In E. Eivers & A. Clerkin (Eds.). (2013). ***National Schools, international contexts: Beyond the PIRLS and TIMSS test results****. Dublin: Educational Research Centre.*

Chapter 8
Mathematics items: Context and curriculum

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Introduction

TIMSS 2011 is Ireland's first time to participate in an international assessment of mathematics achievement at primary level since 1995. This chapter examines the performance of Irish pupils on mathematics in TIMSS 2011 at a broad level, and provides an in-depth analysis of performance on a subset of released test items in particular. Previous performance on TIMSS 1995 is considered, as are mathematics outcomes from the National Assessments and initiatives arising from *Literacy and Numeracy for Learning and Life* (DES, 2011).

Since Ireland last took part in TIMSS in 1995, a revised Primary School Mathematics Curriculum (PSMC) was introduced. Relative to its predecessor, the PSMC introduced in 1999 places more emphasis on constructivist theories of learning and teaching, on problem-solving, communication and discussion, and advocates the use of digital technology in teaching and learning. There were also some minor changes in content including the introduction of estimation in computation and measurement, simple probability, and encouraging the use of calculators from Fourth class onwards (DES/NCCA, 1999a).

Although Ireland has not participated in a large international assessment of mathematics since 1995, National Assessments of Mathematics Achievement (NAMA) were carried out at the Fourth class level in 1999 and 2004 (Shiel & Kelly, 2001; Shiel, Surgenor, Close, & Millar, 2006) and in Second and Sixth classes in 2009 (Eivers et al., 2010). Overall performance in Fourth class in 1999 and in 2004 was not significantly different, indicating no change in overall achievement from just before the revised curriculum was introduced to immediately after. There were significant improvements on two mathematics content areas (Data, and Shape and Space) and one skill process (Reasoning). In both assessments, relative weaknesses were identified in the content areas of Measures and aspects of Number, and in the process skills of Applying and Problem-solving.

In the National Assessments 2009 (NA 2009) of Second and Sixth class, performance on the process skills of Applying and Problem-solving and on the content area of Measures was poor, relative to other process skills and content areas, especially at Sixth class. TIMSS 2011 provides a timely opportunity to look at mathematics learning and achievement in Irish primary schools from an international comparative perspective. Full details of Irish pupils' performance in TIMSS 2011 are provided in the main report for Ireland (Eivers & Clerkin, 2012), but, broadly, national mathematics achievement is similar to that reported in TIMSS 1995, and slightly better than that reported in various PISA (Programme for International Student Assessment) cycles at post-primary level. In TIMSS 2011, Ireland's mean of 527 was significantly above the study centrepoint of 500, ranking 17th of 50 participating countries. Thirteen countries achieved mean scores that were significantly higher than Ireland's. Boys and girls in Ireland obtained similar mean scores on the overall assessment.

This chapter looks at relationships between TIMSS 2011 item performance in mathematics, at Irish and international levels, and item structures and demands in the context of the mathematics curriculum and the TIMSS 2011 mathematics framework and survey results.

This will be achieved by:

- comparing the TIMSS mathematics framework with the PSMC.
- clarifying the relationship between item difficulty and the international performance scale on which countries' mathematics performances are placed.
- analysing a selection of released items whose difficulty levels for Irish pupils are unusually high or low compared to the international norms, or are peculiar to Ireland in terms of gender differences.

The remainder of this chapter is divided into four sections, the first of which compares the TIMSS mathematics framework to the PSMC. Section two outlines International Benchmarks and items exemplifying each. Section three analyses a selection of mathematics items used in TIMSS 2011 and subsequently released for public review. The final section discusses some of the findings and the implications arising. 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 mathematics framework and the Irish PSMC

This section provides a brief comparison of the TIMSS 2011 mathematics framework for Fourth grade and the Irish mathematics curriculum for Third and Fourth class as set out in the PSMC handbook for teachers, and the results of a Test-Curriculum Matching Analysis (TCMA) carried out by a team of Irish mathematics educationalists.

TIMSS mathematics framework and item specifications

The TIMSS 2011 mathematics assessment framework provides an organisational structure for describing the mathematical knowledge and skills assessed in the 2011 survey, including the proportions of items assigned to test those skills (Mullis, Martin, Ruddock, O'Sullivan, & Preuschoff, 2009). As was the case with previous TIMSS frameworks the 2011 framework has two main dimensions: a **content** dimension, describing the three mathematical content domains to be assessed – Number; Geometric Shapes and Measures; and Data Display; and a **cognitive** dimension, listing the three domains of cognitive processes to be assessed – Knowing; Applying; and Reasoning. Table 8.1 gives the item percentages allocated to each of the content and cognitive domains assessed at Fourth grade in TIMSS 2011.

Table 8.1: Percentages of items for the content and cognitive domains in the TIMSS 2011 Fourth grade mathematics assessment

Content domains	Percentages of items
Number	50%
Geometric Shapes and Measures	35%
Data Display	15%
Cognitive domains	
Knowing	40%
Applying	40%
Reasoning	20%

The content dimension

The Number domain is assessed by approximately 50% of the items, and includes knowledge and skills relating to: numeration and place value; number operations with whole numbers (including estimation); fractions; decimals; measurement units;[1] number sentences; and number patterns. Geometric Shapes and Measures, which is assessed by 35% of the items, includes: length, area, and volume of figures; parallel and perpendicular lines; angles; 2-D coordinate system; properties of 2-D and 3-D shapes, line symmetry; rotational symmetry; and relationships between 2-D and 3-D shapes. The Data Display domain, which is assessed by 15% of the items, includes: data collection and classification; data representation with tables, pictograms, bar charts, pie charts, scales; interpretation of data displays and inference. Table 8.2 summarises the main topic areas under each content domain.

Table 8.2: Mathematical content domains and associated topic areas

Number	Geometric Shapes and Measures	Data Display
Whole numbers Fractions and decimals Number sentences with whole numbers Patterns and relationships	Points, lines and angles Two- and three-dimensional shapes	Reading and interpreting Organising and representing

The cognitive dimension

TIMSS is based on three cognitive domains – Knowing, Applying, and Reasoning. Table 8.3 summarises the key process skills associated with each. As can be seen, Knowing (assessed by roughly 40% of test items) refers to the basic facts, concepts, and procedures that pupils need to be able to recall to carry out routine mathematical tasks such as computation, measuring and identification, skills which are also often prerequisites for dealing with more complex tasks such as problem-solving and reasoning.

