TIMSS 2019 SOUTH AFRICAN ITEM DIAGNOSTIC REPORT

SCIENCE

GRADE 5

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HSRC
Human Sciences Research Council

IEA

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ACRONYMS

CAPS	Curriculum and Assessment Policy Statement
CRQ	Constructed Response Question
DBE	Department of Basic Education
FET	Further Education and Training
HSRC	Human Sciences Research Council
IEA	International Association for the Evaluation of Educational Achievement
LoLT	Language of Learning and Teaching
MCQ	Multiple-Choice Question
TIMSS	Trends in International Mathematics and Science Study
TIMSS-SA	TIMSS in South Africa

PREFACE

The Human Sciences Research Council (HSRC) released the results of the 2019 Trends in International Mathematics and Science Study (TIMSS) in December 2020. TIMSS is a cross-national assessment of the mathematics and science achievement of Grade 4 or 5 and Grade 8 or 9 learners from the participating countries. The TIMSS was developed by the International Association for the Evaluation of Educational Achievement (IEA) to allow participating nations to compare learners' educational achievement across borders.

This report is one of four educator resource documents. The four reports contain diagnostic analyses of a set of items shared by the IEA, called restricted use items: Grade 5 mathematics TIMSS restricted use items, Grade 5 science TIMSS restricted use items, Grade 9 mathematics TIMSS restricted use items and Grade 9 science TIMSS restricted use items, and suggestions for remediation.

Two reports containing the highlights of the Grade 5[1] and Grade 9[2] TIMSS 2019 national results were published in December 2020. Two reports with the full analyses, The South African TIMSS 2019 Grade 9 Results and The South African TIMSS 2019 Grade 5 Results, were published in January 2022.

These reports, together with additional resources, are available on the TIMSS SA website[3].

This report was compiled by Dr Edith Dempster, Dr Sharon Grussendorff and Sylvia Hannan, with Dr Palesa Sekhejane. This report is best described as a resource for educators that will contribute to their understanding of what science our Intermediate Phase learners know and can do and inform, through the recommendations, how to support the successful teaching and learning of science constructs.

The HSRC appreciates the support from the Department of Basic Education (DBE) in conducting TIMSS 2019 in South African schools.

Dr Vijay Reddy
Principal Investigator of TIMSS 2019, South Africa
Human Sciences Research Council

[1] https://www.timss-sa.org/publication/timss-2019-highlights-of-south-african-grade-5-results-in-mathematics-and-science
[2] https://www.timss-sa.org/publication/timss-2019-highlights-of-south-african-grade-9-results-in-mathematics-and-science
[3] https://www.timss-sa.org/

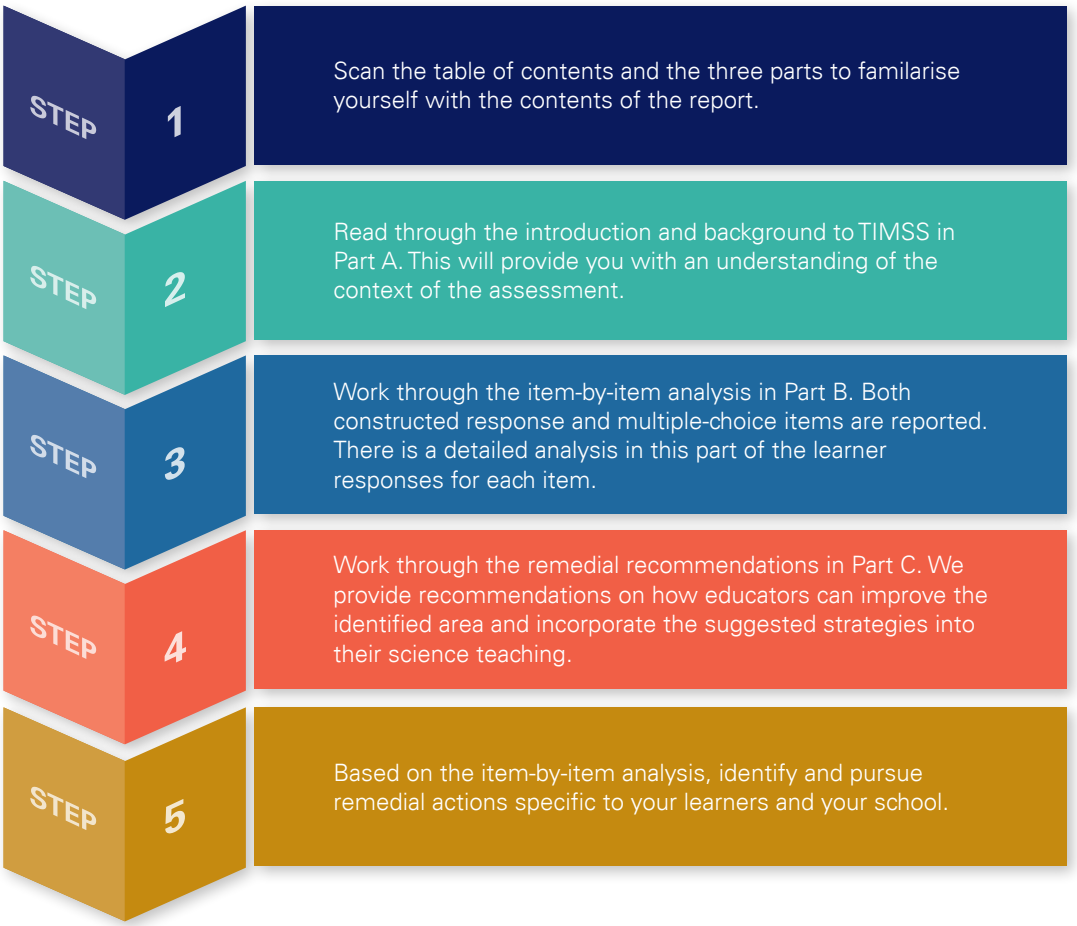
HOW DO I USE THIS REPORT?

This report can be used by all educators, although it specifically focuses on Grade 5 learners. It does not replace or contradict any official DBE policies or documents, particularly those related to assessment and the delivery of the intended curriculum.

This report is presented in three sections:

1. Part A presents the Introduction and Background and highlights some broad performance trends from the analysis of the Grade 5 TIMSS 2019 restricted use science items.
2. Part B presents the analysis of individual restricted use science items.
3. Part C presents ideas for remediation to improve the teaching and learning of science.

When an educator or DBE official receives this resource report, an easy way to navigate it is through the steps below. This sequence of steps has been outlined to assist educators in helping their learners and/or to assist DBE officials in their mentoring, coaching, training and support of educators.



Please note, in this report, for ease of reading, the learner frequency responses were rounded to whole numbers.

PART A

INTRODUCTION AND BACKGROUND

A.1. INTRODUCTION

The Trends in International Mathematics and Science Study (TIMSS) is an assessment of the mathematics and science knowledge of fourth or fifth grade (Intermediate Phase) and eighth or ninth grade (Senior Phase) learners around the world. TIMSS was developed by the International Association for the Evaluation of Educational Achievement (IEA) to allow participating nations to compare learners' educational achievement within and across borders. The goal of TIMSS is to help countries make informed decisions about how to improve teaching and learning in mathematics and science.

In South Africa, the Human Sciences Research Council (HSRC), with the support of the Department of Basic Education (DBE), has conducted the TIMSS since 1995, administering the test at the Grade 8 or 9 levels in 1995, 1999, 2003, 2011, 2015 and 2019. In 2015, South Africa participated in TIMSS-Numeracy at the Grade 5 level and in 2019 South Africa continued TIMSS participation at the Intermediate Phase, testing both mathematics and science.

We begin by giving you some background information about the TIMSS. Further details are available on the TIMSS-SA website[4]. We go on to review what we already know about how children learn science and how they approach assessment questions. We then show you where we have identified common errors in South African learners' answers. Finally, we give you some ideas for assisting learners and improving your teaching.

A.2. WHO PARTICIPATES IN TIMSS?

TIMSS is generally written by children in the fourth year of formal schooling, which is Grade 4 in South Africa. South African learners wrote the test when they were in Grade 5, a year later than most other countries. In October and November 2018, 297 schools formed a nationally representative sample of schools that took part in TIMSS 2019. The selected schools included both rural and urban schools from quintiles 1 to 5, and independent schools, from all nine provinces. Altogether 11 891 Grade 5 South African learners wrote the test and this sample was representative of the Grade 5 learner population.

[4] https://www.timss-sa.org/

Globally, 64 countries and benchmarking entities participated in TIMSS 2019 at the intermediate level. The learners were required to write a mathematics and a science test. South African learners did not perform well in either assessment. In fact, South Africa achieved the third-lowest score out of the 64 countries (Reddy et al., 2020). You can read more about South African learners' performance in the TIMSS 2019 Grade 5 Highlights Report[5]. About 72 percent of our Grade 5 learners did not know basic science facts and concepts, while only two percent of learners performed at the high levels demonstrating that they understood science (Reddy et al., 2020).

The purpose of this report is to support the improvement of teaching and learning and, through that, improve learners' scientific knowledge.

A.3. WHO SETS THE TIMSS ITEMS?

The TIMSS achievement booklets contain both trend and non-trend items. The trend items are included in each cycle and form an anchor that allows for estimating achievement over time. The non-trend items are new items generated for each cycle and are subjected to extensive validation processes. For more details on the assessment frameworks and matrix design, refer to the TIMSS 2019 Assessment Frameworks[6].

The TIMSS items are supplied in English and expert translators then translate the questions into the language of instruction in the participating countries (Centurino & Jones, 2017). There are two languages of learning and teaching (LoLT) in South Africa at Grade 5 level: English and Afrikaans. Most South African learners wrote the test in English, with a few writing the test in Afrikaans. Thirty-five percent of the TIMSS Grade 5 learners reported that they 'always or almost always' spoke the language of the test at home, while 53 percent reported 'sometimes' speaking the language of the test at home. Grade 5 is the second year of most learners transitioning to English or Afrikaans as the LoLT in schools.

A.4. WHAT IS THE TIMSS CURRICULUM FOR GRADE 4 OR 5 SCIENCE?

TIMSS 2019 assessed three *content areas* at the Intermediate Phase: 45 percent of items were devoted to life science, 35 percent to physical science and 20 percent to Earth science.

The TIMSS assessment items incorporate three cognitive domains: 40 percent of items were classified as *knowing*, and 60 percent of the items were at the higher cognitive levels of *applying* and *reasoning*. You can find more details about the science cognitive domains in the TIMSS 2019 Science Framework.[7]

There are two types of items in the TIMSS assessments: half of the items are in the form of multiple-choice questions (MCQ) and the other half are constructed response questions (CRQ) that require learners to write sentences and provide explanations.

Also refer to Chapter Four of the South African TIMSS 2019 Grade 5 Results[8] Report for a discussion of the TIMSS and the Curriculum and Assessment Policy Statement (CAPS) curriculum match, as well as performance by content and cognitive domains.

[5] http://www.hsrc.ac.za/uploads/pageContent/1044991/TIMSS%202019_Grade%205_HSRC_FinalReport.pdf

[6] http://timssandpirls.bc.edu/timss2019/frameworks/

[7] https://timssandpirls.bc.edu/timss2019/frameworks/framework-chapters/science-framework/science-cognitive-domains-fourth-and-eighth-grades/

[8] Reddy, V., Winnaar, L., Harvey, J., Hannan, S., Isdale, K., Arends, A. & Juan, A. (2022). *The South African TIMSS 2019 Grade 5 results: Building achievement and achievement gaps.* Cape Town: HSRC Press. Available at https://www.timss-sa.org/

A.5. RESTRICTED USE ITEMS

After each TIMSS cycle, the IEA releases a number of TIMSS assessment items – called 'restricted use items'. Twenty-two Grade 4 or 5 items were released after the TIMSS 2019 cycle. Ten of the 22 items covered life science content, eight were physical science and four were Earth science. Two items were two-part questions – hence we report on 24 items (10 MCQs and 14 CRQs).

The restricted use items will not be used again in the TIMSS assessment, but the analysis of learner performance at an item level can help us understand what types of difficulties learners have and where they have gaps in their knowledge.

A.6. COUNTRIES THAT FORM THE 'INTERNATIONAL' AVERAGE

The 'international' average used in this set of analyses is the average percentage correct of a group of 11 countries that participated in TIMSS at Grade 4 or 5. These countries wrote the Less Difficult Mathematics TIMSS test[9]. Table 1 shows the list of countries, the languages in which they wrote the test and their scores. In every country, the language of the test was the same as at least one of the languages of instruction.

Table 1: Countries that made up the 'international average' in Grade 4/5 science

Country	Language of test	Science scale score	Language of instruction
Albania	Albanian	489	Albanian
Bosnia & Herzegovina	Bosnian/Croatian/Serbian	459	Bosnian/Croatian/Serbian
Kosovo	Albanian	413	Albanian/Serbian
Kuwait	Arabic/English	392	Arabic
Montenegro	Montenegrin	453	Montenegrin/Serbian/ Bosnian/Croatian
Morocco	Arabic	374	Arabic
North Macedonia	Macedonian/Albanian	426	Macedonian
Pakistan	Urdu/English/Sindhi	290	Urdu/English/Sindhi
Philippines	English	249	English
Saudi Arabia	Arabic/English	402	Arabic
South Africa	**English/Afrikaans**	**324**	**English/Afrikaans**

Source: Exhibit 3 (in Kelly et al., 2020).

[9] Some countries wrote both the Regular Mathematics Assessment as well as the Less Difficult Mathematics Assessment.

A.7. BROAD LEARNER PERFORMANCE PATTERNS

Compared with the group of low-performing countries, South African Grade 5 learners still performed very poorly in the TIMSS science study. We must look for reasons why levels of science knowledge and skills are so poor in South Africa so that we can improve teaching and learning in science. In this section we report on:

- The link between the TIMSS restricted use items and the South African Curriculum and Assessment Policy Statement (CAPS) for the Intermediate Phase;
- Common patterns between South African and international performance on restricted use items;
- Performance by cognitive domain;
- The role of language and, in particular, difficulty with the readability of items;
- Performance in Multiple-Choice vs Constructed Response Questions;
- Questions not answered or incorrectly answered; and
- Performance differences between boys and girls.

A.7.1. Do the TIMSS restricted use items match our CAPS curriculum?

Children learn science from a variety of sources, such as books, TV programmes, adults, older siblings and school. The match between the school curriculum and the TIMSS assessed curriculum varied between countries. Some high-performing countries such as Singapore and Korea had a low match between their school curriculum and the TIMSS assessed curriculum. In South Africa for TIMSS 2019, there was an 80 percent match between the CAPS curriculum and the TIMSS curriculum (Reddy et al., 2022).

To answer this question for the TIMSS restricted use items, we matched each item against the South African Natural Sciences and Technology curriculum[10] for Grades 4 and 5, up to the time the TIMSS was written (Table 2). We graded the match on a scale from 0 to 3:

0 = no match (i.e. the topic of the TIMSS item does not appear in the South African curriculum);
1 = weak match;
2 = partial match;
3 = full match.

Table 2: Level of match between TIMSS restricted use items and the South African Natural Sciences curriculum for Grades 4 and 5

	No match (0)	Weak match (1)	Partial match (2)	Full match (3)	Average match*
CRQ	3	3	3	5	1.7
MCQ	4	1	4	1	1.2
TOTAL	**7**	**4**	**7**	**6**	**1.5**

*An average match of 3 would be a perfect match, 0 would be no match.

[10] The Intermediate Phase curriculum consists of two strands: the Natural Sciences strand and the Technology strand. In this report, we focus on the Natural Sciences.

Table 2 shows that the match between the South African school curriculum and TIMSS restricted use items was weak to partial for the total number of items, as well as for CRQ and MCQ questions separately.

Next, we explored whether the weak match between our curriculum and the TIMSS restricted use items contributed to our learners' poor performance. Figures 1 and 2 show learners' performance for individual questions and the extent of the curriculum match. Focus only on the green-shaded bars in each figure for the moment. Four questions had a full match with the South African curriculum and learners performed well in those questions. Two questions had a full match with the South African curriculum, but learners performed poorly. One question (**ITEM 18** on page 44) did not match the South African curriculum, but learners performed well.

