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Chapter 9
Science items: Context and curriculum

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Introduction

This chapter examines the science performance of Irish pupils in Trends in Mathematics and Science Study (TIMSS) 2011 at a broad level, and provides an in-depth analysis of performance on a subset of released test items. The TIMSS assessment framework is reviewed in the context of the Primary School Science Curriculum (PSSC) (DES/NCCA, 1999). Unlike reading and mathematics, there are no formal national assessments of primary science in Ireland on which to draw. Thus, the chapter draws on previous performance on TIMSS 1995, and from the OECD's Programme for International Student Assessment (PISA), which assesses the reading, mathematics and science skills of 15-year-olds.

Irish pupils have participated in three international assessments of science achievement (including two at primary level), with mixed results. In the International Assessment of Educational Progress in 1988, Irish children aged 9 and 13 years did not perform as well in science-related activities as pupils from other participating countries, and Irish girls had the lowest average science proficiency of any group involved (Lapointe, Mead, & Phillips, 1989). It was suggested that inadequacies in the 1971 curriculum and Irish teachers' lack of confidence affected Irish pupils' performance (INTO, 1987). In contrast, the Third International Mathematics and Science Study (also called TIMSS) in 1995 revealed that whilst Irish 9-year-olds' overall performance in science was above the international average, Irish pupils did not perform particularly well on Physical Science topics (Martin, Mullis, Beaton, Gonzalez, Smith, & Kelly, 1997).

Since Ireland last took part in TIMSS, the Primary School Curriculum has been revised. Regarding science in particular, the PSSC is an extensive expansion of its precursor, Curaclam na Bunscoile (Department of Education, 1971), which predominantly focused on biology and environmental science and in which Physical Science was only an optional component of the Fifth and Sixth class programmes. In addition to developing pupils' physical and biological content knowledge at all class levels, the PSSC also places considerable emphasis on the application and development of pupils' scientific skills. With the implementation of this revised PSSC since TIMSS 1995, one might expect an improvement in pupils' performance in TIMSS 2011.

At post-primary level, Irish 15-year-old students have performed slightly above the OECD average for science in repeated cycles of PISA (Cosgrove, Shiel, Sofroniou, Zastrutzki, & Shortt, 2005; Eivers, Shiel, & Cunningham, 2008; Perkins, Cosgrove, Moran, & Shiel, 2012; Shiel, Cosgrove, Sofroniou, & Kelly, 2001). The aim of PISA is to assess students' knowledge and skills in three domains: scientific literacy, mathematical literacy and reading literacy. Each year one of these areas is the "major" domain examined and the other two are examined in less depth. Science has been the major domain only once – in 2006. Then, Ireland's average score (508) was significantly higher than the OECD average of 500 and Irish students performed best on *identifying scientific issues* items, where their mean score of 516 was significantly higher than the OECD mean (499) (Eivers et al., 2008). Irish students' mean score (506) on *using scientific evidence* was also significantly higher than the OECD mean (500).

However, Irish students' mean score for *explaining phenomena scientifically* (505) was not significantly above the OECD average score of 500. Ireland's mean scores for *knowledge about science* (513) and *knowledge of Earth and space systems* (508) were also significantly higher than the OECD average scores. Their mean scores for *knowledge of living things* and *physical systems*, although higher than the OECD average scores, were not significantly so (Eivers et al., 2008). While PISA assesses post-primary rather than primary level scientific literacy, similar patterns of relative strengths and weaknesses emerged amongst Irish Fourth class pupils' performance in the cognitive and content domains of TIMSS 2011.

Full details of Irish pupils' performance in TIMSS 2011 are provided in the main national report by Eivers and Clerkin (2012), but, broadly, national science achievement is similar to that reported in TIMSS 1995 and in successive PISA cycles. In TIMSS 2011, Ireland performed slightly above average on the science component. Ireland's mean of 516 was significantly above the study centrepoint of 500, ranking 22nd of 50 participating countries. Seventeen countries achieved mean scores that were significantly higher than Ireland's. Boys and girls in Ireland obtained identical mean scores on the overall science assessment.

In the Irish research literature concerns have been expressed about the teaching and learning of primary science. From a teaching perspective, concerns include: inadequate time being devoted to hands-on inquiry-based approaches to science; teachers' lack of competence and confidence in teaching science; poor scientific content and pedagogical knowledge amongst teachers; and insufficient provision of hands-on pedagogical courses at both pre-service and in-service levels (INTO, 1987; Murphy & Smith, 2012; NCCA, 1990; Varley, Murphy, & Veale, 2008; Waldron et al., 2009). From a learning perspective, concerns include: scientific literacy; attainment in science; and infrequent engagement with inquiry-based approaches to science (DES Inspectorate, 2012; Murphy, Murphy, & Kilfeather, 2011; Murphy, Neil, & Beggs, 2007; Murphy, Varley, & Veale, 2012; Smyth, McCoy & Darmody, 2004; Varley, Murphy, & Veale, 2008, 2011). Some of these concerns and their significance in terms of Irish pupils' performance in TIMSS 2011 will be considered later.

In this chapter, Irish pupils' performance on the TIMSS 2011 science assessment is discussed in detail. The next section, section two, compares the TIMSS 2011 science framework with the content strands from the PSSC and discusses a Test-Curriculum Matching Analysis (TCMA) that was conducted to establish the extent of overlap between the assessment and the Irish curriculum. An overview of International Benchmarks is provided in section three, with illustrative exemplar items. Section four begins with an overview of Irish pupils' performance in the three content domains (Life Science, Physical Science, and Earth Science) in TIMSS 2011. This is followed by a detailed analysis of a number of the released science items in which Irish pupils' performance was deemed unusual or "out of the ordinary'. A number of possible factors which may have affected Irish pupils' performance are also considered. Finally, in section five, a brief overview of developments in primary science in Ireland since TIMSS 1995 is presented and the potential impact of these changes on Irish pupils' performance on TIMSS 2011 is considered. Readers should note that this chapter examines only one element of the TIMSS 2011 data. Those who would like more general information about TIMSS or about Ireland's participation in PIRLS and TIMSS in 2011 are referred to Chapter 1 of this volume (Eivers & Clerkin, 2013).

TIMSS 2011 science framework and the Irish PSSC

This section briefly compares the TIMSS 2011 science framework and the Irish PSSC (DES/NCCA, 1999) for Fourth class.

TIMSS science framework and item specifications

TIMSS 2011 assessed pupils' conceptual scientific knowledge and their application of science skills. Each test item addressed both **content** and **cognitive** domains. The content domain assessed the scientific content (or science subject matter) that is taught in school science and the cognitive domain assessed the different types of behaviours or thinking processes that pupils would be expected to engage with during scientific inquiry.

TIMSS 2011 contained three content domains: Life Science, Physical Science and Earth Science. Life Science examined pupils' knowledge of the processes and characteristics of living things (plants, animals and human life). The Physical Science content domain assessed pupils' knowledge of energy and forces (light, heat, electricity, magnetism, forces and sound) and the properties of matter (physical properties of materials, and materials and change). Finally, the Earth Science content domain assessed pupils' conceptual knowledge of the solar system and their knowledge of Earth's physical characteristics and resources.

There were also three cognitive domains in TIMSS 2011: Knowing, Applying and Reasoning. These required pupils to demonstrate their aptitude for applying different scientific skills including inferring, interpreting, analysing, classifying, reasoning and deduction. Table 9.1 shows the percentages of the assessment allocated to each content and cognitive domain in TIMSS 2011.