Table 8.3: Mathematical cognitive domains and associated process skills

Knowing	**Applying**	**Reasoning**
Recall terms, definitions, rules and properties Recognise various mathematical objects and entities Compute – carry out algorithms and procedures Retrieve information and data Measure things and choose appropriate units Classify/Order objects, numbers, expressions	Select suitable method, operation or strategy for solving routine problems Represent mathematical information and relationships in different modes Model routine problems with suitable expressions or equations Implement a set of mathematical instructions Solve routine problems	Analyse mathematical relationships and problem situations Generalise/Specialise mathematical patterns, rules, and principles Integrate/Synthesise mathematical elements and representations Justify methods, strategies and solutions Solve non-routine problems

Applying, assessed by 40% of the items, is concerned with the use or application of basic facts, concepts, and procedures in representing and solving routine well-practiced

[1] In the PSMC, measurement units are included in the Measures domain rather than the Number domain as in TIMSS 2011.

problems set in familiar mathematical or practical contexts. Reasoning (assessed by about 20% of the test items) is concerned with pupils' ability to analyse and think logically about mathematical objects, rules and relationships in the process of solving non-routine problems in both practical and purely mathematical contexts.

About 50% of the TIMSS 2011 items were multiple-choice, where pupils selected their answer from a choice of four, and about 50% were constructed-response, where pupils wrote in the answer. Pupils were not allowed access to calculators.

TIMSS mathematics framework and PSMC for Fourth class compared

Since TIMSS assessments were aimed at Fourth grade the focus in this section is on the PSMC for Fourth class.[2] As with the TIMSS mathematics framework, the PSMC has two principal dimensions – a content dimension and a cognitive dimension. The content dimension has five strands: Number, Algebra, Shape and Space, Measures, and Data. The strands and content domains can be loosely matched as follows:

PSMC		**TIMSS**
Number; Algebra	⟺	Number
Shape and Space; Measures	⟺	Geometric Shapes and Measures
Data	⟺	Data Display

To provide a rough comparison between TIMSS and the PSMC on the content dimension, Table 8.4 shows the percentage of specific teaching objectives listed in the PSMC for Fourth class for each content strand/domain, compared with the percentage of TIMSS items for each content domain. It can be seen from the table that, apart from Data, which is more heavily weighted in TIMSS, the PSMC content strands and the TIMSS content domains have fairly similar weightings.

Table 8.4: Percentages of teaching objectives in PSMC and items in TIMSS by content domain

Domain/Strand	% PSMC objectives	% PSMC objectives *(Re-categorised)**	% items in TIMSS 2011
Number, Algebra	45	54	50
Shape & Space, Measures	47	38	35**
Data	8	8	15

*Since TIMSS includes "units of measure" in the Number domain, this column includes PSMC objectives relating to "units of measure" in the Number & Algebra strand.

**TIMSS combines two PSMC strands (Shape and Space, Measures) in a domain called Geometric Shapes and Measures.

The cognitive dimension of the PSMC has six general process skill categories: Understanding and Recalling; Implementing; Reasoning; Integrating and Connecting; Communicating and Expressing; Applying and Problem-solving. One skill, Communicating and Expressing, was not a formal subject of assessment in TIMSS although, the extended constructed-response items could provide some informal information on this domain.

[2] A broader description of the PSMC can be found in DES/NCCA/Eivers' chapter in the TIMSS 2011 Encyclopedia (Mullis, Martin, Minnich, Stanco, et al., 2012). A more detailed description can be found in the PSMC Handbook (DES/NCCA, 1999b).

That aside, the PSMC general process skills and TIMSS cognitive categories align as follows:

PSMC		**TIMSS**
Understanding and Recalling, Implementing	⟺	Knowing
Reasoning, Integrating, Connecting	⟺	Reasoning
Applying and Problem-solving	⟺	Applying

Table 8.5 provides a comparison between TIMSS and the PSMC on the cognitive dimensions. The item percentages for each domain from NAMA 2004 are used as a proxy, since the weightings reflected in these percentages were inferred from curriculum documents and textbooks[3] for Fourth class at the time. It compares the percentage of items in the NAMA 2004 Fourth class test for each cognitive process skill of the PSMC with the percentage of TIMSS items for each cognitive domain. Apart from the combined category of Understanding and Recalling/Implementing, the PSMC and the TIMSS domains are somewhat differently weighted. However, defining categories and classifying items on the cognitive dimension is more subjective than is the case with the content domains and needs to be viewed in this light. For example, non-routine problems are included in the Reasoning category in the TIMSS framework, but in the Applying and Problem-solving category in the PSMC.

Table 8.5: Percentages of items for the cognitive domains of NAMA 2004 and TIMSS mathematics

NAMA 2004			TIMSS 2011	
Cognitive process skill	% items	% items (combined)	Cognitive process skill	% items
Understanding & Recalling	12	40	Knowing	40
Implementing	28			
Reasoning	21	28	Reasoning	20
Integrating & Connecting	7			
Applying & Problem-solving	32	32	Applying	40

Test-Curriculum Matching Analysis

In order to provide further evidence of the degree of correspondence between the TIMSS 2011 framework and the PSMC, a Test-Curriculum Matching Analysis (TCMA) was carried out in which three curriculum experts matched each of the 175 TIMSS test items with the specific objectives in the PSMC for Fourth class. Only 13 of the 175 TIMSS items (7%) were judged not to be covered in the PSMC for Fourth class. These non-matching items were all in the TIMSS Geometric Shapes and Measures domain and tested the topics of coordinates, rotational symmetry, volume of cuboids, and millimetre measures. Despite their not being covered in the PSMC, Irish pupils performed reasonably well on these items, with one exception. An item which belonged to the topic of coordinates systems (i.e., identifying the coordinates of a location) proved unusually difficult, and is discussed later in section four as Example Item 16 (*Write the grid square*). Only nine of the 47 countries that carried out a

[3] Recent National Assessments (Shiel et al., 2006; Eivers et al., 2010) indicate a heavy reliance on mathematics textbooks by teachers. Almost all primary school pupils were taught by teachers who used a textbook almost every day.

TCMA had a higher percentage of TIMSS items that matched their national mathematics curriculum for Fourth grade. When country scores were based solely on the items that matched their national curriculum, there was little change in the percent correct scores – just one or two percent – or on their comparative positions on the international scale (Mullis, Martin, Foy, & Arora, 2012).

The findings from the TIMSS mathematics framework/PSMC comparison and the TCMA indicate the high degree of overlap between the content of the Irish PSMC and the content of the TIMSS mathematics framework and items. It is, of course, TIMSS policy to design the assessment instruments so that they reflect as much as possible the curricula of the participating countries, and in the case of the Irish mathematics curriculum for Fourth class, it is a particularly close match.

International Benchmarks of mathematics performance

As explained in Chapter 1, TIMSS reports pupils' achievement using a scale with a mean of 500 (the centrepoint, anchored from the 1995 assessment) and a standard deviation of 100. In addition, four key points on this scale, **400, 475, 550**, and **625**, were identified for the purposes of setting and describing International Benchmarks of mathematics performance – Low, Intermediate, High, and Advanced, respectively. In order to describe what pupils can do at each of these four Benchmarks, the items used in TIMSS were located on the mathematics scale based on their difficulty. Once the items were placed and grouped on the scale they were used to derive descriptions of the knowledge and skills that pupils who scored at each International Benchmark should be able to demonstrate. (See the TIMSS methods and procedures website – http://timssandpirls.bc.edu/methods/index.html – for more detail). Following are the descriptions for the Fourth grade Benchmarks, along with released items to exemplify the Benchmarks and their descriptions. Readers should note that the manner in which items are presented here are – for reasons of space – somewhat different to how they were presented to pupils.[4]

Figure 8.1 outlines some of the mathematical skills that pupils at the Low International Benchmark are able to demonstrate, accompanied by two items exemplifying those skills. Example Item 1 (*5631 + 286*) involves implementing a procedure for adding a four-digit number to a three-digit number with renaming (carrying), a procedure for which copious practice is provided in textbooks and which is easily mastered by most pupils in most countries, including Ireland. Irish pupils scored 6% above a relatively high international average. Among the higher-performing countries, only Finnish pupils obtained a percent correct (58%) that was significantly lower than the international average. Irish girls scored about 6% higher than Irish boys.