To show the curriculum match for each item on the graphs, we used the following colour coding.

Key for South African curriculum match:

3 = full match 2 = partial match 1 = weak match 0 = no match

Figure 1: Constructed response items: Percentages correct + partially correct, and curriculum match, by content domain

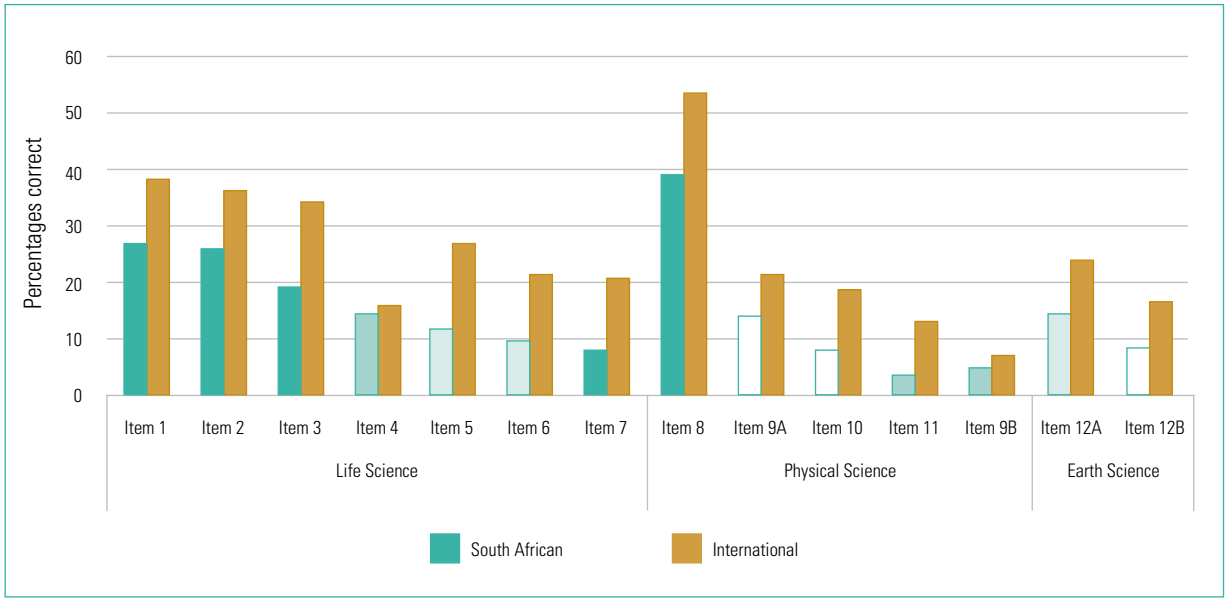


Figure 2: Multiple-choice items: Percentages correct and curriculum match, by content domain

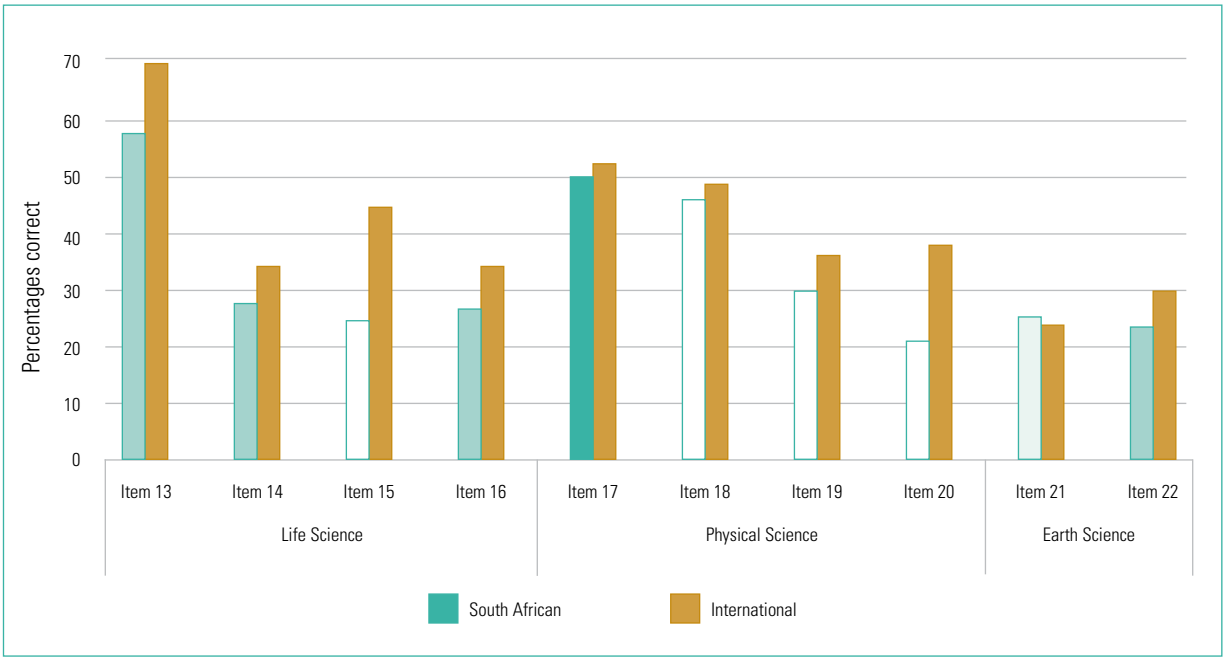


Figure 1 shows that curriculum match plays a part in helping learners answer CRQs correctly. Figure 2 shows that most of the MCQs were partially or not covered in the South African curriculum, yet learners answered some of those questions quite well – look at **ITEM 13**, **ITEM 17** and **ITEM 18** in Figure 2. It is not clear whether a poor curriculum match was responsible for the poor South African performance.

A.7.2. South African vs international scores: Is there a common pattern?

We compared the South African Grade 5 scores with the international average to see if we could find any similarities. Focus on the height of the green and gold bars in Figures 1 and 2.

Figures 1 and 2 show that there was a very similar pattern in the performance of South African and international learners. Questions that were easier (higher scores) for South African learners were also easier for learners internationally. Questions that were more difficult (low scores) for South African learners were also more difficult for learners internationally. However, South African learners scored lower than the international average in every question except **ITEM 21**, where they scored the same. It seems that learners across the world learn scientific facts and concepts at similar stages of development.

A.7.3. Performance by cognitive domain

We asked whether the cognitive domain affected the performance of learners. In theory, 'knowing' items should be easier than 'applying' items, which are easier than 'reasoning' items. Table 3 shows the results of our analysis.

Table 3: Average percentage of learners answering correctly by cognitive domain of restricted use items

Cognitive domain	Number of items	South Africa	International average
Knowing	8 (4 MCQ + 4 CRQ)	40%	50%
Applying	10 (5 MCQ + 5 CRQ)	20%	27%
Reasoning	6 (1 MCQ + 4 CRQ)	19%	28%

As expected, South African and international learners performed better on 'knowing' items than on items related to the other two cognitive domains. There was very little difference in performance between 'applying' and 'reasoning' questions.

A.7.4. Does the language of the TIMSS items contribute to difficulty?

A previous study (Dempster & Reddy, 2007) showed that South African learners' performance was affected by the readability of TIMSS items. They performed worse on items that had many scientific terms and/or long sentences. We were concerned about the readability of some of the items we analysed.

Previously we found that learners avoid answers in MCQs that contain unfamiliar or scientific words (Dempster, 2007). This was confirmed in subsequent research where children told the researcher that they do this (Dempster & Zuma, 2010). Grade 9 learners also told researchers that they translate questions into their home language to try to make sense of them. Sometimes they are unable to translate scientific terms, thereby losing important information. For CRQs, they try to construct an answer in their home language and then translate it into English (Dempster & Zuma, 2010). Thus, language is a significant barrier to their performance in the TIMSS.

Although language contributes to the difficulty South African learners experience in answering TIMSS items, it is not the only problem and must be viewed in relation to other issues that influence the teaching and learning of science (see the South African TIMSS 2019 Grade 5 Results for a comprehensive analysis of factors influencing science achievement).

A.7.5. Performance in Multiple-Choice and Constructed Response items

We asked whether performance differed between MCQ and CRQs in South Africa and internationally. Table 4 shows the percentage of South African learners and the international average for learners who answered the restricted use MCQ and CRQ items correctly.

Table 4: Average percentages of learners answering restricted use items correctly

Question type	South Africa	International average
MCQ (10 questions)	34%	41%
CRQ fully correct (14 questions)	15%	25%
CRQ partially correct with no credit (3 questions)	29%	26%

As expected, South African learners scored lower than the international average on both MCQ and CRQ items. However, both groups scored much lower on CRQ than on MCQ items.

How do we explain this? When learners answer an MCQ, they must read the question and/or look at a picture. They then must recognise the correct answer from the four options provided. When they answer a CRQ, they must read the question and/or look at a picture and recall or reason out the answer. They then write the answer in their own words. Recalling and reasoning out an answer and writing it down is more difficult than recognising an answer that is provided. All learners found CRQs more difficult to answer than MCQs.

A.7.6. Questions not answered or incorrectly answered

We noticed that South African learners seemed more inclined to try to answer questions and risk getting them wrong than learners internationally. Table 5 shows the responses for the MCQs and CRQs.

Table 5: Average percentages of learners giving incorrect answers or omitting items

	Incorrect		Omitted	
Question type	*South Africa*	*International average*	*South Africa*	*International average*
MCQ (10 questions)	58%	51%	9%	8%
CRQ (14 questions)	66%	44%	12%	24%

Table 5 tells us that more South Africans gave incorrect answers to MCQs and CRQs than the international average. The difference was greater for CRQs than MCQs.

Which group omitted more questions? For MCQs, there was very little difference between the South African and international groups. Learners omitted more CRQs than MCQs in both groups, but South African learners were half as likely to omit a CRQ than their international counterparts.

It seems that South African learners were more likely to try to answer CRQs than to leave them out, even if they did not know the answer. This is consistent with the authors' experience, where learners are inclined to try, even if they do not know the answer.

A.7.7. Performance differences between boys and girls

Research has shown that boys perform better than girls on MCQs and the reverse is true for CRQs (Federer, Nehm & Pearl, 2016). At the same time, it has been noted worldwide that girls are outperforming boys at the school and university levels (Stoet & Geary, 2018; Wellington & Ireson, 2012). In South Africa, girls outperformed boys in science by a significant 21 points (Reddy et al., 2022). We explored whether there was a performance difference between boys and girls in the TIMSS 2019 restricted use items. Table 6 shows the results for the items.

Table 6: Average percentages of Grade 5 boys and girls answering MCQs and CRQs correctly for restricted use items

	Boys		Girls		Difference (girls-boys)	
Question type	*South Africa*	*International average*	*South Africa*	*International average*	*South Africa*	*International average*
MCQ (10 questions)	33%	41%	34%	42%	0.7%	0.5%
CRQ (14 questions)	13%	22%	16%	27%	2.4%	4.8%

Girls performed better than boys in South Africa and internationally. The difference was small for MCQs but larger for CRQs. This has implications for how we teach science to boys and girls.

In Part A of this report, we introduced the TIMSS study and the background to South Africa's participation in the TIMSS since 1995. We also presented some broad performance patterns for South African Grade 5 learners in TIMSS 2019 that support a better understanding of their science achievement.

Part B presents an item-by-item analysis of the restricted use items from the TIMSS 2019 Grade 5 science assessment.

PART B

TIMSS 2019 ITEM ANALYSIS FOR GRADE 5 SCIENCE

In this part of the report we present an analysis of each restricted use item (24 items) that appeared in the TIMSS 2019 science assessment. The key research questions that informed the analysis of the items and the reporting were:

1. How did the learners perform (i.e. the correct and incorrect percentages) in each item?
2. What was the TIMSS content and cognitive categorisation of the item?
3. Which part of the South African curriculum did the item fit into?
4. What cognitive processes were required to answer each question correctly?
5. What types of errors did learners make in answering science questions?
6. What is the explanation for the learners' responses?

The first section of Part B discusses each of the restricted use Constructed Response Questions (CRQs) and the second section discusses the Multiple-Choice Questions (MCQs).

The Constructed Response items required a learner to recall information and provide a reasoned response to the question. These items were awarded one point for a correct answer. This was coded as 10.

Incorrect answers were generally coded as 79. If a systematic incorrect answer was observed this may have been coded as 70 or 71. The systematic incorrect responses were noted as well.

For each item, we report on the percentage of learner responses as well as the percentage of learners who did not respond to a question (i.e. omitted an answer). In addition, we provide information about the performance by gender (i.e. the percentage of boys and percentage of girls answering an item correctly) and by school fee status (i.e. the percentage of learners in fee-paying and no-fee schools answering an item correctly).

Each item was also analysed for the level of curriculum match and the coded match was reported. A match of 0 means no match, 1 = weak match, 2 = partial match and 3 = full match. The correct answer for MCQs is shaded darker in each table.

Please note the following:

1. In this analysis, we provide the South African responses as well as a comparison with the international average. The international average is derived from the responses of 11 countries (see the explanation in section 6 of Part A).
2. For ease of reading, the percentages of learner frequency responses were rounded to whole numbers.

ITEM 1

The picture below shows a desert.

What are two **living things** shown in the picture?

1. _____

2. _____

What are two **non-living things** shown in the picture?

1. _____

2. _____

TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match[11]
Life science: Characteristics and life processes of organisms	Knowing	Grade 4 – Living and non-living things (close match)	3 – full match

PERCENTAGES OF LEARNER RESPONSES

	10	70*	71*	79	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct	Fee-paying % Correct
South Africa	27	32	3	35	2	29	25	21	40
International average (n=11)	38	29	5	2	6	42	35		

70*: Responded with two living things correct. No credit.

71*: Responded with two non-living things correct. No credit.

[11] The match between the TIMSS item and the South African Intermediate Phase CAPS, as explained in section 7.1.

COGNITIVE PROCESSING

Learners must know the scientific terms *desert*, *living things* and *non-living things*. They must be able to identify and name objects shown in the picture and separate them into living things and non-living things.

TYPES OF ERRORS

Over a quarter (27%) of South African learners answered this item correctly, compared with an international average of 38 percent. A further 35 percent of South African learners and 34 percent of the international group gave a partially correct answer, for which they did not receive any credit. Almost all learners attempted the question. South African girls were more frequently correct than boys, in agreement with the international average, where the difference was more marked. Learners in fee-paying schools were twice as likely to answer correctly than learners in no-fee schools.

EXPLANATION

This item addressed a topic that should have been familiar to Grade 5 learners since it should be covered in the Grade 4 curriculum. Learners should have been able to answer easily, but 35 percent answered completely incorrectly. Language may have been a barrier since learners had to know the names of the objects in the picture and be able to write those names. However, research has shown that younger children lack the biological knowledge required to distinguish living from non-living things (Harlen & Qualter, 2018). This biological knowledge develops incrementally between the ages of four and 12 years.

ITEM 2

Mark planted a flowering plant in a pot that contained soil with enough fertiliser.

Mark went on a trip and left the plant in a dark room. He knew the room would not get too hot or too cold. When he came back two weeks later, the plant was dying.

Write two reasons the plant was dying.

1. _____

_____

2. _____

_____

TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match
Life science: Organisms, environment, and their interactions	Reasoning	Grade 4 – Conditions for growth – Plants need light, water and air to grow Grade 5 – Food and feeding – green plants need water, CO_2 and sunlight to make food	3 – full match

PERCENTAGES OF LEARNER RESPONSES

	10	70*	79	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct	Fee-paying % Correct
South Africa	26	22	46	6	28	25	18	48
International average (n=11)	37	22	25	16	40	34		

70*: Listed only one reason for the plant dying.

COGNITIVE PROCESSING

Learners need to be able to read and understand the terms *flowering plant* and *fertiliser*. The average complexity[12] of the first four sentences, in the stem, is 12.5. The question is clearly written. Learners must know that plants need light, water and air to grow. Learners need to make the following links: the potted plant had enough soil, fertiliser and warmth to grow. However, it was left in a dark room and the text does not mention anyone watering it while Mark was away. The plant died because it had no light and (most likely) no water.