Table 9.1: Percentages of items assessing the content and cognitive domains in the TIMSS 2011 Fourth grade science assessment

Content domains	Percentages of items
Life Science	45
Physical Science	35
Earth Science	20
Cognitive domains	
Knowing	40
Applying	40
Reasoning	20

Primary School Science Curriculum (Third and Fourth class)

The revised Primary School Curriculum, introduced in 1999, included science as a compulsory subject on the syllabus for all primary school pupils. The content of the PSSC is largely based on the content and cognitive domains found in TIMSS 1995 and is considerably different to its predecessor, Curaclam na Bunscoile (Department of Education, 1971). The PSSC places considerably more emphasis on the development of scientific content knowledge (in biology, physics and chemistry) and on the development of scientific skills at all class levels. This stands in contrast to Curaclam na Bunscoile in which there was a strong emphasis on biological and environmental science, and where physical sciences were only an optional component of the Fifth and Sixth class curriculum.

There are four content strands in the PSSC: Living Things, Energy and Forces, Materials, and Environmental Awareness and Care. Some elements of Earth Science are not areas of content on the PSSC, but are included on the Primary School Geography

Curriculum (PSGC). Some of these are identified and discussed later in sections three and four of this chapter.

The cognitive aspect of the PSSC has 11 "working scientifically" skills: questioning; observing; predicting; investigating and experimenting; estimating and measuring; analysing; sorting and classifying; recognising patterns; interpreting; recording; and communicating.

Comparing the TIMSS science framework and PSSC

Table 9.2 provides a comparison of the TIMSS science framework and the PSSC (and the geography curriculum, where appropriate). Broadly, Living Things in the PSSC equates to Life Science in TIMSS, and Energy and Forces and Materials equate to the TIMSS content area of Physical Science. The TIMSS content area of Earth Science broadly equates to the Environmental Awareness and Care strands of the geography and science curricula, and to Human Environment and Natural Environment strands in geography. The section of the PSSC entitled *Working Scientifically* outlines skills that Irish pupils are expected to be applying and developing while engaging with the science curriculum. The skills correspond broadly to the Knowing, Applying and Reasoning cognitive domains of TIMSS 2011.

Table 9.2: Comparison of TIMSS 2011 framework and Primary Science and Geography Curricula

<table>
<tr><th>TIMSS 2011 content domains and topic areas</th><th colspan="2">Science curriculum strands and strand units</th></tr>
<tr><td rowspan="2">Life Science
Characteristics and life processes of living things
Life cycles, reproduction, and heredity
Interactions with the environment
Ecosystems
Human health</td><td colspan="2">Living Things
Plant and animals
Human life</td></tr>
<tr><td colspan="2">Environmental Awareness and Care
Environmental awareness
Science and the environment
Caring for the environment</td></tr>
<tr><td>Physical Science
Classification and properties of matter
Sources and effects of energy
Forces and motion</td><td>Energy and Forces
Light
Sound
Heat
Electricity and magnetism
Forces</td><td>Materials
Properties of materials
Materials and change</td></tr>
<tr><td rowspan="3">Earth Science
Earth in the solar system
Earth's structure, physical characteristics, and resources
Earth's processes, cycles, and history</td><td colspan="2">Environmental Awareness and Care
(this strand also appears on the geography curriculum)
Environmental awareness and care
Science and the environment
Caring for the environment</td></tr>
<tr><td colspan="2">Geography curriculum strand and strand units</td></tr>
<tr><td>Human Environments
People living and working in the local area and people living and working in a contrasting part of Ireland</td><td>Natural Environments
The local natural environment
Irish land, rivers and seas
Weather climate and atmosphere
Planet Earth in space</td></tr>
</table>

Test-Curriculum Matching Analysis (TCMA)

To examine the extent to which the set of items (or test questions) used in TIMSS 2011 correspond to objectives from the PSSC, a TCMA was conducted. The 175 items from the TIMSS 2011 science assessment were compared with specific objectives from the Third and Fourth class PSSC, or (where appropriate), the geography curriculum for Third and Fourth class. There is a large degree of overlap between the content of the TIMSS science framework and that of the Irish PSSC. Only six of the 175 TIMSS science items could not be matched with objectives from either the science or geography curricula. In other words, almost all content in the TIMSS science assessment was content that an Irish Fourth class pupil would have been expected to cover in school. One of the six non-matched items was amongst the released items, and is discussed later in section four. On this item, Irish pupils performed close to the international average (25%, compared to a TIMSS average of 28% on this item) despite not studying the topic in school.

International Benchmarks of science performance

As with the mathematics and reading assessments, TIMSS 2011 science is reported on a normally-distributed scale with a centrepoint of 500. Ireland's overall national score (516) was significantly higher than the scale centrepoint. As well as test scores, TIMSS 2011 reports pupil achievement at four key points on a scale, known as International Benchmarks:

- Low International Benchmark (400)
- Intermediate International Benchmark (475)
- High International Benchmark (550)
- Advanced International Benchmark (625)

The science items used in TIMSS were anchored on the scale based on their difficulty. Once the items were placed on the scale they were used to produce descriptions of the knowledge and skills that pupils who scored at each of the four Benchmarks should be able to demonstrate (see the TIMSS methods and procedures website - http://timssandpirls.bc.edu/methods/index.html - for more detail). Table 9.3 provides an overview of the percentage of Irish pupils and the international median percentage reaching each of the four International Benchmarks in TIMSS 2011. The table is cumulative; the 7% of pupils in Ireland who reached the Advanced Benchmark are included in the 35% reaching (at least) the High Benchmark, and so on.

Table 9.3: Percentage of pupils reaching the 2011 International Benchmarks for science, Ireland and international median

	Mean	Percent			
		Advanced	High	Intermediate	Low
Ireland	516	7	35	72	92
International median	500	5	32	72	92

As can be seen, while 92% of Irish pupils reached the Low International Benchmark, only 7% reached the Advanced International Benchmark. Similar proportions of Irish Fourth class children reached the Low and Intermediate Benchmarks as the study median. Relative to the international median values, slightly higher proportions of pupils in Ireland reached the High and Advanced Benchmarks. The percentage of Irish pupils reaching each of the four International Benchmarks for science in 2011 was very similar to Irish pupils' performance in TIMSS 1995. Then, 8%, 36%, 70% and 91% of pupils reached the

Advanced, High, Intermediate and Low Benchmarks (respectively), indicating no significant change in Irish pupils' performance since 1995.

The remainder of this section provides a summary description of the skills exemplifying each International Benchmark, and an example of a test item at that Benchmark. The manner in which some items are presented here are – for reasons of space – slightly different to how they were presented to pupils.

As can be seen from Figure 9.1, most Irish pupils were able to answer Example Item 1 (*sailboat*) correctly, as were most pupils internationally. The question required the pupils to demonstrate basic understanding of forces by selecting, from a list of four, which force caused the boat in the picture to sail. As an example of an item at the Low International Benchmark, it is a particularly easy item. The concept of everyday forces in action is an area that is addressed on the Third and Fourth class curriculum and indeed on the First and Second class science curriculum. Therefore, Irish pupils' familiarity with the topic could have had a positive impact on performance here. However, pupils' high performance on this item could also be as a result of their everyday experiences of wind rather than their actual understanding of the forces of gravity, friction or magnetism.

Figure 9.1: Summary description of the Low International Benchmark, and exemplar item

Low International Benchmark

Show some elementary knowledge of Life, Physical and Earth Sciences

Pupils at this Benchmark are expected to:

- demonstrate an ability to read and interpret simple diagrams, complete simple tables and provide written answers to questions that require basic factual information.
- demonstrate knowledge of some simple facts related to human health, and to the behavioural and physical characteristics of animals.
- demonstrate some basic knowledge of energy and the physical properties of matter.

Example Item 1:

The picture shows a boat sailing. Which force causes the boat to move?