On Example Item 2 (*This is a map of Lucy's town*), Irish pupils, girls and boys, did very well despite the fact that it involves Coordinates, a topic that is not on the PSMC for Fourth class. Pupils probably acquire an informal knowledge of reading coordinates from real-life experiences. For example, game boards (on or off computer screens) and maps in shopping centres often have a grid type setup similar to the grid in Example Item 2.

[4] All of the released items, shown as originally presented to pupils, can be viewed at http://www.erc.ie/documents/timss_2011_maths_items.pdf.

Figure 8.1: Summary description of the Low International Benchmark, with two exemplar items

Low International Benchmark – Have basic mathematical knowledge

Pupils at this Benchmark can...

- Add and subtract whole numbers and enumerate into the thousands.
- Identify parallel and perpendicular lines and geometric shapes; locate positions on a map.
- Read and complete simple bar graphs and tables.

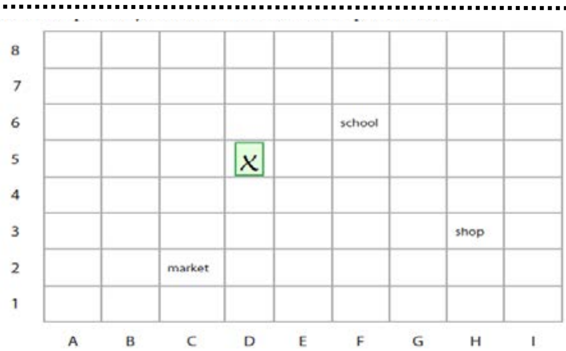
Example Item 1: **5631 + 286 =**

Answer: 5917

Item ID: M05_01[5]
Topic Area: Whole Numbers
Correct: Ireland: 78% TIMSS: 72%

Content Domain: Number
Cognitive Domain: Knowing
Irish Girls: 81% Irish Boys: 75%

Example Item 2: **This is a map of Lucy's town. The market is at the position C2. Lucy's house is at D5. Put an X on the map to show where Lucy's house is.**



Item ID: M06_07B
Content Domain: Geometric Shapes and Measures
Topic Area: Points, Lines, and Angles
Cognitive Domain: Applying
Correct: Ireland: 89% TIMSS: 78%
Irish Girls: 89% Irish Boys: 89%

Figure 8.2 outlines some characteristics of the Intermediate International Benchmark. Example Item 3 (*Joan had 12 apples*) involves connecting a word problem with the appropriate number sentence representing it. Pupils need to recognise which one of the four number sentences has the same structure as the word problem. At 74% correct, Irish pupils, surprisingly, scored marginally (4%) lower than the international average. This may be partly attributed to the fact that Number Sentences for Third and Fourth classes are more focused on multiplication and division sentences rather than on addition and subtraction sentences, which are covered well in the First and Second class curriculum. In fact, 45% of Irish pupils were taught by teachers who (in completing the Teacher Questionnaire administered as part of the overall PT 2011 study) said Number Sentences had been taught before Fourth class. Also, the task requires pupils to choose the number sentence that correctly models the problem rather than simply finding the missing number in a number sentence. By comparison, another released item (not shown here; ID code: M07_04) asked "*4 × □ = 28. What number goes in the box?*" This was answered correctly by 86% of Irish pupils.

In Example Item 4 (*Name the shapes on the bus*), pupils were asked to identify common 2-D shapes in a practical context. Full credit (2 points) was given to pupils who identified all three shapes correctly, while pupils who correctly identified two of three shapes were assigned partial credit (1 point). Irish pupils performed very well on this item, with 72%

[5] The code for each item indicates the location of the item within a block of items (e.g., M05_01 is item 1 in block 5). The codes for the 73 released mathematics items, along with Irish and international scores, can be found at: http://timssandpirls.bc.edu/timss2011/international-released-items.html. Examples of correct answers in cases where pupils had to write an answer, along with percent correct scores, are also available at www.erc.ie/pirlstimss.

obtaining full credit – 19% higher than the international average. In only three countries (Singapore, the Russian Federation and Serbia) were a greater proportion of pupils awarded full credit on this item.

Figure 8.2: Summary description of the Intermediate International Benchmark, and two exemplar items

Intermediate International Benchmark – Apply basic maths knowledge in routine contexts

Pupils at this Benchmark can...

- Add one-place decimals; identify an expression that represents an addition or subtraction situation; identify representations of fractions; solve simple proportional problems involving halving; extend simple geometric number patterns.

- Visualise 3-D shapes from 2-D representations; identify properties of familiar solids; order a set of angles by size; recognise a line of symmetry and draw the reflection of a simple shape; use a grid to describe how to get from one position to another.

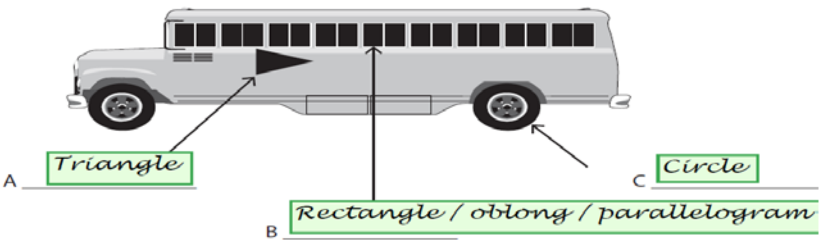
- Use information in bar graphs, pictographs, and tables to solve simple problems, and read and interpret different representations of the same data.

Example Item 3: **Joan had 12 apples. She ate some apples, and there were 9 left. Which number sentence describes what happened?**

A) 12 + 9 = ☐ B) 9 = 12 + ☐ **C) 12 – ☐= 9*** D) 9 – ☐= 12

Item ID: M06_01 **Content Domain**: Number
Topic Area: Number Sentences **Cognitive Domain**: Applying
Correct: Ireland: 74% TIMSS 78% Irish Girls: 81% Irish Boys: 68%

Example Item 4: **Write the names of shapes A, B, and C in the spaces provided**



Item ID: M03_08 **Content Domain**: Geometric Shapes and Measures
Topic Area: 2-D and 3-D Shapes **Cognitive Domain**: Knowing

Full credit:	Ireland: 72%	TIMSS: 53%	Irish Girls: 69%	Irish Boys: 75%
At least partial credit:	Ireland: 82%	TIMSS: 65%	Irish Girls: 81%	Irish Boys: 83%

(Full credit: All 3 shapes correct Partial credit: Two shapes correct)

Figure 8.3 summarises features of the High International Benchmark, including two exemplar items. Example Item 5 (*The scale on a map*) involves the use of a simple map scale to find the distance between two towns, given the distance between them on a map. Irish pupils scored just below the international average on this item (50% and 54%, respectively). This may be due to the fact that scale on charts and graphs is covered in the PSMC for Fourth class, but scale on maps is not.