TYPES OF ERRORS

A quarter (26%) of South African learners gave two correct answers, compared with 37 percent of learners internationally. A further 22 percent of the South African and international learners gave one correct answer. However, 46 percent of South African learners gave a completely incorrect answer, compared with 25 percent internationally.

Less than six percent of South African learners omitted the item, compared with 16 percent internationally. Girls were more likely to answer correctly than boys in South Africa and internationally. Learners in fee-paying schools were much more likely to answer correctly than learners in no-fee schools, with scores above the international average.

EXPLANATION

This item required knowledge that South African learners should have acquired in Grade 4 and that overlaps with part of the Grade 5 curriculum. Reading demand was high for this question, but the language skills needed to write the answers were low. Learners had to infer that no one watered the plant during the two-week period because water was not mentioned in the text. Lack of subject knowledge and poor reading comprehension likely contributed to the poor performance of South African learners on this item.

[12] Sentence complexity is calculated as the number of words in a single sentence or the average number of words per sentence in a section of text, such as a paragraph. We do not have reliable figures for children, but for English-speaking adults, 11 words per sentence is easy to read while 21 words per sentence is fairly difficult (Vincent, 2014).

ITEM 3

Male and female lions take care of their babies to help them survive.

Write two ways that lions help their babies survive.

1. _____

_____

2. _____

_____

TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match
Life science: Characteristics and life processes of organisms	Knowing	Grade 5 – Life cycles – many animals care for their young in order for them to grow and develop	3 – full match

PERCENTAGES OF LEARNER RESPONSES

	10	70*	79	Omitted	Girls % Correct	Boys % Correct
South Africa	19	28	51	2	19	19
International average (n=11)	34	21	26	18	36	32

70*: Lists only one reason. No credit given.

COGNITIVE PROCESSING

There are no scientific terms in this item. The subject of the item is *lions*, which can be assumed to be familiar to most learners. Learners must recall how mammals care for their young and apply that knowledge to lions. A fully correct code of 10 is only awarded to learners who give two different ways that adult lions take care of their cubs. A code of 70 indicates that learners gave only one correct answer.

TYPES OF ERRORS

Nineteen percent of South African learners gave a fully acceptable answer, compared with 34 percent of learners internationally. A further 28 percent of South African learners gave one correct answer and 51 percent gave a completely incorrect answer. These figures contrast with the international averages of 21 percent of learners who gave a partially correct answer and 26 percent who gave an incorrect answer. Only two percent did not answer the question, compared with 18 percent internationally.

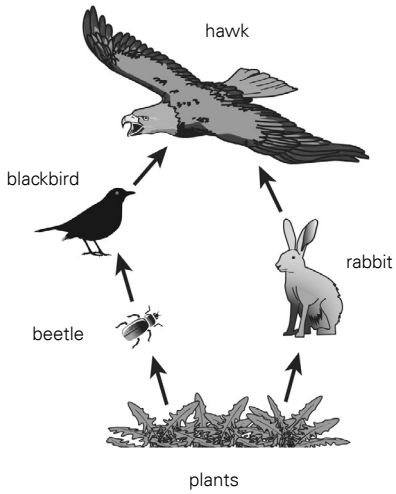
Girls and boys were equally likely to answer correctly in South Africa, but internationally, girls were more likely to answer correctly than boys.

EXPLANATION

This item addressed a concept that South African learners should have studied in the year that they wrote the TIMSS. Almost half of the South African learners could give at least one correct answer. South African learners were more likely than learners internationally to attempt the question although half of them were unable to give a correct answer. This implies that expressive language may have been a barrier to their ability to answer fully, or that they only knew one answer. Lack of knowledge and poor writing skills could account for the poor performance of South African learners in this item.

ITEM 4

The picture below shows a food web in a forest ecosystem.



(This TIMSS item posed on the food web contained two parts. This is Part B. Part A is **ITEM 14**, *on page 36, discussed under Multiple-Choice Questions).*

B. Based on what you see in the food web above, which two animals compete with each other for food?

_____

PART B:
TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match
Life science: Ecosystems	Applying	Grade 5 – Food chains start with a plant; an animal eats the plant; another animal eats that animal Grade 6 – Food webs	2 – partial match (the curriculum for Grade 5 omits food webs and interspecific competition for food)

PERCENTAGES OF LEARNER RESPONSES

Question B	10	79	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct	Fee-paying % Correct
South Africa	15	81	4	17	12	11	24
International average (n=11)	15	69	16	17	13		

COGNITIVE PROCESSING

Learners need to know the concepts *food web, ecosystem* and *competition*. The diagram shows a simple food web that clarifies the context, provided that learners know what the directions of the arrows indicate. The context is a forest ecosystem, which is irrelevant to the actual question. For Part B, learners must make the following links: rabbits eat plants, beetles eat plants, rabbits and beetles eat the same food. Therefore, they compete with each other. Learners must understand that hawks and blackbirds do not eat plants, and therefore eliminate them as possible competitors.

TYPES OF ERRORS

Only 15 percent of South African learners gave a correct answer, while 81 percent gave an incorrect answer. Very few learners omitted the question. Internationally, only 15 percent of learners gave a correct answer, while 69 percent gave an incorrect answer and 16 percent omitted the item.

Boys were slightly less likely to answer correctly than girls in South Africa and internationally. Learners in fee-paying schools were much more likely to answer correctly than learners in no-fee schools, with scores above the international average.

EXPLANATION

This item partially addressed a concept that South African learners had studied in the year that they wrote the TIMSS. Learners should have studied food chains but not food webs, ecosystems or competition. To correctly answer the question, learners had to know the meaning of the directions of the arrows in a food web. This has been shown to be difficult for learners to grasp even at secondary school level. The low international average for this item shows it is a universal problem.

Lack of ability to interpret food web diagrams and unfamiliar vocabulary could account for the poor performance of South African learners in this item.

ITEM 5

Cape ground squirrels live in hot, dry environments.
Sometimes they hold their tails over their heads as shown in the picture.

How does this behaviour help the Cape ground squirrel survive?

_____

TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match
Life science: Organisms, environment, and their interactions	Reasoning	Not in the South African curriculum – no mention of adaptations Grade 5 – Many different plants and animals living in different habitats	1 – weak match

PERCENTAGES OF LEARNER RESPONSES

	10	79	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct	Fee-paying % Correct
South Africa	12	78	11	12	11	5	26
International average (n=11)	27	40	33	28	26		

COGNITIVE PROCESSING

Learners must know the terms *environment* and *survive*. The subject of the item is the *Cape ground squirrel*, which may be an unfamiliar animal to many learners. The image is helpful in visualising the animal and its behaviour. Learners must know about adaptations to the environment, which is linked weakly to the Grade 5 curriculum. They must know that overheating threatens survival in hot environments. Learners must make the following links: overheating is dangerous in hot environments – squirrels hold their furry tail over their heads – the tail helps to keep the squirrel cool – the squirrel survives.

TYPES OF ERRORS

Only 12 percent of South African learners gave an acceptable answer, compared with 27 percent internationally. In South Africa, 78 percent gave an incorrect answer, while 11 percent did not answer the question. This contrasts starkly with the international averages of 40 percent who gave an incorrect answer and 33 percent who did not answer. This indicates that most learners experienced difficulty with the question, but more South African learners were willing to attempt an answer. Girls were slightly more likely than boys to answer correctly in both South Africa and internationally. Learners in fee-paying schools were five times more likely to answer correctly (close to the international average) than learners in no-fee schools.

EXPLANATION

This item addresses a concept (adaptations) that the South African learners had not studied. South African learners were more likely than learners internationally to attempt the question although they were unable to give the correct answer. This implies that expressive language was a barrier to their ability to answer, or that they were willing to take a chance, hoping that their answer may be correct.

Unfamiliar context, lack of knowledge, poor language skills and poor reasoning could all account for the poor performance of South African learners in this item.

ITEM 6

One summer, Sifiso notices that there are fewer insects out at night than in the past. He also notices that there are more bats.

How could the increase in the number of bats explain the decrease in the number of insects?

_____

TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match
Life science: Ecosystems	Reasoning	Grade 5 – Food chains (weak link)	1 – weak match

PERCENTAGES OF LEARNER RESPONSES

	10	79	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct	Fee-paying % Correct
South Africa	10	78	12	11	8	3	22
International average (n=11)	21	42	38	23	20		

COGNITIVE PROCESSING

Learners must know the terms *insect* and *bat*. They must know the difference between *increase* and *decrease*. The first sentence has 16 words, the second sentence has eight words and the question has 17 words. The average sentence complexity[13] of the stem is 12, while the question has a sentence complexity of 17. The reading demand is therefore high for this age group. Learners must make the following links: bats are increasing – insects are decreasing – bats must be eating insects. Learners are required to make an inference based on the information given.

TYPES OF ERRORS

Only 10 percent of South African Grade 5 learners answered correctly, with a further 78 percent giving an incorrect answer and 12 percent omitting the question. This compares with 21 percent internationally answering correctly, while 42 percent gave an incorrect answer and 38 percent omitted the question. This indicates that many learners experienced this as a difficult question to answer. Girls were more likely than boys to answer correctly in South Africa and internationally. Learners in fee-paying schools were seven times more likely to answer correctly than learners in no-fee schools, with their average close to the international average.

EXPLANATION

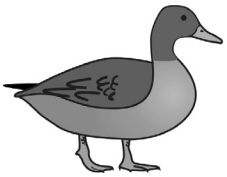
This item addressed a topic that is not explicitly included in the Natural Sciences curriculum for the Intermediate Phase. Learners should be familiar with insects, but bats may not be known. The choice of bats and insects was arbitrary: the item could have included any combination of predator and prey, such as lions and buck or eagles and rabbits. Learners may not have known the feeding relationship between bats and insects, or they were unable to make the inference, or the readability of the question interfered with learners' ability to answer the question.

Research has shown that children are often unable to relate a specific context (bats and insects) to a general principle (predator-prey relationships). Internationally, this item was poorly answered, which supports the notion that learners in this age group did not have sufficient knowledge to answer the question and lacked the reasoning skills to work out the answer.

[13] Sentence complexity is calculated as the number of words in a single sentence or the average number of words per sentence in a section of text, such as a paragraph.

ITEM 7

toy duck



living duck

The pictures show a wind-up toy duck and a living duck.

Do these characteristics describe both the toy duck and the living duck, or only the living duck?

Shade in one circle for each characteristic.

	Toy duck and living duck	Only living duck
1. needs water	A	B
2. needs air	A	B
3. can grow	A	B
4. can move	A	B
5. can reproduce	A	B

TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match
Life science: Characteristics and life processes of organism	Knowing	Grade 4 – Living and non-living things – seven life processes	3 – full match

PERCENTAGES OF LEARNER RESPONSES

	10	79	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct	Fee-paying % Correct
South Africa	8	73	19	10	6	5	20
International average (n=11)	21	67	12	23	18		

COGNITIVE PROCESSING

Learners must know the scientific term *characteristic*. They must understand the terms *wind-up toy duck* and *living duck*. They must understand the characteristics that separate living things from non-living things, which is covered in some detail in Grade 4. The question consists of 17 words, which is high reading demand: learners must say whether each characteristic listed applies to the toy duck and the living duck or only the living duck.

TYPES OF ERRORS

Less than 10 percent of South African learners answered correctly. The international average answering correctly was only 21 percent, indicating that many learners experienced this as a difficult question to answer. Girls were more likely than boys to answer correctly in South Africa and internationally. Learners in fee-paying schools were much more likely to answer correctly (close to the international average) than learners in no-fee schools.

EXPLANATION

This item addressed a topic that is included in the Natural Sciences curriculum for the Intermediate Phase. However, it was framed in a context that is likely unfamiliar to most South African learners, who would not have experienced a wind-up toy duck. This leads to the conclusion that South African learners, particularly those in no-fee schools, did not know the terms and/or have the knowledge on which this question is based.

Research on young children's ability to apply the processes of life to discriminate between living and non-living objects shows that the predominant criteria used are movement (No. 4 in the item) and growth (No. 3). Very few learners selected other life processes such as reproduction (No. 5), digestion (No. 1) or respiration (No. 2) (Osborne, Wadsworth & Black, 1992). It would be interesting to explore the answers given by South African learners in more detail to see if they accord with other research.

ITEM 8

At room temperature, in which state is each of the materials listed below?

Shade in one circle for each material. The first one has been done for you.

Material	Solid	Liquid	Gas
1. paper	●	(B)	(C)
2. oxygen	(A)	(B)	(C)
3. oil	(A)	(B)	(C)
4. table salt	(A)	(B)	(C)

TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match
Physical science: Classification and properties of matter and changes in matter	Knowing	Grade 4 – Materials around us – Solids, liquids and gases Grade 6 – Solids, liquids and gases	3 – full match

PERCENTAGES OF LEARNER RESPONSES

	10	79	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct	Fee-paying % Correct
South Africa	39	48	13	42	36	38	59
International average (n=11)	54	36	11	57	50		

COGNITIVE PROCESSING

Scientific term used: *oxygen*

The language used in this item is fairly straightforward, although learners may have found the instructions to shade a circle for each item unfamiliar and confusing. They also may have struggled to identify oxygen as a gas. To be able to answer this question, learners must be able to identify the state of *each* of the materials listed and understand that oxygen is a gas.

TYPES OF ERRORS

South African learners predominantly answered this question incorrectly (48%), although 39 percent answered correctly. Internationally, learners performed better at this question, with 54 percent answering correctly. There was a fairly high percentage of South African learners who omitted this question (13%). Girls were more frequently correct than boys. Learners in fee-paying schools performed well at this question and were more likely to answer correctly than learners in no-fee schools, as well as international learners.

EXPLANATION

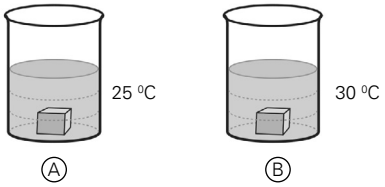
The responses suggest that more learners were unable to correctly identify the state of matter of material than those who could. However, a fair proportion of learners were able to correctly identify the states of matter, since this was covered in the Natural Sciences curriculum in Grade 4.

ITEM 9

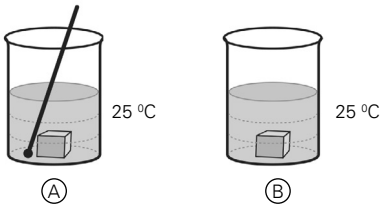
Thando is investigating ways to make the same amount of sugar dissolve quickly in water.
He sets up three tests.

A. For each of the tests, in which beaker will the sugar dissolve faster?

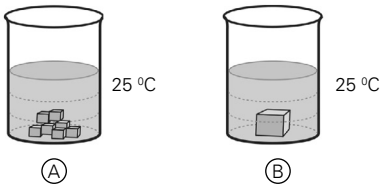
1. Test 1
Different temperatures



2. Test 2
One stirred



3. Test 2
Different cube sizes



B. Why is it important that the amount of water in each beaker is the same?

_____

_____

_____

_____

TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match
Physical science: Classification and properties of matter and changes in matter	Reasoning	General – Major processes and design skills (p. 12) – planning investigations Grade 6 – Rates of dissolving (describes a 'fair test')	A: 0 – no match B: 2 – partial match

PERCENTAGES OF LEARNER RESPONSES

Question Part A	10	79	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct	Fee-paying % Correct
South Africa	14	50	36	15	13	18	31
International average (n=11)	21	57	22	22	20		

Question Part B	10	79	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct	Fee-paying % Correct
South Africa	5	82	13	4	5	2	12
International average (n=11)	7	53	40	8	6		

PART A: COGNITIVE PROCESSING

Scientific term used: *dissolve*

The images used in this item are straightforward but contain a lot of information for learners to digest, which includes both visual and numerical information. To be able to answer this question, learners must know about factors that affect the rate of dissolving (covered in Grade 6 in South Africa) and be able to apply this knowledge to the scenarios depicted in the diagrams. The diagrams require interpretation before the knowledge can be correctly applied.

TYPES OF ERRORS

South African learners performed poorly in this part of the question, with only 14 percent giving a correct response. Internationally, learners also performed poorly, with less than a quarter (21%) providing the correct answer. There was a high percentage of learners who omitted or did not reach this question (36% for South Africa and 22% internationally).

Girls were more frequently correct than boys. Learners in fee-paying schools performed relatively well at this question and were more likely to answer correctly than learners in no-fee schools, as well as learners internationally.