A) Gravity
B) Wind *
C) Friction
D) Magnetism

Item ID: S03_01

Content Domain: Physical Science

Topic Area: Forces and motion

Cognitive Domain: Knowing

Correct: Ireland: 93% TIMSS: 90%

Figure 9.2 outlines a description of the Intermediate International Benchmark. The Example Item (*water, ice and steam*) for this Benchmark requires pupils to show basic knowledge of the temperature of ice, water and steam by ordering them according to temperature from coldest to hottest. As can be seen, Irish pupils' performance was roughly on a par with the TIMSS study average (76% and 73% correct, respectively). This is content that is addressed in the Properties of Materials strand unit of the PSSC and frequently features in Irish primary science textbooks. It is evident that a sizeable percentage of Irish pupils possess good knowledge of the differences in temperature of ice, water and steam. Nonetheless, while Irish performance was above the study average, it is worth noting that in six countries, at least 86% answered correctly – including 90% of pupils in the United States.

Figure 9.2: Summary description of the Intermediate International Benchmark, and exemplar item

Intermediate International Benchmark

Have basic understanding of practical situations in science

Pupils at this Benchmark are expected to:

- identify basic information regarding Life, Physical and Earth Sciences

- show their ability to read and interpret information in pictorial diagrams and to apply scientific knowledge to practical situations.

- know some basic facts about the solar system, and show a basic understanding of the physical characteristics and resources of the Earth.

- show some knowledge of the properties of matter and light, electricity and energy, and forces and motion.

- recognise some basic information related to characteristics of living things, their reproductive and life cycles, and their interactions with the environment, and also to show some understanding of human biology and health.

Example Item 2:

Water, ice and steam all have different temperatures. What is the order from coldest to hottest?

A) Ice, water, steam * B) Ice, steam, water C) Steam, ice, water D) Steam, water, ice

Item ID: S02_06 **Content Domain**: Physical Science

Topic Area: Classification & Properties of Matter **Cognitive Domain**: Knowing

Correct: Ireland: 76% TIMSS 73%

Figure 9.3: Summary description of the High International Benchmark, and exemplar item

High International Benchmark

Apply knowledge and understanding of the sciences to explain phenomena in everyday and abstract contexts

Pupils at this Benchmark are expected to...

- display their ability to compare, contrast and infer in order to reach the High Benchmark

- be able to provide succinct descriptive responses that demonstrate their ability to explain phenomena by combining scientific knowledge with information from everyday and abstract contexts

- show some understanding of plant and animal structure, life processes, life cycles and reproduction, of ecosystems, and of organisms' interactions with their environment, including understanding of human responses to outside conditions and activities.

- demonstrate understanding of some properties of matter, electricity and energy, and magnetic and gravitational forces and motion.

- show some knowledge of the solar system, and of Earth's physical characteristics, processes, and resources.

- demonstrate elementary knowledge and skills related to scientific inquiry.

Example Item 3:

Some animals are very rare. For example, there are very few Siberian Tigers. If the only Siberian tigers left are female, what will most likely happen?

A) The females will find another type of male animals to mate with and produce more Siberian tigers

B) The females will mate with each other and produce more Siberian tigers

C) The females will only be able to produce female Siberian tigers

D) The females will not be able to produce more Siberian tigers and they will die out *

Item ID: S07_02 **Content Domain**: Life Science

Topic Area: Life cycles, Reproduction & Heredity **Cognitive Domain**: Reasoning

Correct: Ireland: 55% TIMSS: 53%

Figure 9.3 outlines a description of the skills associated with the High International Benchmark. Two things are worth noting. First, the list of skills is more detailed than for the preceding International Benchmarks. Second, in addition to the skills listed, a pupil at the High International Benchmark is expected to be able to display those skills listed for the two lower International Benchmarks (similarly, those at Intermediate are expected to display Low International Benchmark skills). As can be seen from Example Item 3 (*Siberian tigers*), the question content is more difficult than examples from the Low and Intermediate Benchmarks. In Ireland, and on average across TIMSS participating countries, just over half of pupils answered this item correctly. In addition to demonstrating their scientific knowledge, Example Item 3 required pupils to combine their knowledge of life cycles and reproduction and to deduce what would happen if only female tigers were left on the planet. The pupils are required to display good reasoning and deduction skills in order to answer this question correctly.

Figure 9.4 outlines a description of the skills associated with the Advanced International Benchmark. Example Item 4 (*circuit diagram*) was considerably more difficult than the sample items from the Low, Intermediate or High Benchmarks. In Ireland, only 22% of pupils, a little below the TIMSS average of 27%, answered this item correctly. It required the pupils to combine their knowledge of simple circuits with an ability to interpret the diagram of the circuit in order to say whether or not the bulb in the circuit would light. In addition, it was a constructed-response item, meaning that pupils had to write a reason explaining their answer. Constructed-response items generally have slightly lower percentages of pupils answering correctly, either because the opportunity to guess is removed, or because pupils are less likely to write an answer than to tick a response option.

Figure 9.4: Summary description of the Advanced International Benchmark, and exemplar item

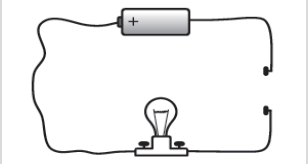
Advanced International Benchmark

Apply knowledge and understanding of scientific processes and relationships and show some knowledge of the process of scientific enquiry

Pupils at this Benchmark are expected to...

- communicate understanding of the characteristics and life processes of organisms, of reproduction and development, ecosystems and organisms' interactions with the environment, and factors relating to human health.
- show an understanding of the properties of light, and relationships among the physical properties of materials.
- apply and communicate their understanding of electricity and energy in practical contexts, and demonstrate an understanding of magnetic and gravitational forces and motion.
- communicate their understanding of the solar system and of Earth's structure, physical characteristics, resources, processes, cycles, and history.
- have a beginning ability to interpret results in the context of a simple experiment, reason and draw conclusions from descriptions and diagrams, and evaluate and support an argument.

Example Item 4:
Gerry connects a battery, a light bulb, and some wire as shown below. Will the bulb light?



A) Yes **B) No***

Explain your answer.

Item ID: S02_08
Content Domain: Physical Science
Topic Area: Sources and effects of energy
Cognitive Domain: Applying
Correct: Ireland: 22% TIMSS: 27%

Item 4 is an unusual item in some regards. While generally difficult, pupils in a cluster of normally low-performing Middle Eastern countries (Bahrain, Oman, Kuwait, Saudi Arabia and Qatar – all of whom offered the test in Arabic) performed above average on this item. In contrast, although generally in the average performance range on TIMSS science, only 7% of pupils in Norway answered correctly.

Analysis of a selection of released items

Out of a total of 175 science items in TIMSS 2011, 72 were released into the public domain in December 2012. Of these 72 items, 30 examined Life Science content, 28 examined Physical Science and the remaining 14 items related to Earth Science content. Amongst the released items there was a representative sample from both content and cognitive domains within each of the International Benchmarks. Accompanying each item was information about the percentage of pupils in each country answering each test item correctly. See http://timssandpirls.bc.edu/timss2011/international-released-items.html for percent correct information for all participating countries or www.erc.ie/pirlstimss for detailed descriptions of how Irish pupils performed (including sample answers) relative to the study average.

For the most part, the TIMSS 2011 participating countries with the highest overall achievement had the highest achievement in all three content domains. However, many countries scored relatively higher or lower than their overall score in one or two content domains (Martin, Mullis, Foy & Stanco, 2012). Ireland was one of only four countries – Finland, Denmark and Romania were the other three – where achievement in each of the three content domains did not differ significantly from overall achievement in science. Irish pupils' overall science mean scale score of 516 was very similar to their mean scale score for Life Science (513), Physical Science (517) and Earth Science (520).

Ireland's overall mean science score was significantly higher than the international centrepoint of 500. Therefore, one would expect that Irish performance on many or most of the test items would generally be slightly higher than the international average. However, Ireland's performance on some items was unusual or "out of the ordinary". An overview of the test items on which Irish pupils' performance was unusually high (defined as at least 10% above the TIMSS international mean) or unusually low (defined as below the TIMSS international mean) is provided in Table 9.4.