Example Item 6 (*How much do the apples weigh?*) involves reading the weight of apples on a weighing scale. Again, Irish pupils scored just below the international average (52% and 56%, respectively). The relatively low performance of Irish pupils was partly due to the poorer performance of girls on this item (45% for Irish girls, and 59% for Irish boys). A similar gender difference was also apparent in the international average (51% for girls, and 62% for boys).

Figure 8.3: Summary description of the High International Benchmark, and two exemplar items

High International Benchmark – Apply maths knowledge and understanding to solve problems

Pupils at this Benchmark can...

- Solve word problems involving operations with whole numbers; multiply two-digit numbers; use division in a variety of problem situations; identify missing digits in whole numbers, order them, and appropriately round them; add two-place decimals; order unit fractions; write a number between two consecutive whole numbers; extend patterns, and use two-step rules to continue a pattern.

- Label gradations on a scale and solve a word problem involving measures and proportional reasoning; solve word problems involving addition of time; classify shapes according to given properties including symmetry; recognise right angles, parallel, and perpendicular lines in different orientations; find perimeters of simple figures; recognise a net of a cube; and identify the stack of cubes with largest volume.

- Interpret and use data in tables and graphs to solve problems; use information in pictographs and tally charts to complete bar graphs.

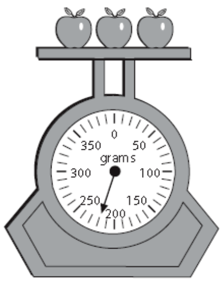
Example Item 5: **The scale on a map indicates that 1 centimetre on the map represents 4 kilometres on the land. The distance between two towns on the map is 8 centimetres. How many kilometres apart are the two towns?**

A) 2 B) 8 C) 16 **D) 32***

Item ID: M01_08 **Content Domain**: Number
Topic Area: Whole Numbers **Cognitive Domain**: Reasoning
Correct: Ireland: 50% TIMSS: 54% Irish Girls: 47% Irish Boys: 53%

Example Item 6: **How much do the apples weigh in grams?**

A) 200 B) 202 C) 210 **D) 220***



Item ID: M05_07
Content Domain: Data Display
Topic Area: Reading and Interpreting
Cognitive Domain: Knowing
Correct: Ireland: 52% TIMSS: 56%
Irish Girls: 45% Irish Boys: 59%

Example Item 7 (*Tom ate ½ a cake*) in Figure 8.4 is one of a number of items on fractions and decimals on which Irish pupils performed remarkably better than the corresponding international averages. For example, for Item 7, the national mean of 53% correct is 30% higher than the international average. Pupils in Northern Ireland also performed very well on this item (68% correct). The low international mean suggests that this is a particularly difficult item in many other countries, including the generally high-performing Japan (28% correct).

The item involves knowing when and how to add two related fractions (½ and ¼) in a practical context (eating parts of a cake), so the low international mean score is surprising. The considerably higher score of Irish pupils may be partly attributed to the familiar context of the task and to the substantial coverage of fraction concepts in the PSMC and Irish textbooks for Third and Fourth classes, although coverage of formal algorithms or procedures for addition and subtraction of fractions is left to Fifth class. The latter is affirmed by the fact that 66% of Irish pupils were taught by teachers who chose “Not yet taught or just introduced" when asked if pupils had been taught addition and subtraction of fractions.

It is interesting to contrast performance on Example Item 7 with performance on the sample item below, on fractions in a similar problem context, which was included in NAMA 2004 (Shiel et al., 2006). Just 6% of Fourth class pupils obtained the correct answer to the item. However, its greater difficulty may be explained by the fact that it involved unrelated fractions (¼ and ⅓), and multiple steps (e.g., converting to twelfths, then combining and partitioning fractions). As a non-routine multi-step type of problem which is less well covered in most Irish textbooks and classroom instruction, it would be expected to be considerably more difficult than Item 7.

From: NAMA 2004 - Sample Item
Peter ordered pizza. He ate ¼ of it. His sister Niamh ate ⅓ of it. What fraction of the pizza was left?
National Score: 6%

Figure 8.4: Summary description of the High International Benchmark, and two exemplar items

Advanced International Benchmark – Apply maths in complex situations and explain reasoning

Pupils at this Benchmark can...

- Solve a variety of multi-step word problems involving whole numbers and proportions; solve problems with number sentences involving whole numbers; determine equivalent fractions represented in a variety of ways; identify a fraction larger than a given fraction. Identify the smallest among a set of one- and two-place decimals; solve two-step problems involving decimals; identify a two-step rule for a linear relationship.

- Apply knowledge of two- and three-dimensional shapes in a variety of situations; estimate the length of a curved line; use knowledge of perimeter to solve a multi-step problem; determine the areas of simple figures, find the number of cubes that fill a rectangular box.

- Use data to solve two-step problems; draw and justify conclusions from data in a table.

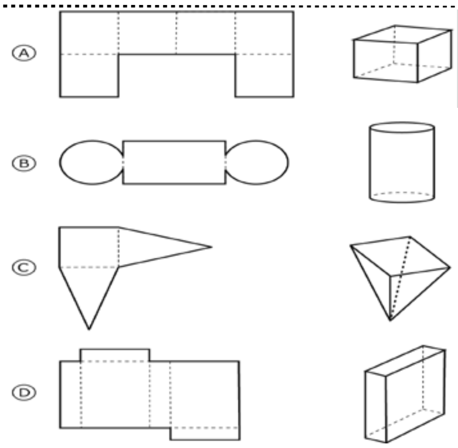
Example Item 7: **Tom ate ½ of a cake, and Jane ate ¼ of the cake. How much of the cake did they eat altogether?**

Answer: *¾ or three-quarters*

Item ID: M03_06
Topic Area: Fractions and Decimals
Correct: Ireland: 53% TIMSS: 23%

Content Domain: Number
Cognitive Domain: Knowing
Irish Girls: 51% Irish Boys: 55%

Example Item 8: **Ina found the following patterns to make containers. Which pattern actually makes the container beside it?**



Item ID: M06_10

Content Domain: Geometric Shapes and Measures

Topic Area: 2-D and 3-D Shapes

Cognitive Domain: Reasoning

Correct: Ireland: 30% TIMSS: 37%
Irish Girls: 33% Irish Boys: 27%

Example Item 8 (*Ina found container patterns*) in Figure 8.4 requires considerable analysis and spatial reasoning as it involves identifying 2-D nets of 3-D shapes. Irish scoring on this item was slightly lower than the international average, with boys' performance below that of girls. This type of task benefits from manipulative activities which can be done with concrete materials or using digital tools in digital learning environments, which earlier research suggests are not being used to an appropriate degree in mathematics teaching in Irish primary schools (Eivers et al., 2010).