EXPLANATION

The responses suggest that learners were not familiar with the factors that affect the rates of dissolving and were unable to apply these to the various depicted scenarios. Their lack of knowledge of these factors is not surprising, since the concept of rates of dissolving is only covered at Grade 6 level.

PART B: COGNITIVE PROCESSING

Scientific term used: *dissolve*

The images used in this item are straightforward but contain a lot of information for learners to digest, which includes both visual and numerical information. To be able to answer this question, learners must be able to explain that the amount of water is the same for each experiment to make it a fair test. The diagrams require interpretation before the knowledge can be correctly applied.

TYPES OF ERRORS

South African learners performed very poorly in this part of the item, with only five percent answering correctly. Internationally, learners also performed poorly, with only seven percent managing to answer correctly. There was a high percentage of learners who omitted or did not reach this question (13% for South Africa and 40% for learners internationally). In South Africa, boys were slightly more frequently correct than girls. Learners in fee-paying schools were more likely to answer correctly than learners in no-fee schools, as well as learners internationally.

EXPLANATION

The responses suggest that learners were not familiar with the concept of a fair test and were unable to apply this in the context of dissolving rates. This concept is complex for Grade 5 learners, which explains why both South African and international learners struggled with this question.

ITEM 10

Tom has a bucket full of sand and small stones.

How can he quickly separate the sand from the stones?

_____

TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match
Physical science: Classification and properties of matter and changes in matter	Applying	Grade 6 – Mixtures (filtering as a means of separating mixtures)	0 – no match

PERCENTAGES OF LEARNER RESPONSES

	10	79	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct	Fee-paying % Correct
South Africa	8	81	11	10	6	7	17
International average (n=11)	19	52	29	21	17		

COGNITIVE PROCESSING

There are no technical scientific terms used in this question. The language used in this item is straightforward and should not present an issue for learners. To be able to answer this question, learners must know about filtration as a way of separating solids and be able to apply this to the scenario of separating sand and stones.

TYPES OF ERRORS

South African learners performed extremely poorly in this question, with only eight percent answering correctly. Internationally, learners also performed poorly, but outperformed South African learners, with 19 percent correct. There was a fairly high percentage of learners who omitted this question (11% for South Africa and 29% internationally). Girls were more frequently correct than boys. Learners in fee-paying schools performed relatively better at this question and were more likely to answer correctly than learners in no-fee schools, but performed slightly worse than international learners.

EXPLANATION

The responses suggest that learners were not familiar with the concept of filtration and were unable to apply it to the scenario of separating stones and sand. Their lack of knowledge of this technique for separating mixtures is not surprising, since the concept of filtering is only covered in Grade 6.

ITEM 11

Akhona placed a cup made of wet clay on the table. Several days later, the clay was dry.

What happened to the water in the clay?

_____

TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match
Physical science: Classification and properties of matter and changes in matter	Applying	Grade 4 – Materials around us – Change of state Grade 6 – Solids, liquids and gases	2 – partial match

PERCENTAGES OF LEARNER RESPONSES

	10	79	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct	Fee-paying % Correct
South Africa	3	89	8	3	4	1	10
International average (n=11)	13	63	23	15	12		

COGNITIVE PROCESSING

There are no technical scientific terms used in this question. The language used in this item is straightforward, although learners who have not experienced clay might have difficulties in understanding the scenario. To be able to answer this question, learners must understand that, for wet clay to have become dry, water must have evaporated from the clay.

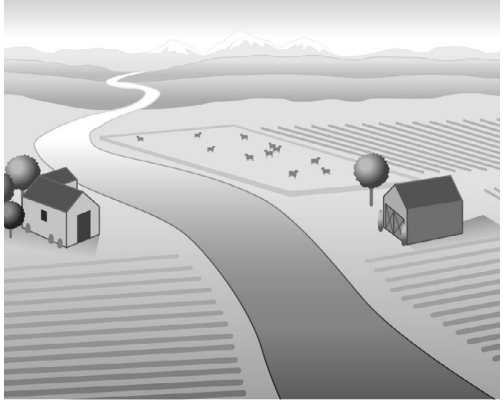
TYPES OF ERRORS

South African learners performed extremely poorly at this question, with only three percent answering correctly. Internationally, learners also performed poorly, with 13 percent providing the correct answer. In South Africa, boys were slightly more frequently correct than girls. Learners in fee-paying schools performed better than learners in no-fee schools, but still performed poorly, and were less successful with this question than learners internationally.

EXPLANATION

Learners may have struggled with this question because they had only encountered the concept of evaporation in the context of a single material – water. To form the link with evaporation as the means of drying wet clay is a level of abstraction that is complex for learners at this level, unless they already encountered another example, such as sweat evaporating from skin or water evaporating from a solution. Since this concept is only covered in Grade 6, the learners would not have encountered it by the time they wrote this test.

ITEM 12



The picture shows a river flowing across a farmland.

There are farms on both sides of the river.

A. Describe one **advantage** of farming near a river.

_____

B. Describe one **disadvantage** of farming near a river.

_____

TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match
Earth science: Earth's physical characteristics, resources, and history	Applying	Grade 5 – Life & Living: Plants and animals on earth – the need for water for living plants and animals to grow	A: 1 – weak match B: 0 – no match

PERCENTAGES OF LEARNER RESPONSES

Question Part A	10	79	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct	Fee-paying % Correct
South Africa	15	74	11	11	11	10	31
International average (n=11)	24	47	33	29	22		

Question Part B	10	79	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct	Fee-paying % Correct
South Africa	9	77	15	9	8	3	22
International average (n=11)	17	48	35	19	15		

PART A: COGNITIVE PROCESSING

There are no technical scientific terms in this question. However, the image used in this item may present an issue for learners, since the use of two farmlands may cause them to think it is a comparative question. To be able to answer this question, learners should interpret that the diagram illustrates farming, which relates to the growth of plants and animals. Learners should then link this growth to the need for access to water, which is illustrated by the presence of the river in the diagram.

TYPES OF ERRORS

South African learners predominantly answered Part A of the question incorrectly. Only 15 percent gave a correct response, which is a lower percentage than learners internationally (24%). There was a fairly high percentage of South African learners who omitted this question (11%), and an even higher percentage of international learners (33%). Girls and boys both performed poorly at this question. Learners in fee-paying schools performed three times better than learners in no-fee schools, as well as better than learners internationally.

EXPLANATION

Although the concept of the need for water in farming should be simple, and something that learners were exposed to in the Natural Sciences curriculum, the poor responses may have been due to the confusing nature of the image.

PART B: COGNITIVE PROCESSING

As with Part A, the image used may have presented an issue for learners. The concept being assessed here is also fairly complex since learners need to relate the image to the possibility of flooding, which involves projection and the ability to surmise.

TYPES OF ERRORS

South African learners predominantly answered the second part of the question incorrectly. Only nine percent gave a correct response, which is a lower percentage than the international average (17%). There was a fairly high percentage of South African learners who omitted this question (11%), and an even higher percentage of international learners (35%). Girls were slightly more frequently correct than boys. What is alarming is that only three percent of learners from no-fee schools were able to answer this question correctly, in contrast to 22 percent of learners in fee-paying schools.

EXPLANATION

Learners' poor performance at this question may have been due to multiple factors: the need to interpret a potentially confusing image, the need to write a sentence in a language that is not the learners' home language, and the complexity of the concept being assessed.

ITEM 13

Which animal has a backbone?

Ⓐ 
octopus

Ⓑ 
spider

Ⓒ 
butterfly

Ⓓ 
frog

TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match
Life science: Characteristics and life processes of organisms	Knowing	Grade 5 – Animal types (vertebrates, including frogs, and invertebrates, including insects and spiders but not molluscs)	2 – partial match

PERCENTAGES OF LEARNER RESPONSES

	A	B	C	D	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct *	Fee-paying % Correct *
South Africa	7	10	5	58	20	58	57	68	84
International average (n=11)	8	8	8	70	7	71	68		

* The 'correct' frequency for no-fee and fee-paying schools is higher than for the national statistic because the missing values were excluded in the calculations.

COGNITIVE PROCESSING

Learners must know the concept of a *backbone*. The animals included in the item are the octopus, spider, butterfly and frog. The images are helpful in visualising the animals. However, *octopus* may be unfamiliar to many learners. Learners must know that a frog has a backbone, but that the other three animals do not. Learners would not have formally studied molluscs as an example of invertebrates.

TYPES OF ERRORS

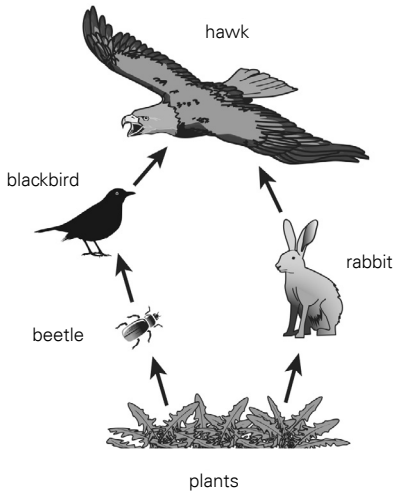
This item was well answered in South Africa and internationally. Almost 20 percent of South African learners omitted the item, compared with about seven percent of learners internationally. This indicates that most learners internationally experienced the question as easy. Girls were slightly more likely than boys to answer correctly in South Africa and internationally. Learners in fee-paying schools were much more likely to answer correctly (above the international average) than learners in no-fee schools.

EXPLANATION

This item addressed a concept that South African learners had studied in the year that the TIMSS was administered. The item did not depend heavily on reading and writing, thereby reducing the language barrier. Nevertheless, it is concerning that so many learners did not attempt to answer the question. Lack of knowledge could have contributed to learners omitting the item.

ITEM 14

The picture below shows a food web in a forest ecosystem.



A. Based on what you can see in the food web, what does the hawk eat?

(A) only the blackbird
(B) only the rabbit
(C) the blackbird and the rabbit
(D) the beetle, the blackbird and the rabbit

(Part B is **ITEM 4** *on page 16, discussed under Constructed Response Questions).*

PART A:
TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match
Life science: Ecosystems	Applying	Grade 5 – Food chains start with a plant, an animal eats the plant, an animal eats that animal Grade 6 – Food webs	2 – partial match (the curriculum for Grade 5 omits food webs and interspecific competition for food)

PERCENTAGES OF LEARNER RESPONSES

	A	B	C	D	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct	Fee-paying % Correct
South Africa	21	15	28	33	4	27	29	24	39
International average (n=11)	14	13	34	34	5	34	34		

COGNITIVE PROCESSING

Learners need to know the concepts *food web, ecosystem* and *competition*. The diagram shows a simple food web that clarifies the context, provided that learners know what the directions of the arrows indicate. The context is a forest ecosystem, which is irrelevant to the actual question. They have to identify that the hawk eats blackbirds and rabbits as shown by the direction of the arrows.

TYPES OF ERRORS

One-third of South African learners chose answer D in preference to the correct answer C. Most rejected B (only the rabbit), but 21 percent chose A (only the blackbird). The same pattern was observed with the international average, with C and D being similarly preferred, and A and B being equally unattractive. Girls were slightly less likely to answer correctly than boys in South Africa and internationally. Learners in fee-paying schools were much more likely to answer correctly than learners in no-fee schools, with scores above the international average.

EXPLANATION

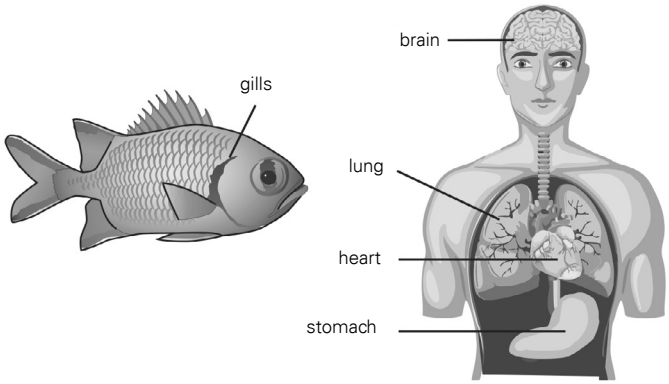
This item partially addressed a concept that South African learners should have studied in the year that they wrote the TIMSS assessment. Learners had studied food chains but not food webs, ecosystems or competition. To correctly answer the question, learners needed to know the meaning of the direction of the arrows in a food web. This has been shown to be difficult for learners to grasp even at secondary school level. It was a universal problem as shown by the low international averages for this item.

The lack of ability to interpret food web diagrams and unfamiliar vocabulary could account for the poor performance of South African learners in this item.

ITEM 15

Which organ in humans has the same function as gills in the fish?

(A) brain
(B) lung
(C) heart
(D) stomach



TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match
Life science: Characteristics and life processes of organisms	Applying	Not in the South African curriculum until Grade 9 (systems in the human body)	0 – no match

PERCENTAGES OF LEARNER RESPONSES

	A	B	C	D	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct	Fee-paying % Correct
South Africa	36	27	22	13	3	27	27	21	38
International average (n=11)	24	45	18	9	4	44	46		

COGNITIVE PROCESSING

Learners must know the scientific terms *organ, gills, brain, lung, heart* and *stomach*. The structures listed are labelled on the diagrams of a fish and a human. They must make the following links: gills are organs of gas exchange in fish, lungs are organs of gas exchange in humans. Therefore, the correct answer is B.

TYPES OF ERRORS

South African learners preferred answer A to the correct answer B, while rejecting answer D. Internationally, 45 percent of learners correctly chose B, with A being the second-favourite answer and D being rejected. There was very little difference between the abilities of boys and girls answering correctly in South Africa and internationally. Learners in fee-paying schools were much more likely to answer correctly than learners in no-fee schools, with a frequency closer to the international average.

EXPLANATION

This item addressed a topic that is not included in the Natural Sciences curriculum for the Intermediate Phase. The preference for answer A may be because of the position of gills on a fish and the brain in a human, relative to the head. Just over a quarter of learners selected the correct answer B, which could be accounted for by guessing. South African learners in fee-paying and no-fee schools may not have known the terms and/or had the knowledge on which this question was based.

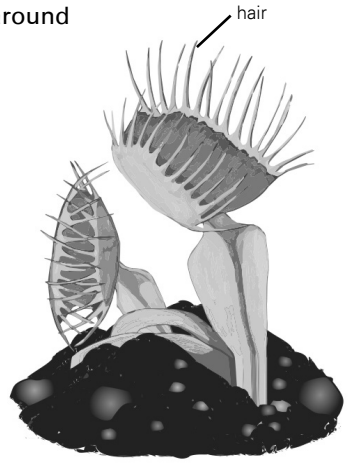
Research on children's ideas about respiration shows that children's understanding of lungs as gaseous exchange organs is related to their knowledge of their internal organs. Such knowledge can develop formally through schooling or informally from home experiences.

ITEM 16

This plant is a Venus flytrap.

When an insect touches the hairs on the Venus flytrap, the trap closes around the insect. Then the plant digests the insect.

In what way is the Venus flytrap different from most other plants?



(A) The Venus flytrap attracts insects and other plants do not.
(B) The Venus flytrap gets nutrients from insects and other plants do not.
(C) The Venus flytrap helps insects reproduce and other plants do not.
(D) The Venus flytrap gets its water from insects and other plants do not.

TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match
Life science: Ecosystems	Reasoning	Grade 5 – Many different plants and animals Green plants make their own food using water and carbon dioxide from the air and energy from sunlight Grade 6 – Plants make their food by photosyn-thesis	2 – partial match

PERCENTAGES OF LEARNER RESPONSES

	A	B	C	D	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct	Fee-paying % Correct
South Africa	29	27	22	15	8	25	29	26	37
International average (n=11)	33	35	13	9	10	35	34		

COGNITIVE PROCESSING

Learners must know the terms *digests, nutrients* and *reproduce*. The context of the item is the *Venus flytrap*, which may be unfamiliar to learners but the text explains that it is a plant that traps insects. The image is difficult to identify as a plant because it is not coloured green. Learners were introduced to the process of photosynthesis in Grade 5.

