response format examples

These examples illustrate different item response formats used in PAT Science assessments.

Simple multiple-choice

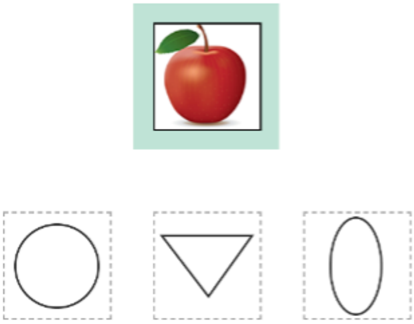
What kind of animal is this?

- a bird
- a koala
- a snake
- a worm

Drag-and-drop

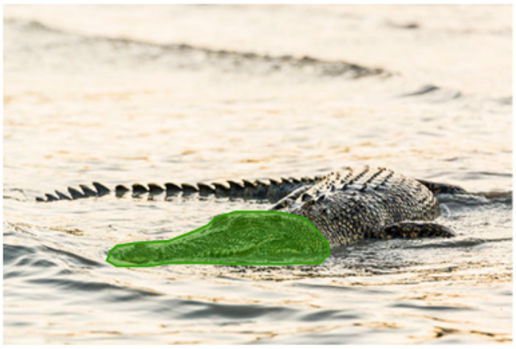
Which shape most closely matches the apple?

Drag the apple to that shape.



Hotspot

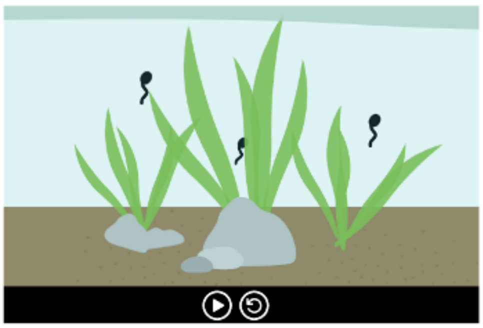
Select the crocodile's head in the picture.



Cloze (with video stimulus)

Watch the following video, pause it to count the numbers of tadpoles.

Look at the video controls, you can play/pause and restart.



Sometimes you see a box like this to answer the question.

How many tadpoles did you see?

Enter the number of tadpoles in the box.