Summary of Benchmark performance

Table 8.6 compares the percentages of Irish Fourth class pupils, overall and by gender, reaching each of the four International Benchmarks in mathematics compared with the international average percentages. It can be seen that higher proportions of Irish pupils reached each of the four Benchmarks than the international averages for all countries, with the difference being greatest at the High Benchmark (41% of Irish pupils having reached this level, and 28% internationally). However, the difference at the Advanced Benchmark was slight and therefore not in keeping with Irish performance generally.

This latter finding is in line with the trend in PISA mathematics surveys of 15-year-olds where high-achieving pupils underperform on the PISA proficiency scale. For example, in the 2003 PISA study (when mathematics was the major domain), 15% of all students internationally achieved the top two proficiency levels, compared with 11% of Irish students, whereas Irish students' overall score on the PISA scale of 503 was around the international mean of 500 (Cosgrove, Shiel, Sofroniou, Zastrutzki, & Shortt, 2005). Gender differences in percentages of Irish pupils reaching each of the TIMSS Benchmarks are relatively small, apart from at the Advanced Benchmark, which was reached by 11% of boys compared with 8% of girls, a difference not present at the international level. In PISA 2003, 13% of Irish males reached the top two proficiency levels, compared with 9% for females. Similarly, in NA 2009, slightly more boys than girls reached the highest proficiency level (12%; 8% at Second class, and 11%; 9% at Sixth class).

Table 8.6: Percentage of Irish pupils, and international median, reaching each International Benchmark, overall and by gender

Benchmark	Irish pupils			International median		
	Overall	Girls	Boys	Overall	Girls	Boys
Advanced	9	8	11	8	8	9
High	41	39	42	31	29	32
Intermediate	77	76	77	61	60	61
Low	94	95	93	82	82	81

Table 8.7 compares, by content and cognitive domains, the percentages of Irish Fourth class pupils reaching each of the four International Benchmarks in mathematics, compared with TIMSS international mean percentages of Fourth grade pupils. Apart from Data Display at the Advanced Benchmark, higher percentages of Irish pupils reached the four Benchmarks in the three content domains than the international average, with the advantage being substantially greater for Number than for the other two domains. This latter finding is in keeping with the results of NAMA 2004 at Fourth class where the lowest mean percent correct scores were in the Shape and Space (48%) and the Measures domains (56%), and the highest in Number (69%). Table 8.7 also shows that, apart from Reasoning at the Advanced Benchmark, higher percentages of Irish pupils reached the four Benchmarks in the three cognitive domains than the international averages, with the advantage being substantially greater for Knowing than for Applying or Reasoning. This finding is also in

keeping with the NAMA 2004 results, where the lowest mean percent correct score was in the Applying and Problem-solving domain (48%), and the highest in Understand and Recall (62%).

Table 8.7: Percentages of Irish pupils, and international mean percentage, reaching each International Benchmark, by content and cognitive domains

International Benchmark	IRL	TIMSS	IRL	TIMSS	IRL	TIMSS
	Number		Geo. Shapes & Measures		Data Display	
Advanced	11	9	10	9	9	10
High	43	32	37	31	38	32
Intermediate	78	62	72	59	74	59
Low	94	83	92	79	93	78
	Knowing		Applying		Reasoning	
Advanced	16	10	10	9	7	9
High	47	32	41	31	32	31
Intermediate	78	61	77	60	68	60
Low	94	81	94	81	91	80

Analysis of a selection of released items

After the initial achievement results were released, 73 items from a total pool of 175 items used in the TIMSS 2011 mathematics assessment were released into the public domain (see http://www.erc.ie/documents/timss_2011_maths_items.pdf for all released items, sample responses, and information on percent correct answers for Ireland and for TIMSS overall). The released items are representative of the distribution of all TIMSS items in terms of content and cognitive domains, as specified by the mathematics framework described earlier. Item-by-item percent correct information for each participating country can also be accessed at: http://timssandpirls.bc.edu/timss2011/international-released-items.html. Item-level analysis of the TIMSS data provides useful information relating to the teaching and learning of mathematics in Third and Fourth classes, as well as factors contributing to the difficulty of the items.

Table 8.8 lists a selection of 35 items from the 73 released items that can be considered to be "out of the ordinary" in terms of Irish performance. The Irish mean scale score for TIMSS 2011 was 527, which is significantly above the international mean scale score of 500. On this basis one would expect the Irish pupils' percent correct score on most mathematics items to be slightly above the international mean, by up to 5%-10%. Therefore, for this section, items for which Irish pupils' percent scores were substantially above the international mean (i.e., difference ≥ +15%) and those that were at or below it (i.e., ≤0%) were considered to be "out of the ordinary". Items with substantial gender differences, particularly where they are not in line with international gender differences in performance, are also included.

Inspection of these 35 "unusual" items in Table 8.8 shows that, in terms of the content dimension, most of the items on which Irish Fourth class pupils did unusually well were in the topic area of Fractions and Decimals (7 items) and most of the 35 items on which they did relatively poorly were, surprisingly, on the topic area of Whole Numbers (5 items). Most items with unusual gender differences (an at least 10% gender gap in Ireland) were also on Whole Numbers (6 items). All of the "unusually high" items were in the Knowing and Applying domains and half of the "unusually low" items were in the Reasoning domain. In terms of International Benchmarks, 28 of the 35 items are at the High and Advanced International Benchmarks with just 7 of them at the Intermediate level and none at the Low level. These "out of the ordinary" items are discussed further with a particular emphasis on items on which Irish pupils underperformed.

Table 8.8 "Out of the ordinary'" TIMSS released mathematics items, by item ID, size of gap and International Benchmark level for item

Content domain (*N released items*)	Topic area	Unusually high IRL - INT ≥ 15% *Item ID* (gap) IBM*	Unusually low IRL – INT ≤ 0% *Item ID (gap) IBM*	Unusual IRL gender gap ≥ 10% *Item ID (gap) IBM*
Number (*40*)	Whole numbers	M05_03 (+31) Adv M07_02 (+19) Adv	M01_03 (0) Adv M01_08 (-4) High M02_04 (-2) Adv M06_02 (-6) High M06_03 (-13) Adv	M01_01A (-10) Inter M01_01B (-11) Adv M01_02 (-11) Adv M02_03 (-21) Adv M02_05 (+10) High M03_01 (-10) Inter
	Fractions & decimals	M02_01 (+15) Inter M02_02 (+24) Adv M03_03 (+28) Inter M03_05 (+19) High M03_06 (+30) Adv M06_05 (+28) Adv M07_01 (+16) Adv		
	No. sentences with whole numbers	M07_05 (+16) Adv	M05_06 (-1) Adv	M06_01 (+13) Inter
	Patterns & relationships	M07_03 (+19) Adv		
Geometric Shapes & Measures (*24*)	Points, lines, & angles	M02_07B (+15) Inter	M07_07 (-12) Adv M02_07A (-6) High	
	Two- & three-dimensional shapes	M03_08 (+20) Inter M05_11 (+16) High M06_08 (+27) High	M03_12 (-5) Adv M01_07 (0) Adv M06_10 (-6) Adv	M06_09 (-10) Adv
Data Display (*9*)	Reading & interpreting			M05_07 (-14) High
	Organising & representing			

*All items are identified by a unique ID (shown at http://www.erc.ie/documents/timss_2011_maths_items.pdf to the right of each item).