There is one long sentence of 16 words in the stem, the question consists of 12 words and the average sentence complexity of the answers is 11.5. The reading demand is therefore high for this age group. Learners must make the following links: most plants make their own food/get nutrients from the soil – digestion releases nutrients from food – the Venus flytrap digests insects – the Venus flytrap gets nutrients by digesting insects – this is different from other plants.

TYPES OF ERRORS

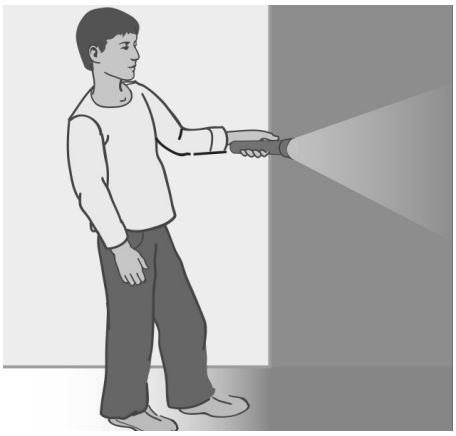
South African learners chose answer A, then B, C and D in that order of preference. Only 27 percent chose the correct answer (B), which is slightly above random guessing. Internationally, the order of preference was B (35%), then A (33%), C and D. This indicates that many learners internationally found it difficult to separate answers A and B, but most were able to reject answer D. Girls were less likely than boys to answer correctly in South Africa, while there was little difference internationally. Learners in fee-paying schools were much more likely to answer correctly (above the international average) than learners in no-fee schools.

EXPLANATION

This item relied on the knowledge that most plants make their food by photosynthesis which learners should have studied early in Grade 5. The Venus flytrap is an unfamiliar context, and the readability of the item may have contributed to the difficulty learners experienced. Many learners did not make the link between digestion and releasing nutrients, which accounts for the popularity of answer A in South Africa and internationally. The term *nutrients* is used in the correct answer B, but not in the stem of the item. Many learners may have avoided selecting answer B because they did not know the scientific term *nutrients*.

High reading demand, unfamiliar context and poor reasoning skills all contributed to the answering pattern of South African learners in this item.

ITEM 17



Jake switches on a torch.

One kind of energy changes into another kind of energy in the torch.

Which statement describes this change?

(A) Electrical energy changes into light energy.
(B) Motion energy changes into light energy.
(C) Light energy changes into electrical energy.
(D) Light energy changes into motion energy.

TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match
Physical science: Forms of energy and energy transfer	Knowing	Grade 5 – Electricity and energy Grade 6 – Electric circuits and systems to solve problems	3 – full match

PERCENTAGES OF LEARNER RESPONSES

	A	B	C	D	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct	Fee-paying % Correct
South Africa	50	13	23	8	6	51	48	44	63
International average (n=11)	53	11	22	8	6	53	53		

COGNITIVE PROCESSING

Scientific terms used: *electrical energy, motion energy* and *light energy* (none of which are complex or unfamiliar). The language and image used in this item are straightforward and should not present an issue for learners. To be able to answer this question, learners must know about different forms of energy and be able to identify the specific energy change taking place in the content provided.

TYPES OF ERRORS

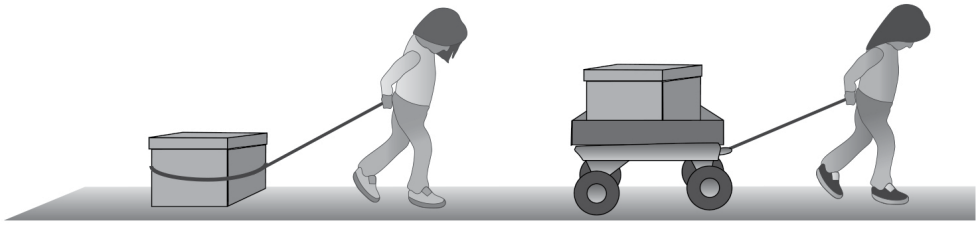
South African learners preferred answer A, which is the correct answer. International learners also preferred the correct answer, slightly outperforming South African learners. The second-most popular response was option C for both South African and international learners. Girls were more frequently correct than boys. Learners in fee-paying schools performed very well at this question and were more likely to answer correctly than learners in no-fee schools, as well as learners internationally.

EXPLANATION

The concept of electrical energy is covered in the Grade 5 CAPS (term 3), and the question itself is straightforward, which would explain the good performance of learners overall. The responses suggest that learners were able to correctly identify forms of energy and energy transfer in a simple electrical system. The second-most popular response, option C, means that learners had correctly identified the forms of energy, but had switched the direction of energy transfer.

ITEM 18

Tina and Mary need to move identical heavy boxes.
Tina has to pull harder on her box to move it than Mary does.



Why is it easier for Mary to move her box?

(A) Gravity acting on Tina's box is much stronger.
(B) Air resistance acting on Tina's box is much greater.
(C) The cart increases the magnetic force acting on Mary's box.
(D) The cart's wheels decrease the force needed to move Mary's box.

TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match
Physical science: Forces and motion	Applying	Not in the South African curriculum (starts in Senior Phase)	0 – no match

PERCENTAGES OF LEARNER RESPONSES

	A	B	C	D	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct	Fee-paying % Correct
South Africa	16	11	20	47	6	50	43	42	64
International average (n=11)	14	9	22	49	7	50	47		

COGNITIVE PROCESSING

Scientific terms used: *gravity, magnetic force* and *air resistance* (none of which learners have encountered at this stage). The language and image used in the stem of this item are straightforward and should not present an issue for learners, but the options involve some terms that learners have not yet encountered by Grade 5. To be able to answer this question, learners must use their common sense or everyday experience. Although the question appears to involve the concept of forces, no prior knowledge of forces is needed to be able to reason one's way to the correct answer.

TYPES OF ERRORS

South African learners preferred answer D, which is the correct answer. Internationally learners also preferred the correct answer, slightly outperforming South African learners. Girls were more frequently correct than boys. Learners in fee-paying schools performed very well at this question and were more likely to answer correctly than learners in no-fee schools, as well as learners internationally.

EXPLANATION

The responses suggest that learners were able to correctly apply their reasoning to the motion of a system involving wheels. The second-most popular response was option C for both South African and international learners, which is an unexpected response, since magnetism does not come into the scenario at all. Learners are introduced to magnetic materials in Grade 5 *Matter & Materials*, so their responses may be based on their recognition of familiar terms.

ITEM 19

When paper is torn, the shape of the paper changes, but the materials in the paper stay the same.

In which of the changes below do the materials in the objects stay the same?

(A) stretching rubber
(B) rusting metal
(C) burning wood
(D) baking bread

TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match
Physical science: Classification and properties of matter and changes in matter	Knowing	Not in the South African curriculum (only at FET Phase)	0 – no match

PERCENTAGES OF LEARNER RESPONSES

	A	B	C	D	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct	Fee-paying % Correct
South Africa	30	26	24	13	7	32	28	28	42
International average (n=11)	37	21	22	12	8	39	35		

COGNITIVE PROCESSING

There are no complex scientific terms or images used in this item. However, the first sentence has 19 words and the question has 15 words, making this item difficult to read and comprehend. To be able to answer this question, learners must know the difference between physical changes, where the material itself does not change chemically, and chemical changes, where there is an irreversible change to the material. Although the concepts of physical and chemical changes are only dealt with at the Further Education and Training (FET) Phase, learners may be able to answer this question using their general knowledge and common sense.

TYPES OF ERRORS

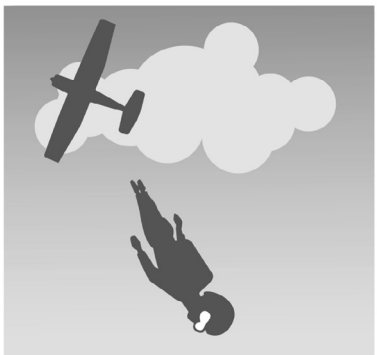
South African learners preferred answer A, which is the correct answer. This is also the answer preferred by learners internationally. The distractors B and C were selected by roughly a quarter of the learners, following a similar trend for learners internationally. Girls were more frequently correct than boys. Learners in fee-paying schools were more likely to answer correctly than learners in no-fee schools, and performed above the international average.

EXPLANATION

The responses suggest that, despite not covering the core concepts of physical and chemical changes in their Natural Sciences learning, the answer is apparent from the given example of paper tearing, and can be reasoned logically using common sense. The concepts of rusting metal (option B) and burning wood (option C) may have a closer perceived link with science than baking bread (option D), which may explain why these were the second and third-most frequent choices.

ITEM 20

A skydiver jumps out of an aeroplane and parachutes to Earth.



What causes the skydiver to fall toward the Earth?

(A) Earth's air
(B) Earth's magnetic force
(C) Earth's gravity
(D) Earth's rotation

TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match
Physical science: Forces and motion	Knowing	Not in the South African curriculum (starts in Senior Phase)	0 – no match

PERCENTAGES OF LEARNER RESPONSES

	A	B	C	D	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct *	Fee-paying % Correct *
South Africa	39	14	21	20	6	20	23	14	39
International average (n=11)	31	16	38	11	5	37	39		

COGNITIVE PROCESSING

Scientific terms that are unfamiliar to learners are included in this question: *magnetic force, gravity* and *rotation*. The images help the reader to visualise the scenario, but the concepts skydiver and parachute might not be familiar to all learners. To be able to answer this question, learners must know the concept of gravitational force, and be able to apply this concept to the image of the skydiver falling to earth.

TYPES OF ERRORS

South African learners preferred answer A, whereas the correct answer was C. More international learners selected the correct answer. The concept of forces in general, and gravitational force in particular, is only covered in the Senior Phase, so learners would be unfamiliar with the terminology in the options provided. However, they would be familiar with the concept of air, which is covered in Grade 4 *Life & Living* and *Earth & Beyond*, as well as in Grade 5 *Energy & Change*. This would explain their preferred choice of option A, which is also the second-most popular response from learners internationally. Boys were more frequently correct than girls. Learners in fee-paying schools were more likely to answer correctly than learners in no-fee schools, but were slightly below the international average.

EXPLANATION

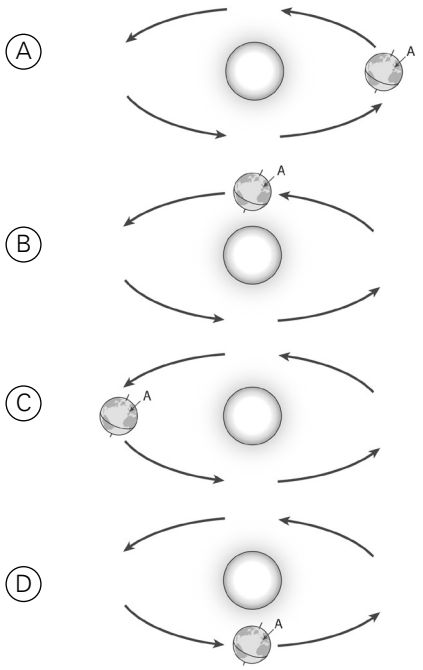
The responses suggest that learners correctly identified that the skydiver was falling through the air, but because of their lack of knowledge of the concepts of gravitational and other forces, were mostly unable to answer the question.

ITEM 21

Earth's seasons are caused by the tilt of its axis.

It is summer in City A.

In what position is the Earth when it is summer in City A?



TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match
Earth science: Earth in the solar system	Applying	Grade 4 – The Earth orbits around the Sun Grade 5 – The Earth orbits around the Sun Grade 6 – The Earth orbits around the Sun No mention of Earth's axis and seasons	1 – weak match

PERCENTAGES OF LEARNER RESPONSES

	A	B	C	D	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct	Fee-paying % Correct
South Africa	18	24	26	16	17	24	27	28	35
International average (n=11)	17	25	24	20	14	23	24		

COGNITIVE PROCESSING

Scientific terms used: *tilt, axis* (the term axis is covered in Grade 5, but not the tilt of the Earth's axis).

The image used in this item is a complex abstraction, representing the Earth's orbit around the Sun. However, learners should have been exposed to images like this in their learning in *Planet Earth and Beyond* in both Grade 4 and 5. To be able to answer this question, learners must know how the tilt of the Earth's axis causes the different positions of the Earth in its orbit around the Sun that give rise to the seasons of the year.

TYPES OF ERRORS

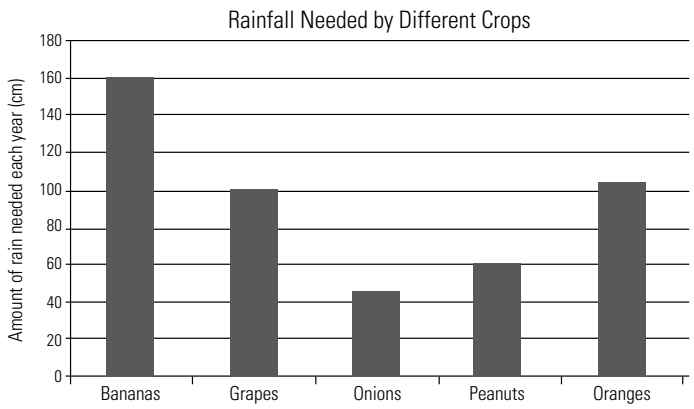
Just over a quarter of South African learners selected the correct answer C. International learners preferred the incorrect answer B, thus performing slightly worse than South African learners. Option B was the second-most popular choice of South African learners. There was a fairly high percentage of South African learners who omitted this question (17%). Boys were more frequently correct than girls. Learners in fee-paying schools performed slightly better at this question and were more likely to answer correctly than learners in no-fee schools, as well as learners internationally. However, no group of learners performed well with this question.

EXPLANATION

The concept of seasons in relation to the tilt of the earth's axis is not covered in the South African Intermediate Phase curriculum. However, in discussing the Earth's orbit around the Sun, which is part of the curriculum, educators may have included a discussion of seasons. An added complexity in the diagram is the fact that City A is facing the Sun in option B (i.e. experiencing daytime), and facing away from the Sun in option D (i.e. experiencing night-time), which may explain why option B was preferred by learners internationally and was the second-most common choice of South African learners.

ITEM 22

The amount of rainfall needed by different crops is shown in the graph below.



A farmer wants to plant crops in an area that gets about 60 cm of rain each year.

Which crops will probably grow best in this area?

(A) onions only
(B) onions and peanuts
(C) grapes and oranges
(D) bananas, oranges and grapes

TIMSS DOMAINS AND LINK TO CAPS

Content Domain	Cognitive Domain	Link to CAPS	Coded match
Earth science: Earth's weather and climates	Applying	General: Major processes and design skills (p. 12) – recording and interpreting information from graphs	2 – partial match

PERCENTAGES OF LEARNER RESPONSES

	A	B	C	D	Omitted	Girls % Correct	Boys % Correct	No-fee % Correct	Fee-paying % Correct
South Africa	8	23	7	51	11	24	22	22	36
International average (n=11)	13	30	10	32	15	31	30		

COGNITIVE PROCESSING

There are no technical scientific terms used in this question. However, the question involves the interpretation of information from a graph, which may be challenging to some learners. In addition, there is some information conveyed through subtle language in the question that learners who do not speak the language of the test as their first language may find confusing. The question "Which crops will probably grow best" is intended to allow for a range of approximate answers. However, at this stage of development, this kind of reading for subtle meaning is possibly inappropriate, and a more exact phrasing of the question may be more suitable.

To answer this question, learners must be able to interpret the meaning of the bar graph, namely the required rainfall for specific crops, and use this information to identify the crops that would grow best with the given rainfall. There is a level of difficulty presented by the nature of the question, since learners need to read the bar graph in an inverted way, identifying the crops that require a lower rainfall than the expected quantity. At this stage of development, learners will mostly interpret the information in a bar graph in a straightforward way, looking for data that exceeds the given quantity.

TYPES OF ERRORS

More than half the South African learners preferred answer D, where the data shown for the crops exceeds the 60 cm of rainfall given in the question. The second-highest response was the correct answer, which is B. Internationally, learners also preferred the distractor D, with the second-highest response being the correct answer, B. International learners slightly outperformed the South African learners but had the same misconception of the information conveyed in the graph and question. There was a fairly high percentage of learners who omitted this question (11 %). Girls were more frequently correct than boys. Learners in fee-paying schools performed better than learners in no-fee schools, as well as learners internationally.