Irish pupils achieved a considerably higher percent correct score than the international average percent correct on 17 items, which were evenly spread across the three content domains; six from Physical Science; six from Life Science; and five from the Earth Science domain. Irish participants performed particularly poorly on two items from each of the three content domains. In terms of Benchmarks, of the 17 items on which Irish participants scored very well, six were at the Advanced International Benchmark, five were at the High Benchmark, four were at the Intermediate and two were at the Low Benchmark. With regard to the test items on which Irish participants performed considerably lower than the international average, two items were from the High International Benchmark and four were at the Advanced International Benchmark.

A selection of the 17 items on which Irish participants performed unusually high or low will be considered in the next section. The original versions of the items, as they were presented to pupils, can be viewed on www.erc.ie/pirlstimss, together with examples of correct answers in cases where pupils had to write a response to the question. The item IDs in Table 9.4 indicates the item location within a block of items (e.g., S01_03 is item 3 in block 1). This ID is also shown to the right of each item in their original formats, as presented on www.erc.ie/pirlstimss.

Table 9.4: Items on which Ireland pupils scored unusually higher and unusually lower than the international mean along with the International Benchmark levels

TIMSS content domain *(N total released items)*	Curriculum strand	Unusually high (IRL 10%+ above TIMSS mean)			Unusually low (IRL below TIMSS mean)		
		Item ID	Gap	IBM	Item ID	Gap	IBM
Life Science *(30)*	Living things	S07_07	+13%	Low	S06_02	-19%	High
		S01_03	+15%	Low	S03_04	-10%	Adv
		S05_05	+12%	Inter			
		S02_01	+21%	High			
		S06_03	+13%	High			
		S05_01	+24%	Adv			
Physical Science *(28)*	Energy and forces	S07_06	+14%	Adv	S03_02	-5%	Adv
		S02_07	+16%	Inter			
		S01_07	+16%	Inter			
		S07_09	+10%	High			
		S06_08	+10%	Adv			
	Materials	S07_05	+10%	High	S03_10	-7%	High
Earth Science *(14)*	Natural environments	S03_13	+10%	High	S03_11	-11%	Adv
		S06_12	+10%	Adv	S05_11	-14%	Adv
		S05_03	+13%	Adv			
		S07_10	+17%	Adv			
		S06_10	+14%	Inter			

Life Science

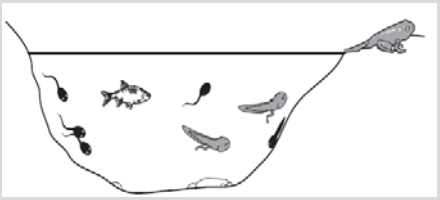
The six test items on which Irish participants performed particularly well in the Life Science domain all related to life cycles, processes and characteristics of animals and human life, and to human health. Figure 9.5 shows three of the six items – Example Items 5 (*tadpoles*), 6 (*wings*), and 7 (*body parts*). On both Item 5 and Item 6, the percent correct obtained by Irish pupils is 12% above the TIMSS study average. The life cycle and characteristics of frogs, butterflies and birds are areas that are frequently taught in the majority of Irish primary schools each year, starting from Junior Infants. They are also topics that feature in many of the Irish primary science textbooks that are commonly used in schools. It would seem possible, therefore, that Ireland's good performance on the two items can be attributed to the frequency in which these topics are taught in schools. Data from the Teacher Questionnaire suggest that only 59% of Irish pupils had been taught the topic of life cycles and reproduction in plants and animals, compared to a study average of 77% of pupils. However, while life cycle and reproduction of *animals* is a topic that is frequently taught in most Irish primary schools, this is not the case for the life cycle and reproduction of *plants*. It would be interesting to see what teachers' responses would have been if this question had been divided into two; one asking about life cycle and reproduction in animals and the second about life cycle and reproduction in plants.

Both Example Items 5 and 6 required pupils to apply basic classification skills and to demonstrate their ability to make inferences. These skills are identified in the PSSC as skills that pupils should be applying and developing while engaging with school science, and it is apparent from Irish pupils' responses to both that they were able to apply these skills in answering these questions.

Figure 9.5: Examples of Life Science items on which Irish pupils performed well

Example Item 5:
Melissa found some tadpoles and fish in a pond as shown above. How did the tadpoles get there?

a) They hatched from eggs laid by fish in the pond
b) They formed from mud at the bottom of the pond
c) They were made from materials dissolved in pond water
d) They developed from eggs laid by frogs in the pond *



Item ID: S05_05 **Content Domain**: Life Science
Topic Area: Life cycles, reproduction & heredity **Cognitive Domain**: Applying
Location PSSC: *Strand*: Living Things. *Strand Unit*: Plants and Animals.
Benchmark: Intermediate
Correct: Ireland: 88% TIMSS: 76%

Example Item 6:
What do birds, bats and butterflies have in common?
a) Feathers b) Hair c) Internal skeleton d) **Wings***

Item ID: S01_03 **Content Domain**: Life Science
Topic Area: Characteristics & life processes of living things **Cognitive Domain**: Applying
Location PSSC: *Strand:* Living Things. *Strand Unit:* Plants and Animals
Benchmark: Low
Correct: Ireland: 95% TIMSS: 83%

Example Item 7:
The table shows three functions carried out by parts of the human body. Write the name of the body part beside its function.

The first one has been done for you.

Function	Body Part
Supports the body	Skeleton [pre-filled]
Pumps blood through the body	*Heart*
Used for thinking	*Brain*

Item ID: S02_01 **Content Domain**: Life Science
Topic Area: Characteristics & life processes of living things **Cognitive Domain**: Knowing
Location PSSC: *Strand:* Living Things. *Strand Unit:* Human Life.
Benchmark: High
Correct: Ireland: 70% TIMSS: 50%
(Credit: **Both** heart and brain named correctly)

Example Item 7 (*body parts*) also relates to the topic area of characteristics and life processes of living things, but assesses the cognitive dimension of Knowing. It is an item classified as at the High International Benchmark. Irish pupils performed very well on the item (70% correct, higher than the international average by a margin of 20%). This can be contrasted with Irish performance on similar items in TIMSS 1995. Then, Irish pupils were slightly above the study average on a question about the human skull and slightly below average on a question about heart functions. Some of the relative improvement in Irish performance might be attributable to elements of the PSSC. A recently published review of the implementation of the PSSC found that pupils demonstrated a relative strength on tasks relating to the strand unit Human Life (DES Inspectorate, 2012). The Inspectorate report suggested that one reason for key concepts in this strand unit being reinforced effectively may be due to the fact that Myself / Human Life is also a strand in the Social, Personal and Health Education element of the Irish curriculum.

The variety, characteristics and processes of humans and animals are included amongst the content objectives in the Living Things strand of the PSSC for all class levels. Similar content was also included in the previous Curaclam na Bunscoile. These are not areas in which Irish teachers report concerns (NCCA, 2008; Murphy & Smith, 2012) and are aspects of the science curriculum in which the pupils report positive attitudes towards and with which they frequently engage (Varley et al., 2008). The functions of the human body and human health are also topics that are addressed in virtually all of the Fourth class primary science textbooks that are currently being used in Irish schools. This would seem to explain Irish pupils' good performance on these items.

Irish pupils performed below the TIMSS average on two items from the Life Science content area (Figure 9.6). The topics for Example Item 8 (*plants use energy*) and Item 9 (*parts of a plant*) are both related to plant processes and structures. The cognitive domain for both items is Knowing. They are classified as at the Intermediate and Advanced International Benchmarks, respectively.