Number

This section examines selected items in the TIMSS topic areas of Fractions and Decimals; Whole Numbers; and, Ratio and Proportion.

Fractions and Decimals

As mentioned earlier, Irish Fourth class pupils performed unusually well on items relating to the topic of Fractions and Decimals. This was illustrated earlier by Example Item 7 (*Tom ate ½ a cake*) at the Advanced Benchmark. Irish pupils also performed very well on items involving Decimals, as next illustrated by Example Item 9 (*Write a number between 5 and 6*) (Figure 8.5). Item 9 involves knowing the concept of a decimal to one place. Two-thirds of Irish pupils obtained the correct answer, compared to an international mean of just 48%, a difference of 18%. The inclusion of a specific teaching objective relating to ordering of decimals on the number line in the PSMC and the resulting substantial coverage of it in classroom teaching and in textbooks may help to explain the much higher score of Irish pupils.

Figure 8.5: Examples of mathematics items related to Fractions and Decimals

Example Item 9: Write a number that is larger than 5 and is smaller than 6.	
Any decimal or fraction between 5 and 6 e.g. 5.2, 5½, 5.27, 5¾	
Item ID: M03_05	**Content Domain**: Number
Topic Area: Fractions and Decimals	**Cognitive Domain**: Knowing
Benchmark: High	
Correct: Ireland: 66% TIMSS: 48%	
Example Item 10: Duncan first travelled 4.8km in a car and then he travelled 1.5km in a bus. How far did Duncan travel?	
6.3 km	
Item ID: M02_01	**Content Domain:** Number
Topic Area: Fractions and Decimals	**Cognitive Domain:** Applying
Benchmark: Intermediate	
Correct: Ireland: 75% TIMSS: 60%	

Another item on Decimals on which Irish pupils did particularly well was on the application of decimals to calculations with units of measurement – Example Item 10 (*Duncan travelled 4.8km*), at the Intermediate Benchmark. This item would be classified under Measures in the PSMC since it involves addition of units of length (km) but comes under the topic area of Fractions and Decimals in the Number domain of the TIMSS framework as it involves decimals. Irish pupils scored highly on this item – 75% correct compared with 60% for the international mean. It is a simple routine one-step problem classified as Applying on the cognitive dimension of the TIMSS framework.

Whole Numbers

On the other hand, Irish performance on many items in the topic area of Whole Numbers was unusually low or had unusually large gender differences. One of these items, Example Item 3 (*Joan had 12 apples*), which relates to the topic of Number Sentences for the Intermediate Benchmark, had unusual gender differences and was discussed earlier. One of the poorest items in terms of Irish performance was Example Item 11 (*Circle factors of 12*), which is at the Advanced Benchmark (Figure 8.6). Only 14% of Irish pupils answered this item correctly, compared to an international mean of 27%. Based on Irish performance in general one would expect the Irish score on this item to exceed 30%. However, the concept of a factor is not formally introduced in the PSMC until Fifth class (in the strand unit Number Theory). Although pupils may be familiar with divisibility from work on multiplication and division with whole numbers in Third and Fourth classes, few would seem to be able to transfer this knowledge to generating lists of factors for numbers and solving problems involving factors.

Another item shown in Figure 8.6 in which Irish pupils did less well than the international mean is Example Item 12 (*Mary cycling to Brandon*) at the Advanced Benchmark. As with the previous item, this item involves a concept, speed, which is not introduced until Sixth class in the PSMC (in the strand unit Time) and so is not covered in Fourth class lessons and textbooks. Speed is also a more complex concept as it represents a ratio of two more basic variables – distance and time (e.g., kilometres per hour). These facts may explain the poor Irish performance (only 35% answered correctly) on this item. The international mean is also low at 38%, so the absence of concept of speed in the Fourth grade mathematics curriculum may have been a problem for some other countries.

Irish girls (45%) did substantially better than Irish boys (34%) on Example Item 13 (*23 × 19*) whereas the international mean gender difference was only 3%. This task normally involves knowing the steps in a long multiplication procedure, although more able pupils might use reasoning such as 23 × 19 = (23 × 20) – (23 × 1) = 460 – 23 = 437. Given the considerable emphasis on multi-digit multiplication procedures in Irish Fourth class textbooks a better performance might be expected. Performance on this item varied greatly from country to country. While 90% of pupils in Chinese Taipei answered correctly, less than 10% of pupils in a number of countries did so, including Finland (5%), New Zealand (8%) and Poland (6%). This may reflect curriculum coverage or a de-emphasis on teaching formal algorithms.

Figure 8.6: Examples of mathematics items related to Whole Numbers

Example Item 11: Circle each number which is a factor of 12

1	2	3	4	5	6	7	8	9	10	11	12

Item ID: M06_03 Benchmark
Content Domain: Number
Topic area: Whole Numbers
Cognitive Domain: Knowing
Benchmark: Advanced
Full credit: Ireland: 14% TIMSS: 27%
At least partial credit: Ireland: 27% TIMSS: 44%
(2 points: all six correct numbers - 1, 2, 3, 4, 6, 12; 1 point: Four or five correct numbers)

Example Item 12: Mary left Apton and rode at the same speed for 2 hours. She reached this sign. Mary continues to ride at the same speed to Brandon. How many hours will it take her to ride from the sign to Brandon?

(A) 1 ½ hours (B) 2 hours **(C) 3 hours*** (D) 3 ½ hours

Item ID: M02_04
Cognitive Domain: Reasoning
Topic Area: Whole Numbers
Content Domain: Number
Benchmark: Advanced
Correct: Ireland: 35% TIMSS: 38%

Example Item 13: 23 × 19 =

437

Item ID: M02_05
Content Domain: Number
Topic Area: Whole Numbers
Cognitive Domain: Knowing
Benchmark: High
Correct: Ireland: 40% TIMSS: 41%
Irish Girls: 45% Irish Boys: 34%

Ratio and Proportion

A particular subsection of the topic area Whole Numbers on which Irish pupils did relatively poorly was that of simple proportions. This includes concepts such as ratio, scale, rate and the procedures of multiplication, division, and unitary method. Included among these items are some which showed unusual gender differences in favour of boys (see Table 8.8). Four of these items relate to one stimulus, shown in Example Item 14 (*Trading Cards*) (Figure 8.7).