EXPLANATION

The responses suggest that most learners failed to fully comprehend the meaning of the graph and the essence of the question. Their responses show that they had a very literal interpretation of the graph, and had not fully comprehended the meaning of the values that were represented. They were thus unable to apply a higher cognitive level of reasoning to this information. This is in line with research related to graphing ability, where learners in lower grades are able to read literal graphs with ease, but are less successful in answering questions requiring higher-level cognitive skills (Curcio & Smith-Burke, 1982; Pereira-Mendoza & Mellor, 1990). The second-most popular response was the correct option B (both for South African and international learners), meaning that some learners had correctly interpreted the meaning of the information given in the bar graph.

This part of the report has analysed each of the restricted use Grade 5 science items in relation to learners' performance, the errors made and possible explanations for the way learners answered the questions. In Part C, we present a set of recommendations for how educators can attempt to improve science teaching and learning in their classrooms.

PART C

IDEAS FOR REMEDIATION TO IMPROVE SCIENCE TEACHING AND LEARNING IN CLASSROOMS

The TIMSS 2019 results have shown that Grade 5 learners performed poorly in science. We therefore need to identify ways in which science teaching and learning can be enhanced. The analysis of the learner responses to the TIMSS restricted use items suggest that the following areas need to be strengthened to assist teaching and learning:

1. **Use of scientific terms**
2. Talking about science
3. Reading science
4. Writing science
5. Interpreting images and graphs in science
6. Using the scientific method
7. Encouraging higher-order thinking skills
8. Content areas that need strengthening

Each item number is hyperlinked to the full item described in Part B. Click on the item number and it will take you to the relevant item.

C.1. USE OF SCIENTIFIC TERMS

The language of science is different from the language of everyday speech. It is more precise, and it uses words that have a specific scientific meaning (Harlen & Qualter, 2018). Table 7 lists some examples of scientific terms that learners need to be familiar with in Natural Sciences in Grades 4 and 5.

Table 7: Scientific terms needed for Grade 4 and 5 Natural Sciences

Life & Living	Matter & Materials	Energy & Change	Earth & Beyond
GRADE 4			
Plants: root, stem, leaf, flower, fruit, seed ---------- Animals: head, tail, body, limb, sense organ ---------- Habitat: grassland, forest, river, sea	Materials: Solid, liquid, gas ---------- Properties: shape, flow ---------- Change of state: heating, cooling, melting, evaporating, condensing, freezing, water cycle, Raw materials, manufactured materials ---------- Properties of materials: hard, soft, stiff, flexible, strong, weak, light, heavy, waterproof, absorbent	Energy: energy chain/food chain ---------- Types of energy: movement, heat, light, sound, stored energy, Energy transfer, Input energy, output energy ---------- Energy & sound: vibrations, volume, pitch, noise pollution	Features of the Earth: sphere, land, water, air, soil, rocks, continents, islands, oceans, seas ---------- Earth & space: planet, space, Sun, Moon, stars ---------- Moving around the Sun: orbit, solar system ---------- Phases of the Moon
GRADE 5			
Indigenous Inter-dependence: depend, resources ---------- Animal types: invertebrates, vertebrates Animal skeletons: bones, joints, skull, backbone, ribs, shoulder blades, arms, legs, hip bones Movement: muscles ---------- Food & feeding: water, carbon dioxide, sunlight energy, release, life processes (move, feed, sense the environment, excrete, breathe, reproduce), herbivore, carnivore, omnivore, food chain, energy transfer ---------- Growth & development: life cycle, generation, reproduction, death, care for young	Properties of metals: shiny, hard, strong, malleable, ductile, melt, temperature, conduct heat, magnetic, rust, tarnish ---------- Non-metals: dull, brittle ---------- Processed materials: durable, waterproof, fire-resistant, texture	Fuels: source, useful energy, output energy, burning ---------- Energy & electricity: torch cells, batteries, circuit, electrical energy ---------- Energy & movement: elastic, spring, stretch, twist, movement energy	Earth's movements: spin, year, day. Surface of the Earth: crust, subsoil, topsoil, sand grains, sandy, clayey, loamy, humus, decomposed, compost, organisms, conserve ---------- Sedimentary rocks: deposit, compacted, hardened, shale, sandstone, limestone ---------- Fossils: ancient, evidence, body fossils, trace fossils, features, fossil record, early humans, coelacanth, dinosaur

Some scientific terms are words that we use in everyday life, but they have a different meaning in science. The word 'fruit' in everyday life means bananas, apples or oranges, but in science, a fruit is a structure that develops after a flower is fertilised. We use the word 'cell' to mean a cellphone or a prison cell, but it also means 'the smallest unit

of life' in biology and 'an electrical power supply' in physics. Words with more than one meaning cause difficulties for learners learning science and even more so for learners learning in a second language (Harlen & Qualter, 2018). They can learn the term in one context but find it difficult to use in a different context.

When children read scientific texts, they tend to focus on the content words, mainly the nouns and verbs. Linking words are important in science, for example, *therefore, however, because, consequently, whereby, thus, hence, similarly* and *as*. Prepositions like *before, after, above, below, into, on top of* and *underneath* are also important small words in science.

We will use the science restricted use item about *Venus flytraps* (**ITEM 16**, page 40) to illustrate topic content words, linking words and prepositions.

- Content words: plant, Venus flytrap, insect, touches, hairs, trap, closes, digests;
- Linking words: when, then, in what way, different from;
- Prepositions: on, around.

Learners are probably unfamiliar with the Venus flytrap. The image helps them to visualise the plant. If they focus on the content words only, they will not understand the question. The linking words *when* and *then* tell the learner about a sequence of events. The linking words *in what way* and *different from* tell learners that they must compare the Venus flytrap with other plants. Can you see that linking words are very important words in science?

We see from the TIMSS 2019 results that South African learners have difficulty with scientific language. This finding is also true for learners in other countries (Harlen & Qualter, 2018). We need to work on building learners' language skills so that they use the language of science correctly when they are talking about, reading and writing science. Sections C2, C3 and C4 give you some ideas for developing the language of science.

C.2. TALKING ABOUT SCIENCE

Talking about science provides a foundation for learning science. At the Intermediate Phase, you should encourage learners to talk about the science they are learning. It is best if they talk about actual objects or processes. Science provides interesting contexts and opportunities to observe and discuss observations.

Children should talk in their own language if that encourages free expression, but if the language of learning and teaching (LoLT) at the school is English or Afrikaans, you need to speak English or Afrikaans. If your home language is the same as most of your learners, you are probably code-switching from your home language to English in the science classes (Maluleke, 2019). This is a common practice, especially at the stage of schooling where learners are changing from their home language to English as the LoLT. You probably use the home language to make sure learners understand the science concepts and to encourage your learners to participate actively in class. Your 'teacher-talk' may consist of scientific terms in English with other parts of the sentence in their home language.

C.2.1. Introducing scientific terms

When should you introduce scientific terms? The best time is when learners have experienced a phenomenon (Harlen & Qualter, 2018). Sometimes what they are learning about is a real object, such as plants in Grade 4. Here is an example:

You have brought some whole plants to class. Learners talk about the parts of the plants. When they have talked about the parts of the plants, you can introduce the terms.

These parts that grow into the soil have a scientific name. It is 'roots'. The stalk that grows up into the air is called the 'stem'. The flat green parts joined to the stem are called 'leaves'.

Draw a plant on the board and point to different parts of the plant. Ask learners individually to say the name of each part. From then on, use the scientific terms for those parts of the plant.

Some scientific terms describe a concept rather than a physical object. For example, suppose you are teaching the concept of vibrations in Grade 4.

Learners have been exploring what they feel when they beat a drum, blow a whistle, or pluck a string on a guitar. They talk about what they feel. They may use words that mean 'shaking', 'trembling' or 'moving'.

Now is a good time to introduce the scientific term 'vibrating'. You could say, "Science has a name for that shaking you can feel. It is called 'vibrating'". While the children are learning the new term, use their own word and the scientific word together, for example, "The drum is shaking or vibrating". Put the learners' own word in place of 'shaking' so that they connect that experience with the term 'vibrating'.

Notice that learning scientific terms starts with experiencing the thing they are learning about. If you are teaching about a change of state, learners must experience and talk about the process of melting, evaporating, condensing and freezing. They can use their own language to describe what happens. Then you can introduce the scientific terms, linking them to the children's own words until the new words become familiar.

C.2.2. Linking words

We said earlier that linking words are very important in science (Wellington & Osborne, 2001). Look at two examples taken from the TIMSS restricted use items:

ITEM 4 (page 16)

The picture shows a food web in a forest ecosystem.

A. *Based on* what you can see in the food web, what does the hawk eat?

The question is 'What does the hawk eat?' The first part of the question instructs learners to look for the answer in the picture. Their answer must be based on the picture. It is important that learners read the whole question to answer correctly.

ITEM 15 (page 38)

Pictures of a fish and a human with parts labelled.

Which organ in humans has the *same* function *as* gills in fish?

Identifying *same as* and *different from* are important words in science. We use similarities (same as) and differences (different from) to group materials into raw materials and manufactured materials, metals and non-metals, or solids, liquids and gases. We use similarities and differences to classify objects as living and non-living, organisms into plants and animals, or animals into herbivores, carnivores and omnivores.

Spot the difference

Show learners two almost identical pictures (e.g. two zebras) or two similar materials (e.g. sand and soil) and ask them questions like:

'What is the **same** in the two objects?'

'What is **different** in the two objects?'

If you are code-switching, translate 'same' and 'different' into words that are familiar to the learners. Then introduce the English words. Emphasise the words 'same' and 'different' so that learners link the familiar words to the English words.

In the Intermediate Phase, you should aim to introduce the most used linking words. Four examples are *as, if, therefore* and *because*. As is a challenging word because it is used in different ways. Look at these examples:

As soon *as* you have finished. = *When* you have finished.

Stir the mixture *as* you heat it. = Stir the mixture *while* you heat it.

A whistle is *as* loud *as* a drum. = A whistle is *like* a drum in loudness.

As the substance takes the shape of its container, we can say it is a liquid. *As* = *because* or *since*.

Fill in the blanks

Talk about a few linking words at a time, as you need them. Write the words on the chalkboard and read them together with the learners. Explain what they mean, using equivalent words in their home language if you are code-switching.

For example:

As *if* *therefore* *because*

Explain what each word means using the home language if necessary. Now read some sentences and ask learners to say which of the linking words fits in the gap (note: more than one may fit):

The Moon has no air and water …… people can't live there. *(Answer: therefore)*

We use wood for fuel …… it contains stored energy. *(Answer: as* or *because)*

…… you heat a liquid, it changes to a gas. *(Answer: if* or *as)*

Your plants will die …….. you forget to water them. *(Answer: if)*

I know a rock is non-living …….. it does not grow or reproduce. *(Answer: because)*

C.2.3. Teaching prepositions

English has far more prepositions than other languages. Think about these words: *'in, on, over, under, before, behind, in front of, around, to, at, by, into, beside'.* Learners need to know what these words mean.

Look at these sentences. In each case, the preposition tells the learner where to put the ice.

Put some ice *into* a jar. The ice is *in* the jar.

Put some ice *under* a jar.

Put some ice *beside* a jar.

Put some ice *around* a jar.

Hold some ice *over* a jar.

The most frequently used preposition in the TIMSS restricted use items is *in*. Look at the prepositions in two items:

ITEM 5 (page 18)

Cape ground squirrels live *in* hot, dry environments. Sometimes they hold their tails *over* their heads as shown *in* the picture.

ITEM 8 (page 24)

At room temperature, *in* which state is each *of* the materials listed below? Shade *in* one circle *for* each material.

Teaching tips:

- Introduce a few prepositions when you need them for your teaching.
- Practice using prepositions by doing the action each sentence tells you to do.
- Make some mistakes and ask learners to say what is wrong.
- Make sure that you say whole sentences in English, using prepositions, when you talk about science.

C.3. READING SCIENCE

Learners must be able to read to answer TIMSS questions. The Natural Sciences curriculum includes reading as a suggested activity for some topics, e.g. 'read about how paper is made from plant fibres'. Learners must be able to read scientific terms to understand science and answer questions in science.

We know from previous research that reading affects how learners perform on TIMSS items (Dempster & Reddy, 2007). **ITEM 13** (page 34) is easy to read. Fifty-eight percent of South African learners chose the correct answer (D).

Which animal has a backbone?

Ⓐ 
octopus

Ⓑ 
spider

Ⓒ 
butterfly

Ⓓ 
frog

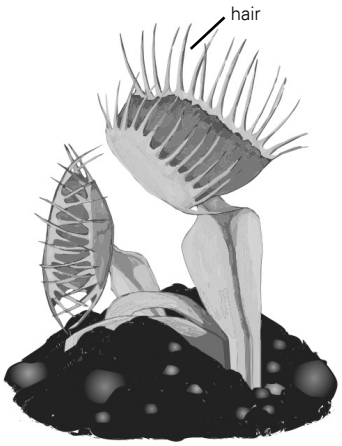
ITEM 16 (page 40) is difficult to read because it contains unfamiliar words *(Venus flytrap, digests, nutrients, reproduce)* and it has long sentences in the question and the answers. Only 27 percent of South African learners chose the correct answer (B).

This plant is a Venus flytrap.

When an insect touches the hairs on the Venus flytrap, the trap closes around the insect. Then the plant digests the insect.

In what way is the Venus flytrap different from most other plants?

Ⓐ The Venus flytrap attracts insects and other plants do not.
Ⓑ The Venus flytrap gets nutrients from insects and other plants do not.
Ⓒ The Venus flytrap helps insects reproduce and other plants do not.
Ⓓ The Venus flytrap gets its water from insects and other plants do not.



C.3.1. How can we help learners read science?

One of your aims should be to increase learners' vocabulary of scientific terms. You should do this by talking about science, but you need to reinforce the scientific words through reading. Make name-cards for physical objects, such as for roots, stems, leaves, flowers and fruits. Ask learners to place the name-cards in the correct place on physical objects or pictures of the objects.

Reading whole sentences is different from learning the terminology of science. First, choose a text that is at or a little above your learners' reading level. You may have to write your own material if the textbooks are too difficult to read. If you write your own material, keep the sentences short and use labelled diagrams to help learners visualise the material. At the intermediate level, keep the text short. Make it longer as the grades progress.

Second, encourage active reading instead of passive reading. Active reading means that learners are reading for a specific purpose. As the educator you are the coach, helping learners to achieve that purpose. Active reading is usually done in groups of two or three learners who work together to achieve the purpose (Wellington & Ireson, 2012; Wellington & Osborne, 2001).

Here are techniques you can use to encourage active reading (Wellington & Ireson, 2012; Wellington & Osborne, 2001):

Diagram labelling – use descriptive text with a blank diagram. Learners must use the text to label the diagram.
Table completion – provide a table with rows and columns labelled. Fill in some of the cells as examples. Learners must use the text to fill in the blank cells in the table.
Question setting – learners make up their own questions after reading a section of text.
Underlining – use this to identify specific words in the text. You can use underlining to identify content words, linking words and prepositions.
Unscrambling disordered text – this requires learners to understand the 'when-then' relationship. Use this technique if you have text that describes a sequence of events.
Labelling parts of text – this technique is very useful when learners make sense of test questions.
Ask a question – to ensure learners focus on what they must do to answer the question. Focus attention on important linking words, such as 'different from', which tell the learner they must make a comparison.
Ask a higher-order question – one that requires learners to make a connection based on the question. It directs learners towards the correct answer.
Diagram construction – use this to show the sequence of events described in the text.

Give just one or two activities for each text. Your overall purpose is to encourage learners to interact with the text so that they understand what they are reading. They are also learning the structure of scientific writing. Which are the content words? Which are the linking words? Which are the prepositions? Most importantly, what do I learn from reading this text?

C.4. WRITING SCIENCE

We can tell from the scores for the Constructed Response Questions that learners have difficulty giving written answers to questions (Table 4).

Let's revisit **ITEM 1** (page 10) and the question it asks about living and non-living things in a desert.

The item is easy to read and the picture helps learners. They must write one-word answers. A quarter (27%) of South African learners correctly identified the two living things as well as the two non-living things shown in the picture. One-third (32%) of learners identified the two living things correctly, but the non-living things incorrectly, and three percent of learners named two non-living things correctly, but living things incorrectly or incompletely.