Figure 9.6: Examples of Life Science items on which Irish pupils performed poorly

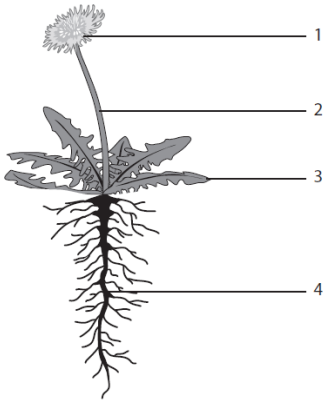
Example Item 8:
Plants use energy directly from the sun. What do they use the energy from the sun for?

A) **To make food*** B) To disperse seeds C) To fertilise the soil D) To prevent insect damage

Item ID: S06_02 **Content Domain**: Life Science
Topic Area: Ecosystems **Cognitive Domain**: Knowing
Location PSSC: *Strand*: Living Things. *Strand Unit*: Plants.
Benchmark: Intermediate
Correct: Ireland: 30% TIMSS: 51%

Example Item 9:
The diagram shows a flowering plant. Four of its parts are numbered. In the table below, write the name of each part, and state its function.

Part	Name	Function
1	*Flower / seeds / petals*	**[e.g.]** *attracts insects to pollinate*
2	*Stem / stalk*	**[e.g.]** *transports water*
3	*Leaves*	**[e.g.]** *makes food for the plant*
4	*Roots*	**[e.g.]** *anchors the plant*



Item ID: S03_04 **Content Domain:** Life Science
Topic Area: Characteristics & life processes of living things
Cognitive Domain: Knowing
Location PSSC: *Strand:* Living Things. *Strand Unit:* Plants.
Benchmark: Advanced
Full credit: Ireland: 10% TIMSS: 21%
At least partial credit: Ireland: 46% TIMSS: 52%

Full credit: Name 4 parts AND 3+ functions. Partial credit: Name 2+ parts AND 1+ functions.
No credit was given for naming the parts correctly without any functions.

In TIMSS 1995, Irish pupils also performed poorly on a similar item relating to the functions of different parts of a flowering plant. Then, 22% of Irish pupils answered correctly, less than half the international average (46%). However, plant structures and processes are areas of content that are included in the 1999 PSSC and were included in the

1971 Curaclam na Bunscoile, suggesting that lack of curriculum coverage does not explain poor performance. Further, these are not areas of curriculum content on which teachers report concerns (NCCA, 2008), and are areas about which Irish pupils hold positive attitudes (Varley et al., 2008).

In relation to TIMSS 2011, to complete Example Item 9 (*parts of a plant*) is quite a complex procedure. Pupils were required to fill in the names of four parts of the plant, and to provide one function for each part. Essentially, that meant the pupil had to retrieve eight pieces of information. This may be one reason why the overall international performance on this item was low – the level of work involved to respond, rather than the complexity of the item content. The percentage of Irish pupils obtaining partial credit for their answers was 46%, 8% lower than the international average. However, a considerably lower percentage (10%) of Irish pupils was awarded full credit for their responses than was the average across all TIMSS countries (21%). Also of note is the fact that a number of generally low-performing countries scored well above average on this item (e.g., Thailand and Bahrain) while some of the overall, very high-performing countries were below average (e.g., only 20% of pupils in Japan and 16% in Hong Kong SAR obtained full credit).

Another explanation for Irish pupils' poor performance on this item perhaps could be due to teaching methodologies. The Inspectorate's evaluation of the implementation of the PSSC for example, found that Irish pupils' weakest performance was on tasks relating to plant and animal life, and suggested that there was evidence that teachers did not understand fully how to implement a scientific approach to the study of plant and animal life and were not sufficiently familiar with the objectives and suggested methodologies underpinning this strand unit in the PSSC (DES Inspectorate, 2012).

Physical Science

Irish pupils performed particularly well on six of the test items in the Physical Science domain and performed particularly poorly on two. Of the six on which Irish pupils performed unusually well, two related to the strand unit Light, one to Electricity, two to Forces, and one to the Properties (and characteristics) of Materials.

Light

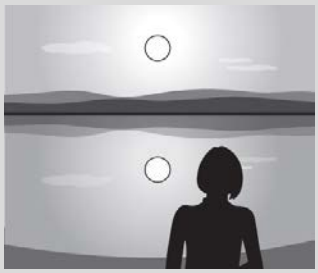
The first of the two items on light (Example Item 10 [*Alice's sunrise*]) tested pupils' knowledge regarding how the moon reflects the light from the sun (Figure 9.7). The second, Example Item 11 (*sunlight contains different colours*) assessed their knowledge of how sunlight is made up of seven different colours. Both of these concepts are included on the PSSC for Fourth class, under the strand unit Light, in the Energy and Forces strand. Most Irish pupils (77%) were taught by teachers who indicated that the topic of light had been taught prior to taking TIMSS 2011, noticeably higher than the 61% of pupils across all TIMSS countries. Further, 62% of Irish pupils were taught by teachers who reported being *very well prepared* to teach the topic, compared to a TIMSS average of 50% of pupils.

Irish pupils performed very well on Items 10 and 11. For *Alice's sunrise,* 91% answered correctly, while 52% were able to name something that showed sunlight is composed of different colours – both percentages were considerably higher than the international average. On a similar type of item relating to light reflection in TIMSS 1995, Irish pupils displayed only an average performance. Irish pupils' possibly improved relative position on understanding of light and reflection might be attributable to the better coverage of Physical Science in the PSSC, relative to Curaclam na Bunscoile.

Figure 9.7: Examples of Physical Science items related to Light

Example Item 10:
Alice watches a sunrise from across a calm lake. She sees a sun in the sky and a sun in the lake as shown below. Why does Alice see a sun in the lake?

a) The sunlight warms that part of the lake
b) The sky spreads sunlight over the lake
c) The sunlight reflects off the lake water *
d) Clouds reflect sunlight into the lake



Item ID: S02_07 **Content Domain:** Physical Science
Topic Area: Source and effects of energy **Cognitive Domain:** Applying
Location PSSC: *Strand*: Energy and Forces. *Strand Unit*: Light.
Benchmark: Intermediate
Correct: Ireland: 91% (girls 93% boys 88%) TIMSS: 76% (girls 75% boys 75%)

Example Item 11:
Name one thing you have seen that shows that sunlight is made up of different colours.

[e.g.] rainbow / prism / soap bubbles / sunrise

Item ID: S07_06 **Content Domain:** Physical Science
Topic Area: Source and effects of energy **Cognitive Domain:** Applying
Location in PSSC: *Strand*: Energy and Forces. *Strand Unit*: Light.
Benchmark: Advanced
Correct: Ireland: 52% TIMSS: 38%
(Credit given for providing a specific, valid example)

Example Item 12:
Which two objects produce their own light?

A) Candle and moon B) Moon and mirror **C) Sun and candle *** D) Mirror and sun

Item ID: S03_02 **Content Domain:** Physical Science
Topic Area: Sources and effects of energy **Cognitive Domain:** Applying
Location in PSSC: *Strand:* Energy and Forces*. Strand Unit:* Light.
Benchmark: Advanced
Correct: Ireland: 45% (girls 36% boys 55%) TIMSS: 50% (girls 46% boys 52%)

In contrast, Irish pupils, particularly girls, did not perform well on Example Item 12 (*Which two objects*). This is an Advanced Benchmark item requiring pupils to draw on their knowledge of sources of light to identify familiar everyday objects that produce their own light. In TIMSS 1995, Irish pupils also performed marginally below the international average on an item relating to identifying objects as sources of light. This suggests that despite the introduction of the PSSC, a sizeable percentage of Irish pupils – and almost two-thirds of Irish girls – remain unable to identify sources of light from a list of familiar objects. While acknowledging that, like many adults, pupils often confuse objects that reflect light with objects that produce light, Irish girls' poor performance on this item is a little worrying, in particular as this concept is meant to be addressed on both First and Second class and Third and Fourth class science curricula. Therefore, all Irish pupils who took part in TIMSS 2011 should have basic familiarity with the underlying concept.