In the stimulus, two ratios are provided as pictorial representations: i.e.

1 animal card = 2 cartoon cards and 2 animal cards = 3 sports cards

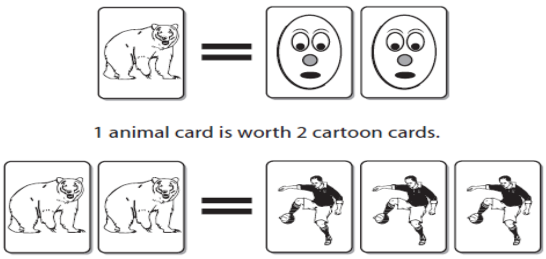
The pupil has to use these ratios to solve the four questions. The first question involved constructing the relationship below and carrying out the appropriate multiplication (normally a one-step problem).

2 cartoon cards for 1 animal card = [?] cartoon cards for 5 animal cards

This was generally easy for Irish pupils (73% correct) and in terms of the international mean (62%). However, substantially fewer Irish girls than boys obtained the correct answer (68% of girls, and 78% of boys). The difference in favour of boys at the international level was just 6%.

Figure 8.7: Examples of mathematics items related to Ratio and Proportion (Whole Numbers)

Example Item 14: The town fair had a booth where people could trade cards.



Some children went to the booth to trade cards

Item IDs: M01_01A, M01_01B, M01_02, M01_03 **Content Domain:** Number
Topic Area: Whole Numbers **Cognitive Domain:** Reasoning (except M01_01A, which was Applying)

1A. Becky had 5 animal cards to trade for cartoon cards. How many cartoon cards would she get?
10 cartoon cards
Ireland: 73% TIMSS: 62%. Irish Boys: 78% Irish Girls: 68%

1B. Jim had 8 animal cards to trade for sports cards. How many sports cards would he get?
12 sports cards
Ireland: 35% TIMSS: 31%. Irish Boys: 40% Irish Girls: 29%

2. Steve had 15 sports cards to trade for animal cards. How many animal cards would he get?
10 animal cards
Ireland: 27% TIMSS: 25%. Irish Boys: 32% Irish Girls: 23%

3. Brad had 8 cartoon cards to trade for sports cards. How many sports cards would he get?
6 sports cards
Ireland: 17% TIMSS: 18% Irish Boys: 22% Irish Girls: 11%

The second question involved constructing the relationship below and carrying out the appropriate operations (normally a two-step problem).

3 sports cards for 2 animal cards = [?] sports cards for 8 animal cards

This proved to be considerably more difficult, with only 35% of Irish pupils getting the correct answer and again, Irish boys scoring considerably better than Irish girls (40%, compared with 29%), whereas the advantage for boys at the international level was just 5%.

The next question involved constructing a slightly more complex proportion:

2 animal cards for 3 sports cards = [?] animal cards for 15 sports cards

Overall, 27% of Irish pupils obtained the correct answer compared with 25% internationally. Irish boys' performance exceeded that of Irish girls by about 9% (the gender difference at the international level was 4% in favour of boys).

Finally, the fourth element was the most complex, and involved construction of a transitive relationship among the proportions:

IF 3 sports cards = 2 animal cards **AND** 1 animal card = 2 cartoon cards;
THEN [?] sports cards = 8 cartoon cards.

This is a multi-step problem involving a higher level of proportional reasoning and understanding than the previous three questions and one that might benefit more from formal classroom experience. This is reflected in the performance figures with just 17% of Irish pupils answering correctly (the same as the international mean). Again, boys' percent correct (22%) exceeded girls' (11%) by over 10%, twice the magnitude of the difference at the international level.

Apart from 1A in Example Item 14, these questions are classified as Reasoning on the cognitive dimension of the TIMSS framework and are at the Advanced Benchmark. The performance of Irish pupils on these items is not in line with their performance on the TIMSS 2011 mathematics assessment in general. As with some earlier items showing this trend, a partial explanation may be found in the PSMC and in textbooks. The topic of Ratio and Proportion is not formally introduced in the PSMC until Sixth class. (In the pre-1999 curriculum a procedure for solving ratio tasks called "unitary method" was taught in Fourth class but was not included in the PSMC for Fourth class). Consequently, the topic is not dealt with in the textbooks and resource materials for Fourth class. However, proportionality is a broadly-based topic affecting a number of other topics including multiplication and division, fractions, decimals, percentages, scale, and conversion of measures, all of which are covered in the PSMC for Third and Fourth classes. There should be some transfer of learning, particularly for the more able pupils, from these topics to proportionality tasks as per the four questions above. There has been considerable research on proportional reasoning (e.g., Hart, 1984; Vergnaud, 1983), indicating that its development takes place over a number of years from the age of eight or nine to 14 or 15 years. In this regard, 11 of the 85 tasks in PISA 2003, which tested 15-year-olds, directly involved proportional reasoning, with percent corrects ranging from 8% to 80% (OECD, 2009).

The relatively weaker performance of Irish Fourth class girls on the four proportionality tasks is more difficult to explain. The context of trading cards may have been a factor, although this type of game does not seem to be a predominantly male activity. Example Item 15 (*In a soccer tournament*) is another item classified as Reasoning in the TIMSS framework, but involving reasoning with additive structures of whole numbers rather than multiplicative or proportional number structures (Figure 8.8). Again, there was a large gender difference in favour of boys (21% gap), and again, potentially gendered content. A possible reason for this large difference is that boys are stereotypically more interested in and more familiar with soccer league tables than girls, possibly giving them an advantage in working out the correct answer (3 + 3 + 3 + 1 + 1, which is 5 games).

Figure 8.8: Example of a Whole Numbers mathematics item with a large gender gap

Example Item 15: In a soccer tournament, teams get: **3 points for a win** **1 point for a draw** **0 points for a loss** **Zedland has 11 points.** **What is the smallest number of games Zedland could have played?** *Five / 5*	
Item ID: M02_03	**Content Domain:** Number
Topic Area: Whole Numbers	**Cognitive Domain:** Reasoning
Benchmark: Advanced	
Correct: Ireland: 39% TIMSS: 27%	Irish Boys: 50% Irish Girls: 29%

Geometric Shapes and Measures

Table 8.8 lists ten released items in the Geometric Shapes and Measures domain which were considered to be unusual in terms of typical Irish Fourth class performance. Some of those items are considered further in this section.

Points, Lines, and Angles

Three of the unusual items are in the topic area of Points, Lines and Angles and two of these, shown in Example Items 16A and 16B (*Write the grid square*) concern the topic of Coordinates in the context of grid maps (Figure 8.9). The topic of Coordinates was considered briefly in section three in relation to Example Item 2 for the Low Benchmark which also involved a grid map context. As mentioned there, Coordinates are not on the Fourth class PSMC but familiarity with grids, particularly in the context of games, may have affected performance. The performance of Irish pupils on the two items shown next is striking in this regard as, relative to international levels, they performed unusually well (79% in Ireland; 63% internationally) on Example Item 16B, but unusually poorly (43% in Ireland; 49% internationally) on Example Item 16A.