This means learners were able to identify and name living things more easily than they could identify and name non-living things.

Now let's look at the item with the lowest correct percentage (**ITEM 11**, page 30):

> Akhona placed a cup made of wet clay on the table. Several days later, the clay was dry.
>
> What happened to the water in the clay?

Only three percent of South African learners answered this question correctly. For a learner to get a point, they had to use the term 'evaporated' or 'evaporation' OR they had to say that the water went into the air. An answer of 'dried up' was scored as incorrect, unless the learner also said the water became water vapour. South African learners should know the term 'evaporation' from Grade 4. They should have been able to write 'The water evaporated', but most learners were unable to answer this question correctly.

C.4.1. How can we help learners write science?

The first requirement is knowing the vocabulary of science, such as the scientific terms, linking words and prepositions. **Before learners write their own sentences, they must be able to talk and read about scientific topics. Writing science reinforces the language of science.**

Research shows that learners think they copy a lot of notes during science classes (Wellington & Osborne, 2001). Think about your teaching in science. Do you make learners copy notes from the chalkboard? How often do you expect learners to write their own sentences in science?

Here are three ideas – fill in the blanks, rearranging words to make sentences, and converting pictures to words – to encourage active writing instead of copying:

Fill in the blanks

1. Give learners sentences written in English with key words missing. The words can be scientific names (as in Table 7), linking words or prepositions.
2. Supply the words as a separate list.
3. Learners must fit the missing words into the correct places in the sentences.

For example, here is an exercise suitable for Grade 4 or 5 Earth science. Read the instructions with the class to make sure they understand what they must do.

> Use words from the list below to fill in the blanks in the sentences below. You can use a word more than once or not at all.
>
> Planet | space | Sun | orbit | solar system | Moon | star
>
> The ..... is a star.
>
> Earth is a .....
>
> A ..... moves around the ..... in a path called its .....

The ..... consists of the Sun and its planets.

The ..... revolves around the Earth.

Rearranging words to make sentences

Learners must learn how to write whole sentences in science. The CAPS has this suggested activity for Grade 4: 'Drawing and writing about the water cycle'. You can use this activity to develop scientific writing skills.

Use this sentence:

'Water evaporates from the sea, dams and plants.'

Cut the sentence into separate words and jumble the words:

Water and evaporates from dams plants the sea

Ask learners to arrange the words to make a correct sentence. The word 'water' is written with a capital letter, showing that it is the first word in the sentence. You are reinforcing the term 'evaporates' and the sequence of words in a sentence.

There are several correct answers:

Water evaporates from the sea, dams and plants.

Water evaporates from dams, plants and the sea.

Water evaporates from plants, dams and the sea.

Here is a sentence containing linking words:

'Water vapour condenses because it cools as it rises.'

because cools vapour it condenses it as Water rises

The first word in the sentence is 'Water'. After that, learners must work out the order of the words.

Here is an alternative sentence that is also correct: Water vapour condenses as it rises because it cools.

Learners should write the sentence into their notebooks and read it aloud. They should be able to identify errors in their own sentences or in sentences that you read out as incorrect.

Converting pictures to words

Food chains are included in the Grade 4 Natural Sciences curriculum and repeated in Grade 5. A suggested activity for Grade 4 is to draw or write about food chains. **ITEM 4** (page 16) is based on understanding *food chains*.

Only 28 percent of South African learners could choose the correct answer to the question, "What does the hawk eat?" Many did not understand diagrams showing food chains or food webs. You can use a diagram like the one in **ITEM 4** to get learners to write about food chains. Provide the beginnings of the sentences:

The food chain starts with ..... that get their energy from .....

Energy passes from the plants to .....

The blackbird .....

The hawk .....

The arrows show .....

Learning the language of science needs practice, practice and more practice. **Our children will not improve their performance in science until they can talk about science confidently, read with meaning, and express their ideas in scientific language.**

C.5. IMAGES AND GRAPHS IN SCIENCE

Science uses images because they are very helpful in communicating information, illustrating relationships and showing patterns and trends. Learners must be able to understand and interpret images to answer the TIMSS questions. Some images in the TIMSS assessment are simple and straightforward and others are complex with many pieces of information. In this section, we will discuss some of the images and the difficulties learners may have experienced, and then suggest ways to help learners to understand images and graphs better.

The image used in **ITEM 17** (page 42) to illustrate the use of a torch is straightforward. South African learners performed fairly well in this item, with half of the learners choosing the correct answer A, and their performance was slightly below that of the international average for learners (53%).

Another item that involves a simple illustration is **ITEM 18** (page 44) where Tina and Mary are moving boxes. Again, South African learners performed fairly well on this question, with just under half the learners (47%) choosing the correct answer D, and their performance was again just slightly below that of the international learners (49%).

However, some images are more complex and difficult to understand. For example, the image used in **ITEM 20** (page 48) illustrates a skydiver jumping from an aeroplane. This image is difficult for South African learners because many of them are not familiar with the concept of skydiving. South African learners preferred answer A (39%). This choice shows that learners correctly interpreted the diagram as showing that the skydiver was falling through the air but, because of their lack of knowledge of the way a parachute works, as well as not yet having encountered the concepts of gravitational and other forces, they were unable to answer the question correctly.

Another difficult image for learners at this level is the one used in **ITEM 21** (page 50), which shows the Earth's revolution around the Sun. This is an abstract image for learners to understand easily, since it is not something that they can see in their everyday lives—we are used to looking at the Sun *from* the position of Earth. However, a quarter (26%) of South African learners chose the correct answer C.

This shows the importance of learners becoming familiar with scientific images, allowing them to gain confidence in interpreting these images.

Learners in Natural Sciences must be able to interpret the meaning of graphs. **ITEM 22** (page 52) involves the interpretation of a bar graph. To be able to answer this question, learners must be able to interpret the meaning of the bar graph, namely the required rainfall for specific crops, and use this information to identify which crops would grow best with the given rainfall. This is a challenging question since learners need to understand and interpret the bar graph to identify the crops that require a *lower* rainfall than the given quantity. At this stage of development, most learners will interpret the information in a bar graph in a straightforward (literal) way, looking for bars that show rainfall *greater* than 60 cm.

More than half of the South African learners preferred answer D, where the data shown for the crops is more than the 60 cm of rainfall given in the question. The second-highest response was the correct answer, which is B. The responses show that most learners failed to fully understand the meaning of the graph. Their responses show that they had a very literal interpretation of the graph and were thus unable to apply a higher level of reasoning to this information. This is in line with research on learners' understanding of graphs, which showed that younger learners could read literal graphs with ease but were less successful in answering questions requiring higher-level cognitive skills (Curcio & Smith-Burke, 1982; Pereira-Mendoza & Mellor, 1990).

C.5.1. How can we help learners to understand images and graphs?

Here we will look separately at images and bar graphs.

a. Understanding the information given in an image

Images are a very helpful way of communicating information and help the reader to take in a lot of information in a short space of time, and to better remember the information (Levie & Lentz, 1982). According to studies, the human brain processes images 60 000 times faster than text (Parkinson, 2010), and presentations that use visual aids are likely to be 43 percent more effective than those without (Hanke, 1998). We need to help our learners to be able to better understand visual information.

When we work with an image in science, it is important that we take some time to understand what the image is telling us. The following are three suggested activities for helping learners to understand scientific images: discuss the meaning of images together, create scientific images, and label and colour in scientific images.

Discuss the meaning of images together

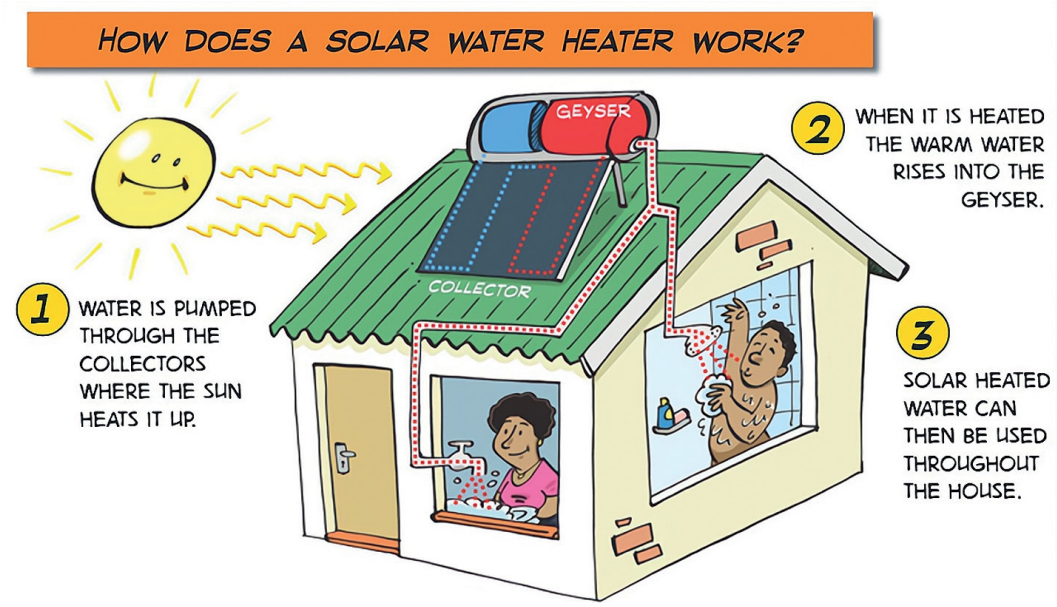
Give learners practice in understanding images by showing them various scientific pictures that relate to the theme they are studying at the time. Ask them what information the pictures are showing them and encourage them to discuss their ideas so that they help each other to see more elements in the pictures. When they discuss the image in groups, they can use questions to guide them, such as:

- What is this a picture of (name the different objects that you can see, and try to describe for yourself what is happening with the objects in the picture)?
- What type of image is it, e.g. a photo, a sketch, a labelled diagram, a graph?
- Does it show a process? If so, how?
- If it is a graph, what kind of graph is it, e.g. line graph, bar graph?

Here are a few examples of different kinds of images you could use to give your learners some practice.

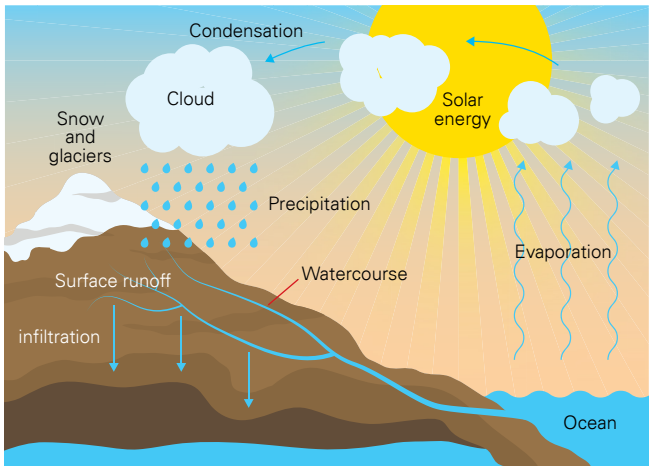
PICTURE 1[14]

PICTURE 2[14]



[14] Picture 1 and 2: Creative Common Licenced image from http://www.sciencespaza.org/resources/
[14] Picture 3 Creative Common Licenced image from https://commons.wikimedia.org/wiki/File:Water_Cycle-en.png

PICTURE 3[15]



Creating scientific images

After you have completed a section of work, encourage your learners to create a collage, poster or even a comic strip that illustrates some of the key concepts that they have learned. Here is an example:

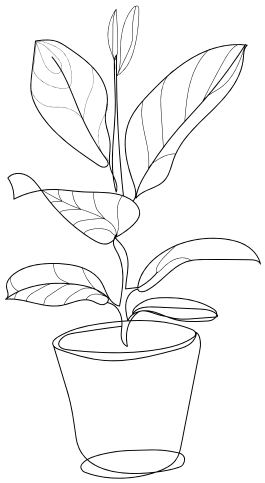
DRAWING OF HEAT TRANSFER[16]

Labelling and colouring in scientific images

A helpful way to familiarise young learners with scientific images is to ask them to provide labels, and to colour in the picture. You could find pictures on the internet that they could label and colour in. Here is an example[17].

[15] Creative Common Licenced image sourced from https://www.vecteezy.com/vector-art/99334-water-cycle
[16] Creative Common Licenced image sourced from https://www.vecteezy.com/vector-art/2852633-diagram-showing-methods-of-heat-transfer
[17] Creative Common Licenced image sourced from https://www.vecteezy.com/vector-art/4805168-indoor-plant-in-a-pot-hand-drawing-illustration-outline-style-vector-linear-illustration-of-a-ficus-flower-in-a-pot-isolated-on-white-background

Colour in the picture and label the following:



Soil
Stem
Leaf
Flower
Roots (show where these are even though they are hidden)

b. Understanding bar graphs

Being able to draw and interpret graphs is an important scientific skill, so it is important to help your learners to understand scientific graphs. It is important that learners spend some time trying to understand what a graph is telling them before they answer any questions about the graph.

In this section, we will look at bar graphs. A bar graph is a graph with rectangular bars that have different heights or lengths, to show the values that they represent. The axis labels are important to tell us about the meaning of the graph.

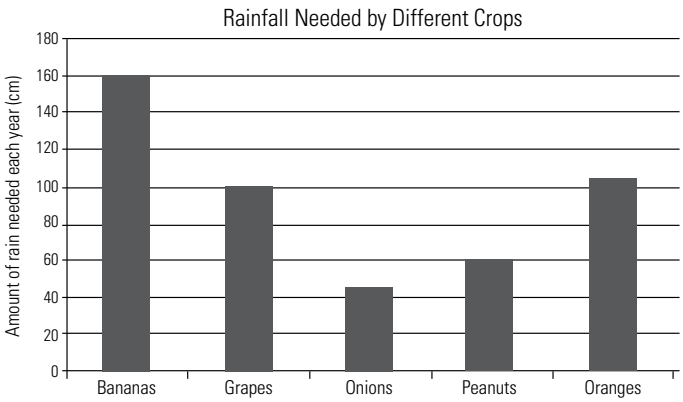
Some possible questions you could ask learners to help them to make sense of graphs are:

- Look at the label of the vertical axis (on the left of the graph). What does this axis tell you?
- Look at the label of the horizontal axis (usually at the bottom of the graph). What does this axis tell you?
- Explain the meaning of the graph in your own words.

Practice exercise:

Practice is very important for learners to become confident in understanding graphs. As an activity, you could ask your learners to look at the bar graph given below (from **ITEM 22**, page 52) and answer the following questions in groups. Possible answers are shown in italics.

The amount of rainfall needed by different crops is shown in the graph below:



1. Look at the label of the vertical axis (on the left of the graph). What does this axis tell you?
   Answer: *This tells us the amount of rain needed by crops each year, in cm.*
2. Look at the label of the horizontal axis (at the bottom of the graph). What does this axis tell you?
   Answer: *This tells us the specific crops we are looking at.*
3. Explain the meaning of the graph in your own words.
   Answer: *This graph tells us that bananas need the most rain (160 cm), and onions the least (approximately 45 cm).* Encourage learners to describe all of the possible information that they can read from this graph.
4. From this graph, how much rainfall do oranges need each year?
   Answer: *This graph tells us that oranges need approximately 102 cm of rainfall per year* (They can answer with 100 cm).
5. If you try to grow grapes in an area that receives only 40 cm of rain, will they be able to grow?
   Answer: *No, grapes need 100 cm per year to grow.*

Now ask your learners to discuss the answer to the question for this graph from the TIMSS assessment:

A farmer wants to plant crops in an area that gets about 60 cm of rain each year.
Which crops will probably grow best in this area?

(A) onions only
(B) onions and peanuts
(C) grapes and oranges
(D) bananas, oranges and grapes

The correct answer is B.

C.6. SCIENTIFIC METHOD

Science is investigated through the scientific method. Part of the scientific method involves formulating a hypothesis and then designing an experiment where we make sure that we are using a fair test by keeping some things the same (controlled variables) while changing other variables. Learners must be able to understand and apply the concept of a fair test to answer the TIMSS questions.