A possible partial explanation might be the terminology used, rather than the content of the question. Pupils may have had some difficulty interpreting the word "produce" in the context of light, and if the question had been reworded to "which of these items are sources

of light", it is possible that performance may have been higher. Another explanation may relate to misconceptions held by the teachers themselves. The Inspectorate's evaluation of the implementation of the PSSC found that the strand with which Irish pupils are encountering most difficulty is Energy and Forces, and the strand unit relating to light, and recommended that additional professional development support was required (DES Inspectorate, 2012). Many research studies have highlighted concerns regarding primary teachers' understanding of key science topics, and show that many primary teachers' ideas regarding science are very similar to the "misconceptions" or "alternative conceptions" commonly recognised in children (Driver, 1983; Harlen & Holroyd, 1997; Jarvis & Pell, 2004). One commonly held "alternative conception" is confusing objects that are reflectors of light with objects that are sources of or produce their own light. As part of TIMSS 2011, teachers were asked about their formal education. On average, 37% of pupils were taught science by a teacher who reported a major in either primary education and science, or a major in science but not primary education, compared to 12% of pupils in Ireland. It may therefore be the case that teachers without requisite subject knowledge of this aspect of light find it difficult to teach it effectively to pupils.

Indeed, the recent DES Inspectorate evaluation of the implementation of the PSSC found that the strand in which Irish pupils are encountering most difficulty is Energy and Forces and that only 51% of the pupils assessed successfully completed tasks relating to the strand unit Light (DES, 2012). The report recommended that additional professional development support, focusing particularly on the strand Energy and Forces, was required. Energy and Forces content from PSSC falls into the Physical Science content domain in TIMSS. It is worth noting that the percentage of Irish pupils whose teachers reported being *very well prepared* to teach Physical Science content (60%) was just below the TIMSS average (62%).

Forces

Irish pupils performed well on Example Item 13 (*object falls to ground*) which required them to apply their knowledge of gravity acting on falling objects to explain what happens when a ball is dropped, a familiar everyday context. Although classified as a High Benchmark item, 71% of pupils in Ireland (and in Northern Ireland) correctly selected gravity as the answer, compared to a TIMSS average of 61% (Figure 9.8).

Figure 9.8: Example of Physical Science item related to Forces

Example Item 13: **What causes an object to fall to the ground when you let it drop from your hand?**			
A) Magnetism	**B) Gravity ***	C) Air resistance	D) The push from your hand
Item ID: S07_09		**Content Domain:** Physical Science	
Topic Area: Forces and motion		**Cognitive Domain:** Applying	
Location in PSSC: *Strand:* Materials. *Strand Unit:* Forces.			
Benchmark: High			
Correct:	Ireland: 71%	TIMSS: 61%	

A majority of Irish pupils (73%) had been taught by teachers who reported that they had already covered the topic of forces in science lessons, compared to only 46%, internationally. In addition, 92% of Irish pupils were taught by teachers who indicated that they felt either *very well prepared* or *somewhat prepared* to teach about forces that cause objects to move, perhaps partly because a strong emphasis is placed on this concept in pre-service and in-service programmes.

Electricity

Example Item 14 (*uses of electricity*) addressed scientific content that is included in the electricity strand unit of the PSSC. A far higher percent of pupils answered this item correctly in Ireland than in most other countries. Three-quarters (76%) of pupils in Ireland obtained full credit on this item (TIMSS average: 57%) while 90% obtained at least partial credit (Figure 9.9). One might question whether Irish pupils' good performance on this item is attributable solely to science lessons in school, or whether it is more to do with everyday experience with electrical appliances. However, a number of reasons could strengthen the argument for the positive effect of school science on achievement.

Figure 9.9: Example of Physical Science item related to Electricity

Example Item 14:
Name two things electricity can be used for in daily life.

[e.g.] *For light bulbs / Television / phones*

Item ID: S01_07 **Content Domain:** Physical Science
Topic Area: Sources and effects of energy **Cognitive Domain:** Knowing
Location in PSSC: *Strand:* Energy and Forces*. Strand Unit:* Electricity and Magnetism*.*
Benchmark: Intermediate

Full credit:	Ireland: 76%	TIMSS: 57%
At least partial credit:	Ireland: 90%	TIMSS: 75%

(Full credit: **Two** correct examples. Partial credit: **One** correct example).

First, based on teacher reports, 67% of Irish pupils had participated in lessons on electricity compared to an average of only 51% across all countries. Second, prior to the formal implementation of the PSSC in 2003, teachers were provided with two days of related in-service, of which electricity was a significant element, and it is an area that is addressed on all initial teacher education science programmes in the Republic of Ireland. These pre-service and in-service workshops may have had a positive effect on teachers' competence and confidence in implementing this strand unit of the curriculum.

Finally, as with most aspects of academic achievement, there is a positive correlation between pupils' attitudes towards science and achievement in science (Hattie, 2009). A national survey on Irish pupils' experiences and attitudes towards the 1999 curriculum revealed that almost 60% of the pupils surveyed displayed positive attitudes towards learning about electricity in school (Varley et al., 2008), perhaps suggesting that Irish pupils' own positive attitudes towards learning about electricity may have had a positive impact on their performance.

Properties of Materials

Figure 9.10 shows two items related to the Properties of Materials, on which Irish pupils displayed contrasting performance. On Example Item 15 (*metal and wooden spoons*), Irish pupils performed relatively well (65% correct compared to a TIMSS average of 56%), while on Item 16 (*tables describing materials*) they performed relatively poorly (40% correct compared to a TIMSS average of 47% correct). To answer Item 15, pupils had to use their knowledge about the conduction of heat to infer why the metal spoon would feel hotter than the wooden spoon. Materials that are good conductors of heat is a topic that is covered in the PSSC, and it is included as a topic in many of the Fourth class textbooks currently used in Irish primary schools. Thus, it is not surprising that teacher reports suggest that most (70%) Irish pupils had been taught about the states of matter prior to participating in TIMSS.

Example Item 16 (*tables describing materials*) required pupils to deduce, from a list of properties, that the two materials being described were iron and sugar. Irish girls in particular did not perform well on this item, which assesses pupils' scientific reasoning skills. Irish pupils' poor performance on this item is of concern – materials that are attracted to magnets, solids, liquids and gases, and dissolving are all aspects of the PSSC which the children should have encountered prior to taking TIMSS 2011. Materials that are attracted to magnets is a concept that is addressed from Junior Infants, so one might expect that Fourth class pupils should be able to identify such materials. With regard to states of matter, changes in materials and forming mixtures concepts, teacher reports suggest that most Irish pupils should have encountered most of the topics during science lessons. Again, however, so too had pupils in most other countries.

Figure 9.10: Examples of Physical Science items related to the Properties of Materials

Example Item 15:
A metal spoon and a wooden spoon are used to stir a pot of hot soup. After a few minutes, the metal spoon feels hotter than the wooden spoon. What explains this?

A) Metal is always hotter than wood
B) Metal conducts heat better than wood *
C) Metal conducts electricity better than wood
D) Metal heats up the water better than the wood

Item ID: S07_05 **Content Domain:** Physical Science
Topic Area: Sources and effects of energy **Cognitive Domain:** Applying
Location in PSSC: *Strand:* Energy and Forces. *Strand Unit:* Heat.
Benchmark: High
Correct: Ireland: 65% TIMSS: 56%

Example Item 16:
The table below shows the properties of two materials.

Properties of Material 1	**Properties of Material 2**
Conducts heat quickly	Conducts heat slowly
Solid	Solid
Does not dissolve in water	Dissolves in water
Attracted to magnets	Not attracted by magnets

Which statement about materials 1 and 2 is most likely to be correct?