ITEM 9 (page 26) is an item in the TIMSS test where the concept of a fair test is applied. South African learners performed very poorly in this item, with only five percent answering correctly. To be awarded the marks for this question, learners had to be able to explain that the amount of water is the same for each experiment to make it a fair test. In other words, water is a controlled variable. The results showed that learners at this level (both in South Africa and internationally) do not have a good understanding of fair tests and the need to control variables.

C.6.1 How can we help learners to apply the scientific method?

a. Understanding the scientific method

Science is about our experience of the world around us. Sometimes our experiences raise **questions** in our minds. If we do not know an answer to a question, or if we cannot find an answer in books, then we perform an **experiment** to try to find an answer to the question. An important part of designing an experiment is ensuring that we are using a **fair test**, by keeping some things the same (control variables) while changing other variables. We then perform the experiment, and we keep a note of our results. After we have analysed our results, we write a **conclusion** that states what we found out from the experiment.

b. How to design a good experiment

Suppose you want to design an experiment to investigate the following question: *"Is a black cloth a better absorber of radiation energy than a white cloth?"*

To answer this question, you could do the following experiment:

1. Take two bottles of the same size, made of the same material.
2. Fill them with the same amount of tap water.
3. Measure the starting temperature.
4. Wrap one of the bottles in a black cloth, and one in a white cloth.
5. Place both bottles an equal distance from a lamp, or in the sunlight.
6. After a fixed amount of time, measure the temperature of the water in each bottle.

The controlled variables in this experiment are the type of bottle, the amount of water, the starting temperature, the type of cloth fabric, the amount of radiation energy, and the amount of time.

The measured variable, i.e. the one that is being changed in the experiment, is the colour of the cloth.

Practice exercise:

As an activity, you could ask your learners to answer the following questions in groups. Possible answers are shown in italics.

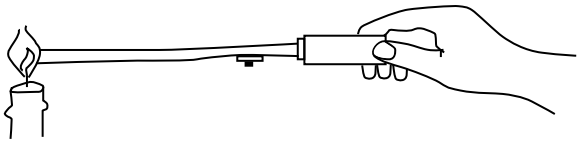
Thandi has noticed that although all metals are good conductors of heat, some seem to conduct heat more quickly than others. She wants to investigate this further. She has three rods made from different metals: copper, iron and aluminium.

Thandi designs an experiment that has the following steps:

Step 1: Take three rods that have the same length and thickness, one made of copper, one made of aluminium and one made of iron.

Step 2: Stick a piece of soft margarine on one end of each rod and attach a smartie sweet to this. Do this the same way for all three rods.

Step 3: Heat the tip of the other end of each rod in a flame.



Step 4: Record the amount of time that it takes for each of the smarties to fall off each rod.

Name as many controlled variables as you can that will make this a fair test.

(***Answers:*** *Controlled variables are: the thickness of the rods, length of the rods, type of margarine, amount of margarine, type of flame, mass of each smartie).*

Look at the three experiments with dissolving sugar from **ITEM 9** (page 26):

In addition to keeping the amount of water the same for all the experiments, name one other variable that must be controlled to make each test a fair test:

Test 1: _____

(***Answer:*** *size / mass / surface area of the sugar cube; amount of stirring — none of them are stirred OR all of them are stirred)*

Test 2:_____

(***Answer:*** *size / mass / surface area of the sugar cube; temperature of the water)*

Test 3:_____

(***Answer:*** *temperature of the water; amount of stirring — none of them are stirred OR all of them are stirred)*

C.7. HIGHER-ORDER THINKING SKILLS

Table 3 (page 6) showed that South African and international learners found questions requiring higher-order thinking, such as applying and reasoning, more difficult than 'knowing' questions.

ITEM 10 (page 29) is an example of an 'applying' question:

Tom has a bucket full of sand and small stones.
How can he quickly separate the sand from the stones?

_____

Only eight percent of South African learners answered this item correctly. Although methods of separating mixtures only appear in the Natural Sciences curriculum in Grade 6, learners could apply everyday knowledge to work out an answer (sieving or washing the sand out).

ITEM 6 (page 20) is an example of a 'reasoning' question:

One summer, Sifiso notices that there are fewer insects out at night than in the past. He also notices that there are more bats.
How could the increase in the number of bats explain the decrease in the number of insects?

_____

Learners must make the following links:

More bats → fewer insects → bats must be eating insects.

Less than 10% of South African learners answered this question correctly. This specific topic is not included in the Natural Sciences curriculum, but learners studied food chains in Grade 5.

C.7.1. What can we do to improve learners' higher-order thinking?

a. Steps involved in answering higher-order questions in science

1. Draw a diagram of the scenario if one hasn't been provided or spend some time understanding the diagram that has been given.
2. Write a list of the information that has been given in the question.
3. Read the question carefully to decide exactly what is being asked.
4. Reflect on which aspect of science this question links to and try to bring to mind the main concepts.
5. Apply the concepts to the problem and try to find a solution.
6. Reflect on your answer, making sure that your solution is sensible, and that you have answered the question identified in Step 3.

b. Encouraging higher-order thinking through questions and discussion

Most of the questions you ask in the science classroom are closed questions, that is, they have a fixed answer, usually a fact. Include some open-ended questions in your teaching strategies. Use 'Can you explain why …' and 'How did you decide …' questions to stimulate group discussion and encourage learners to think about their own reasoning (Adey & Serret, 2010).

Example 1: **ITEM 2** (page 12)

Mark planted a flowering plant in a pot that contained soil with enough fertiliser.
Mark went on a trip and left the plant in a dark room. He knew the room would not get too hot or too cold. When he came back two weeks later, the plant was dying.

Write two reasons the plant was dying.

_____

1. Can you explain why the plant was dying?
2. How did you decide on your answer?

Example 2:

Ryan did an investigation with bean seeds. He put 12 beans into each of two identical containers lined with a paper towel. He poured 20 ml of water over the paper towel and put lids on the containers. He put one container in the fridge and one on the kitchen table. The photograph below shows what he saw after three days.

Ryan showed his results to his class and asked them some questions:

- Which of the two containers was in the fridge?
- How did you decide on your answer?
- Can you explain why the beans in one tray have grown and the others have not?

- What did I do to make this a fair test (Answer: equal numbers of beans, same amount of water, same type of bean seeds, identical containers, sealed both containers)?
- What can I conclude from my investigation?

Notice that in this example, the learner (Ryan) asks the questions. Thinking up questions is a good way to encourage higher-order thinking skills.

C.8. CONTENT AREAS THAT NEED STRENGTHENING

The results from the analysis of restricted use items show that most South African learners tested know very little about the topics tested in these items. The percentage correct was above 50 percent in only two items (Items 13 and 17). Figures 1 and 2 (pages 5 and 6) show that learners did better in **ITEM 1** and **ITEM 13**, which relate to 'Characteristics and life processes of organisms' content in the TIMSS curriculum. However, they performed poorly in **ITEM 7** and **ITEM 15**, which are also related to 'Characteristics and life processes of organisms'. Overall, there was only one 'standout' area of weakness, which is classification and properties of matter.

C.8.1. Classification and properties of matter – Solids, liquids and gases

The only topic from the classification and properties of matter TIMSS questions that South African learners cover in Grades 4 and 5 is 'Solids, liquids and gases'. We therefore decided to focus on strengthening this content area.

The TIMSS **ITEM 8** (page 24) relates to the states of matter. To be able to answer this question, learners must be able to identify the state of each of the materials listed and understand that oxygen is a gas. Thirty-nine percent of South African learners answered this question correctly. This shows that the **majority** of South African learners are unable to correctly identify the state of matter of material. This content area is covered in the Natural Sciences curriculum in Grade 4.

The TIMSS **ITEM 11** (page 30) relates to changes of state:

Akhona placed a cup made of wet clay on the table. Several days later, the clay was dry.

What happened to the water in the clay?

_____

To be able to answer this question, learners need to understand that for wet clay to have become dry, water must have evaporated from the clay, changing from a liquid to a gas.

South African learners performed extremely poorly in this question, with only three percent answering correctly. Although this question is not straightforward, it still shows that learners need assistance with understanding the changes of state between solids, liquids and gases.

C.8.2. How can we help learners understand solids, liquids and gases?

a. Core concepts

All matter around us exists in one of three states:

- as a solid, which keeps its shape;
- as a liquid, which flows to take the shape of the container it is in; and
- as a gas, which has no definite shape and spreads out to fill the space available.

When a substance receives or loses heat energy, this can have two effects:

- It can cause a change in temperature, where the substance gets hotter or colder.
- It can cause a change in phase, for example melting, freezing, condensing or evaporating.

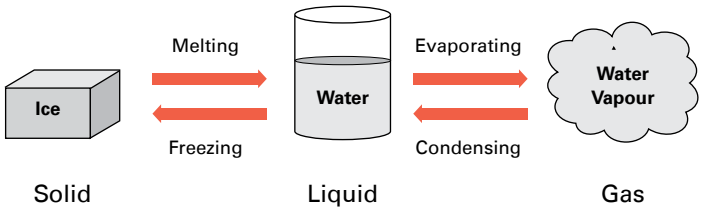
In our everyday lives, the substance with which we are most familiar regarding changes between the states is water:

- Ice is an example of a **solid**.
- When ice melts, it changes in phase to become water, which is an example of a **liquid.**
- When water boils, it is evaporated or vaporised into steam (or water vapour), which is an example of a **gas**.

The reverse of these processes are:

- When steam or water vapour is cooled, it condenses to become liquid water.
- When liquid water is cooled enough it eventually **freezes** to become solid ice (this is also called **freezing** or **solidifying**).

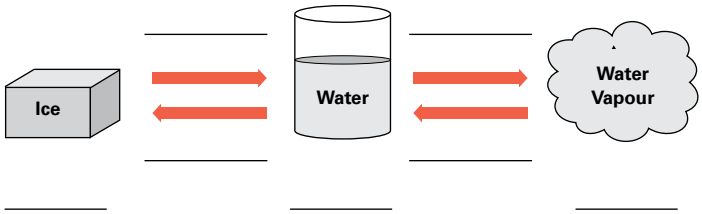
As we saw previously in this report, diagrams can be a very powerful way of communicating information. The diagram below summarises the information given above.



b. Suggested pen-and-paper activities

To give your learners a chance to become familiar with these terms and concepts, you should give them activities to do where they actively engage with these ideas. Here are three examples:

1. Fill in the missing labels using the terms shown in the box below the diagram.



Evaporating | Gas | Freezing | Soild | Condensing | Melting | Liquid

2. Complete the table below (you can cut out pictures from old magazines or draw your own pictures):

State of matter	Describe the properties	Pictures of some examples
Solid		
Liquid		
Gas		

3. Now encourage your learners to try answering the TIMSS test items:

a. **ITEM 8** (page 24); and

b. **ITEM 11** (page 30).

c. Suggested practical activities

One of the most powerful ways to help your learners understand and remember what they learn in science is to allow them to do practical, hands-on activities.

Activity 1:

Properties of solids, liquids and gases

You will need

Two plastic bottles with lids, a solid object and some water

Experimental steps:

1. Fill one of your bottles with water, so that there is a small space left at the top of the bottle, and seal it tightly. Label this bottle 'Liquid'.
2. Seal your other bottle while it is "empty". Can we really say that it is empty? Discuss your ideas in your group. Label this bottle 'Gas'.
3. Label the solid object 'Solid'.
4. Pick up the solid object and move it around – does its shape change when you move it?
5. Try squeezing your solid object. How much can you compress it?
6. Write down the properties of the solid object that you have observed:

_____

7. Now try moving the bottle filled with liquid around – does its shape change when you move it?
8. Try squeezing the bottle filled with liquid. How much can you compress it?
9. Write down the properties of the liquid that you have observed:

_____

10. Lastly, look at the bottle filled with air (which is a gas). Can you see any shape of the gas, other than the shape of the bottle?
11. Try squeezing the bottle filled with gas.
12. How much can you compress it?
13. Write down the properties of the gas that you have observed:

_____

Activity 2:

Do gases have mass?

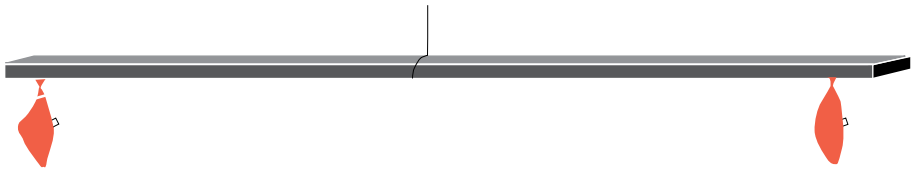
Learners sometimes find it difficult to understand that gas, such as the air around us, is matter. This is because we usually cannot see, feel, hear, taste or smell air. Our senses do not help us to detect air. But if we hold our breath for a short while, we know how important air is for our lives! Learners in Natural Sciences need to understand what gas is. This is a simple activity that shows learners that gases do have mass, and therefore that they are a form of matter.

You will need

A ruler, a piece of string, some paper clips, sellotape and 2 balloons

Experimental steps:

1. Tie your piece of string around the middle of your ruler so that you can hang the ruler from the string. Move the string around until the ruler is balanced.
2. Using your sellotape and paper clips, attach the empty balloons to either end of the ruler, and make sure that the ruler remains balanced. This tells you that the empty balloons have equal masses.



3. Now remove one of the balloons, blow it up, and tie the opening so that it stays inflated.
4. Re-attach this balloon to its place on your ruler, with the other empty balloon still on the opposite end of the ruler. What do you observe?
5. What conclusions can you draw from your observations?

Activity 3:
Changes in the three states of matter

You will need
Some ice, a glass jar, a Bunsen burner or hot plate

Experimental steps:

1. Fill your glass jar with some ice. If you have a thermometer, you could put it in the ice and watch what happens to the temperature during this experiment.
2. Light your Bunsen burner (or turn on the hot plate) and place the jar on the stand over the burner. Observe what happens to the ice as the jar is heated.
3. When the water in your glass jar starts to boil (make bubbles), what do you observe happening above the water? While it is still boiling, hold another glass container above the water, **but be careful to not let the steam burn your hands.** What do you observe?
4. Discuss your observations in your group.

Activity 4:
Exploring evaporation

Learners find evaporation especially difficult to understand. Research has found that many learners assume that, when something dries, the water has 'disappeared'. Learners must understand that matter is conserved and therefore never disappears, but changes from one form into another. When matter seems to become invisible, the reason is that it has changed into a form that we cannot see with the naked eye. Evaporation is an example of this, where liquid, which is visible, changes into a gas, which is invisible to our naked eye. It is helpful to allow learners to observe evaporation in different contexts and to discuss their ideas so that they recognise the misconception of water disappearing. The following activity encourages this discussion.

You will need
Some cloth material, water, a shallow bowl, clay or mud

Experimental steps

1. Pour some water into a shallow bowl and place it in the sun.
2. Wet the piece of material and place it facing the sun next to the bowl of water.
3. Wet the clay or mud and place it facing the sun next to the bowl of water and wet material.
4. Leave these for a few hours and observe what has happened to each.
5. Discuss your observations in your group and try to explain what has happened.

Follow this activity with a discussion of evaporation:

- Water evaporates when it is heated – we can see this from the water in the bowl that was left in the sun (water doesn't have to boil to evaporate!).
- The water particles don't disappear, but they become gas particles (water vapour). Although we can see water because the particles are joined together, making it visible to our eyes, the gas particles are separated from one another as they join with the other gases in the air. Since all particles are too small to see with our naked eyes, we can't see these separate gas particles, so they seem to have disappeared.

- Although we cannot see the water vapour in the air, we know it is there – you can prove this to your learners by asking them to breathe on a mirror or glass object, and they will see the tiny drops of water formed on the surface.
- Similarly, water evaporated from the wet material and the wet clay or mud. The water enters the air as water vapour, causing the material and clay/ mud to become dry.

SOME CONCLUDING REMARKS

By now, you're probably thinking, "I can't do all these things AND cover the curriculum. It's too much". Try to build these activities into your normal science lessons. Practice so that the techniques we've included here become natural to you. Remember, you are still teaching the prescribed content but you're incorporating other skills that are important in science. We encourage you to especially focus on developing your learners' language skills. Science is a language-intensive subject, so a strong grasp of the language of instruction is essential to understanding scientific terms and concepts.

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