A) Material 1 is glass and material 2 is clay
B) Material 1 is copper and material 2 is wood
C) Material 1 is iron and material 2 is sugar *
D) Material 1 is cork and material 2 is gold

Item ID: S03_10 **Content Domain:** Physical Science
Topic Area: Classification & Properties of Matter **Cognitive Domain:** Reasoning
Location in PSSC: *Strand:* Materials. *Strand Unit:* Properties of Materials.
Benchmark: High
Correct : Ireland: 40% (girls 38% boys 41%) TIMSS: 47% (girls 47% boys 47%)

It is possible that part of the item difficulty arises, not from the scientific knowledge being assessed, but from the complex and slightly unusual item layout. Pupils had to focus on a number of variables at the one time in order to answer the question correctly. It would be interesting to establish whether improved performance would result from a restructuring of this question – for example, first identifying iron, and then identifying sugar in a separate

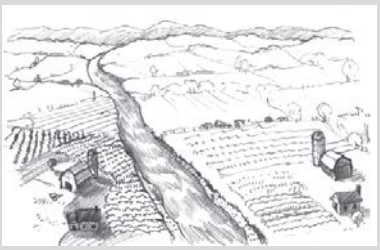
question. This would not necessarily improve Irish pupils' score relative to the TIMSS average, but it might lead to a general increase in the percentage of pupils able to answer correctly.

Earth Science

Eighteen Earth Science items were released after TIMSS 2011, of which three are discussed here. All three contain content included in the geography curriculum, but Example Item 18 (*avoid water wastage*) is also included in the PSSC under the strand Environmental Awareness and Care. Figure 9.11 shows two items on which Irish performance was considerably better than the TIMSS average. Example Item 17 (*farming on a plain*) shows a picture of a river flowing through a wide plain and asks pupils to provide one advantage and one disadvantage of farming in such a location, with scores allocated separately for each. The easy availability of water or reference to good quality soil were among the responses considered appropriate "advantages", and 51% of Irish pupils listed an appropriate advantage, higher than the TIMSS average of 42% of pupils. Almost half (46%) of Irish pupils were able to write a disadvantage (e.g., risk of flooding, or polluted water) – much higher than the 34% internationally who were able to do so.

Figure 9.11: Examples of Earth Science items on which Irish pupils performed well

Example Item 17:
The picture below shows a river flowing across a plain. Farming is carried out on the plain and near the river. There are advantages and disadvantages to farming along a river.



A) Describe one advantage
[e.g.] *They can water their crops easily*
B) Describe one disadvantage
[e.g.] *The river could flood*

Item ID: S03_13 **Content Domain:** Life Science
Topic Area: Earth's structure, physical characteristics & resources **Cognitive Domain:** Applying
Location in PSGC: *Strand*: Natural Environments. *Strand Unit*: The Local Natural Environment.
Benchmark: High
Part A Correct: Ireland: 51% TIMSS: 42%
Part B Correct: Ireland: 46% TIMSS: 34%
(Credit given separately for each part)

Example Item 18:
There is a shortage of fresh water in many parts of the world. Describe two things people can do to avoid wasting water.
[e.g.] *Turn off the taps when you're not using them. / Don't pollute the rivers.*

Item ID: S05_3 **Content Domain:** Earth Science
Topic Area: Earth's structure, physical characteristics & resources **Cognitive Domain:** Applying
Location in PSSC (& PSGC): *Strand:* Environmental Awareness and Care. *Strand Unit:* Caring for the Environment.
Benchmark: Advanced
Full credit: Ireland: 41% TIMSS: 27%
At least partial credit: Ireland: 76% TIMSS: 56%
(Full credit: **Two** correct suggestions. Partial credit: **One** correct suggestion)

The content for Item 17 is addressed in the primary geography curriculum and frequently features in primary geography textbooks for Third and Fourth classes. A higher than average percentage of Irish pupils had been taught about common features of Earth's landscape (e.g., rivers) and relationship to human use (e.g., farming) (85%, compared with a

TIMSS average of 64%). In addition, 73% of Irish pupils were taught by teachers who felt *very well prepared* to teach this aspect of Earth Science, higher than the international average of 58%. Pupils should therefore have been comparatively well prepared for this item. Two other non-school factors may also be relevant. Half (48%) of Irish Fourth class pupils lived in a small town, village, or a remote rural area, compared to a TIMSS average of 38%. As such, direct or indirect experiences of farming practices are more likely to be more common for Irish pupils. Second, pupils in countries such as Ireland with plenty of arable land, rivers, and rainfall might be considered to have a significant advantage over pupils living in arid landscapes when answering this item.

Example Item 18 (*avoid water wastage*), assessed pupils' knowledge of the Earth's structure, physical characteristics, and resources, broadly similar to the PSSC and PSGC strand of Environmental Awareness and Care. Pupils were required to identify two things people can do to avoid wasting water. Over three-quarters (76%) of Irish pupils obtained at least partial credit on this item and 41% obtained full credit (well above the comparable TIMSS averages of 56% and 27%, respectively). Thus, Item 18 offers some support for the Inspectorate's finding that the Environmental Awareness and Care strand was one of two strands on which pupils performed best (DES Inspectorate, 2012).

An objective in the PSSC and PSGC is that children should come to appreciate the need to conserve resources, and the topic is addressed in both science and geography curriculum methodology courses in initial teacher education throughout Ireland. However, it is also likely that it is covered in primary science curricula in most or all TIMSS countries. One reason for Irish participants' higher than average performance on this item may be the education programme from the Sustainable Energy Authority of Ireland (SEAI), which delivers over 740 workshops each year and reaches up to 22,000 5- to 18-year-olds throughout Ireland. The programme engages pupils on the benefits of energy efficiency and renewable energy. Ways of reducing water consumption and avoiding waste of water are areas that are also included in the programme. The additional engagement with this content through the SEAI schools' programme may have been a contributing factor to Irish participants' particularly high performance on this item.

In contrast, Example Item 19 (*Earth rotation*) is an item on which Irish performance is slightly below average (42% correct, compared to a TIMSS average of 53%) (Figure 9.12). The item is part of the TIMSS topic area Earth and the solar system, and is covered in the Irish geography curriculum under the Planet Earth in Space strand unit. It is an item at the Advanced International Benchmark and assesses the cognitive domain of Knowing.

Figure 9.12: Example of an Earth Science item on which Irish pupils performed poorly

Example Item 19:
How often does the Earth rotate on its axis?

A) Once every 12 hours
B) Once every 24 hours *
C) Once every month
D) Once every year

Item ID: S03_11 **Content Domain:** Earth Science
Topic Area: Earth and the solar system **Cognitive Domain:** Knowing
Location in PSGC: *Strand:* Natural Environments*. Strand Unit:* Planet Earth in Space.
Benchmark: Advanced
Correct: Ireland: 42% TIMSS: 53%

The relatively poor Irish performance cannot be attributed to lack of exposure to the topic. While teacher reports indicate that an average of 36% of pupils in TIMSS had not yet been taught about the Earth's solar system, this was true of only 23% pupils in Ireland. Also, 69% of the Irish pupils were taught by teachers who felt *very well prepared* to teach the topic, considerably higher than the international average (55%). A possible explanation is that the solar system is not generally an area that is addressed as part of initial teacher education in the Republic of Ireland. So, although teachers report feeling confident about teaching this aspect of Earth Science, it may be the case that they do not have the requisite pedagogical knowledge.

Discussion and conclusions

As noted earlier, there are no national assessments in primary science in Ireland, and Irish primary pupils have not taken part in any international assessments in science since TIMSS 1995. Since TIMSS 1995, a substantially revised Primary School Science Curriculum (PSSC) has been developed and implemented in Irish schools. The content in the PSSC is largely based on the content and the cognitive domains from TIMSS 1995 and places equal importance on both scientific knowledge and skills development. The PSSC has been formally implemented in Irish primary schools since 2003. Therefore, the Irish pupils who took TIMSS 2011would have been engaging with the PSSC since they started school. While the overall performance of Irish Fourth class primary pupils in TIMSS 2011 is above the international average, it is very similar to their performance in TIMSS 1995, when they had been studying the old (1971) Curaclam na Bunscoile. Broadly, in TIMSS 2011 Irish pupils performed well in Life Science (plant structures and processes aside) and Earth Science topics but did not perform as well in Physical Science topics. In terms of the cognitive domains, Irish pupils did not always display good reasoning skills.

It would appear, therefore, that the PSSC may not be having as big an impact on Irish pupils' achievement as one might have anticipated. Two factors that may have impeded Irish pupils' performance in TIMSS 2011 could have been related to the amount of instructional time that is currently being allocated to science within the primary curriculum and teachers' pedagogical competency. These will be considered in turn.

Instructional time

The TCMA revealed a large degree of overlap between the content of the TIMSS science framework and that of the Irish PSSC, so the actual content of TIMSS should not have been a factor that affected Irish pupils' overall performance. However, the amount of instructional time allocated to science in the Primary School Curriculum in Ireland may have been an issue. As is outlined in Chapter 2 of this volume (Lewis & Archer, 2013), the 4% of instruction time devoted to science in Irish primary schools is far lower than the norm in most countries. With the exception of Austria, no other country that took part in TIMSS 2011 allocated proportionally less time to science than Ireland. Not only is the percentage allocated atypical, but so too the amount of hours allocated. Based on teacher reports, teachers in Ireland spend 63 hours per year teaching science, well below the TIMSS average of 85 hours (Martin et al., 2012).

It is difficult to establish the precise relationship between instructional time and pupil achievement, as many factors influence effective instruction. These factors include quality of curriculum content and quality of approaches to teaching. However, the amount of instructional time devoted to a subject is important and has an impact on achievement (Lavy, 2010; Martin et al., 2012). Therefore, one obvious step towards increasing levels of scientific literacy amongst our primary school pupils is to increase the amount of time allocated to the teaching of science in Irish primary schools.

Developing competency in teaching science

Increasing time allocation for science in schools alone is unlikely to suffice. Additional supports in terms of continuing professional development (CPD) and initial teacher education programmes in developing teachers' competency in teaching science may also be required.

Professional development

Data gathered from Irish primary teachers in TIMSS 2011 suggest that, overall, the percentage of Irish pupils taught by teachers that reported feeling *very well prepared* to teach TIMSS science topics (63%) was similar to the international average (62%). However, when the different content domains were examined, the percentages of Irish pupils with teachers who felt *very well prepared* to teach Life Science topics and Physical Science topics were lower than the TIMSS averages, while the percentage with teachers *very well prepared* to teach Earth Science was higher than the TIMSS average (Table 9.5).

Table 9.5: Percentages of teachers who felt *very well prepared* to teach TIMSS science topics

	Overall	Life Science	Physical Science	Earth Science
Ireland	63	65	60	63
TIMSS	62	70	62	53

Irish studies have highlighted primary teachers' concerns regarding their perceived lack of pedagogical and conceptual knowledge of science (Murphy & Smith 2012; Smith 2012; Waldron et al., 2009; NCCA, 2008; Varley et al., 2008). A recent DES Inspectorate study found evidence that many teachers did not appear to have a thorough understanding of how to implement a more inquiry-based scientific approach towards studying plant and animal life and recommended the need for teachers to become more familiar with the objectives of and approaches underpinning the PSSC (DES Inspectorate, 2012). Prior to the formal implementation of the PSSC in 2003, Irish primary teachers received only two days' in-service training to support them in implementing the revised science curriculum. All teachers, regardless of their level of knowledge or experience, participated in workshops with similar content. Since then, no compulsory professional development in science has been provided to teachers by the DES. In TIMSS 2011, the percentage of Irish pupils who had been taught by teachers who had taken professional development courses in the two years prior to the assessment was, in all five areas examined, considerably lower than the international average (Table 9.6) (see also Clerkin, 2013).

Table 9.6: Percentages of pupils taught by teachers who had undertaken various forms of professional development in the two years prior to PT 2011

	Science Content	Science Pedagogy / Instruction	Science Curriculum	Integrating IT into Science	Science Assessment
Ireland	23	16	24	17	9
TIMSS	35	34	34	28	27

Indeed, the Irish Council for Science, Technology and Innovation (2005) indicated that professional development for Irish primary teachers is not as advanced as that in other countries. Smith (2012) argues that it is time therefore to develop professional development programmes that move away from the "once-off", "one size fits all" models of in-service towards a more long-term in-depth approach that would provide teachers with the necessary subject and pedagogical knowledge to support their pupils in genuine engagement with all

aspects of the science curriculum. Pedagogy in the content and cognitive domains on which Irish pupils consistently perform poorly, for example the strand unit Plants and Animals, the strand Energy and Forces, and the application and development of the Working Scientifically and Design and Make skills, are areas that should be addressed by these CPD programmes.

Data collected as part of TIMSS 2011 indicate that the vast majority (81%) of Irish pupils were taught by teachers who had a major in primary education but no specialism in science. It is quite possible therefore that despite indicating that they felt competent about teaching science topics, perhaps many of these teachers did not have the requisite knowledge and skills to facilitate the successful implementation of the PSSC. Recent research has found that professional development focusing on scientific content has a significant positive effect on pupil achievement (Blank & de las Alas, 2009; Jarvis & Pell, 2004). It would seem important therefore, that future CPD programmes should also provide opportunities for teachers to develop their own scientific content knowledge.

Initial teacher education

Just over half (54%) of the Irish children who participated in TIMSS 2011 were taught by teachers who had been teaching for less than 10 years. These teachers would not have attended the two science in-service days that were provided by the DES in 2003. However, during their undergraduate degree programmes, they would have taken compulsory curriculum science methodology courses aimed at developing their pedagogical knowledge of science. The amount of time allocated for these courses within the three year B.Ed. degree varied considerably from college to college (ranging from 12 to 40 hours over the course of the entire degree) (Waldron et al., 2009). It is difficult to see how student teachers could develop adequate conceptual and pedagogical knowledge of science solely from the small amount of time devoted to science education on their degree programmes. Murphy and Smith (2012) found that, while there was an increase in student teachers' scientific content knowledge at the end of a 40-hour curriculum science methodology course, high percentages of student teachers still revealed inaccurate conceptions within the science disciplines. It is questionable whether student teachers whose only exposure to science pedagogy was through these short initial teacher education courses would have the requisite knowledge to facilitate successful implementation of the PSSC.

Since September 2012, all Bachelor of Education degree programmes in the Republic of Ireland have moved from a three- to a four-year programme. Additional time has been allocated for science pedagogy courses in all four-year B.Ed. programmes. However, as mentioned above, research has indicated that many pre-service primary teachers leave their initial teacher education with scientific misconceptions. This indicates that, in addition to courses in science pedagogy, initial teacher education programmes should offer courses that will support student teachers' *conceptual learning* in science. In one of the four-year B.Ed. programmes a new four-year subject specialism in science education has been developed and is being offered to B.Ed. students. The development of students' scientific conceptual knowledge is one area that is being addressed within this subject specialism. It will be interesting to see whether the increased time being allocated to science and science pedagogy within the undergraduate B.Ed. programmes will have a significant impact on the teaching and learning of primary science.

To conclude, while Irish pupils performed above the international average in TIMSS 2011, their performance was similar to that of TIMSS 1995, despite the introduction of the PSSC. If Ireland's performance in future assessments is to be improved, and more importantly, if Ireland is to develop scientific knowledge among primary school pupils, additional professional development, improved initial teacher education and additional allocation of time for teaching science in primary schools are required.

Additional References

This section does not repeat the core references already listed in Chapter 1. These include the three international reports and the Irish national report on PT 2011 and those related to other key studies such as National Assessments and PISA.

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