In Example Item 16A, pupils are required to identify the coordinates of two specified places on the grid, whereas 16B requires them to identify a place on the grid given its coordinates. As Coordinates do not appear on the Fourth class curriculum Irish pupils would have less experience of the first kind of task but would more likely experience the second kind in some game context (e.g., “go to C3” or “prize is at B5”, etc.). This lack of formal teaching on the topic is supported by data from the Teacher Questionnaire. Three-quarters (78%) of Irish pupils were taught by teachers who said they had not yet taught Coordinates, compared to 45% of pupils internationally.

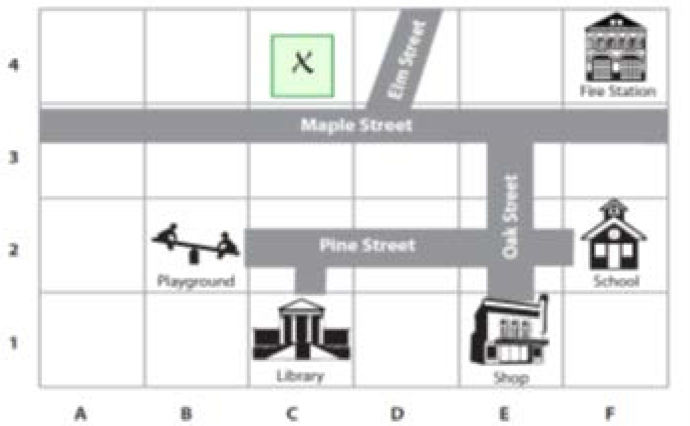
Example Item 17 (*How long is a piece of string?*), which involves estimating the length of a piece of string, proved to be one of the most difficult items on the test for Irish pupils. Only 16% answered correctly, 13% below the international mean. This is unexpected given the strong emphasis on estimation of length in the PSMC for Fourth class. Research suggests that developing estimation skills in measurement among primary school pupils requires considerable learning experiences of a practical nature (Lehrer, 2003). Standard textbooks may be of limited value in this regard. Moreover, National Assessments conducted in 2004 and 2009 indicate that pupils use concrete materials, such as measuring instruments, on a very infrequent basis as they move through the primary school system. More attention could be given to materials and methods of teaching this topic in CPD courses for teachers.

Figure 8.9: Examples of mathematics items related to Points, Lines and Angles

Example Item 16:

A. Complete the table to show where the places are. The first one has been done for you.

Places	Grid Square
Playground	B2
School	F2
Junction of Maple & Oak Streets	E3



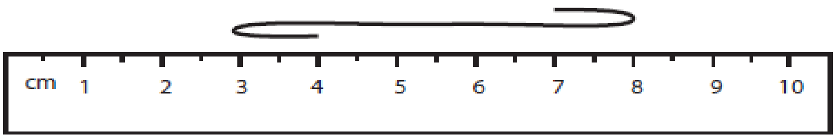
Item ID: M02_07A
Content Domain: Geometric Shapes and Measures
Topic Area: Points, Lines, and Angles **Cognitive Domain:** Knowing
Benchmark: High
Correct: Ireland: 43% TIMSS: 50%

B. Troy lives in a house in square C4. Put an X in the square to show where Troy lives.

Item ID: M02_07B **Content Domain:** Geometric Shapes and Measures
Topic Area: Points, Lines, and Angles **Cognitive Domain:** Applying
Benchmark: Intermediate
Correct: Ireland: 78% TIMSS: 64%

Example Item 17: If the string in the diagram is pulled straight, which of these is closest to its length?

(A) 5 **(B) 7*** (C) 8 (D) 9



Item ID: M07_07 **Content Domain:** Geometric Shapes and Measures
Topic Area: Points, Lines, and Angles **Cognitive Domain:** Applying
Benchmark: Advanced
Correct: Ireland: 16% TIMSS: 29%

Two- and Three-Dimensional Shapes

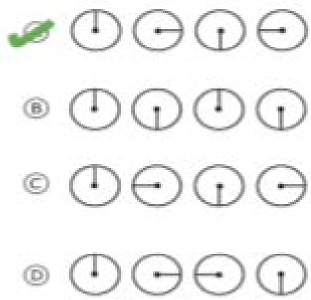
Two of the items on the topic of 2-D and 3-D Shapes were included as examples of Benchmark levels earlier in section three. Example Item 4 (*Name the shapes on the bus*), which assessed recognition of 2-D shapes at the Intermediate Benchmark, proved to be much easier for Irish pupils (72% answered correctly) than for international pupils generally (53%). Recognition of 2-D shapes is easily taught and practised and is given considerable attention in the PSMC and textbooks so this good performance is not surprising. Example Item 8 (*Ina found container patterns*) involved relationships between 3-D shapes and their 2-D nets. It is an Advanced Benchmark item and was more difficult than expected for Irish pupils (only 30% correct), given Irish pupils' performance in general and the international average of 37% correct. It may be due to lack of appropriate manipulative learning experiences in class lessons or in textbook work. Digital learning environments could be used to provide suitable activities on this topic.

Example 18 (*Rotate ¼ turn*) involves rotation in a circle through a specified angle which is not ostensibly on the PSMC, yet Irish pupils scored particularly well on the item with 79% choosing the correct response compared to an international mean of 64% (Figure 8.10). This was probably facilitated by reference in the stem of the item to "¼ turn clockwise", which would be familiar to most pupils, rather than specifying 90° as the rotation, which is not on the curriculum for Fourth class.

This view is supported by the results for a similar item, Example Item 19 (*Rotate 180°*) which specifies a 180° rotation of a flag shape. The performance of Irish pupils on this item (42%) was *below* what would be expected based on the Irish mean performance. Unlike the previous item the required transformation in this item is specified in degrees and there is no familiar analogy such as the clock to help pupils.

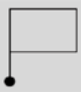
Figure 8.10: Examples of mathematics items related to 2-D & 3-D Shapes

Example Item 18. A pattern rule says "Rotate the shape  **¼ turn clockwise each time. What will the pattern look like?**



Item ID: M05_11
Content Domain: Geometric Shapes and Measures
Topic Area: 2-D & 3-D Shapes
Cognitive Domain: Knowing
Benchmark: High
Correct: Ireland: 79% TIMSS: 64%

Example Item 19



Which of the following shows the position of the shape above after a half turn or 180° rotation?

Item ID: M01_07
Content Domain: Geometric Shapes and Measures
Topic Area: 2-D & 3-D Shapes
Cognitive Domain: Knowing
Benchmark: High
Correct: Ireland: 42% TIMSS: 43%

Although not on the present PSMC, rotation as a geometric transformation was on its predecessor, the 1971 curriculum, but was removed as part of the review of that curriculum. In this regard, 66% of Irish pupils were taught by teachers who reported that the topic of reflections and rotations had not yet been taught or had just been introduced. Reflection is on the PSMC for Fourth class and as a result some teachers may have responded positively to the question on whether or not reflections and rotations had been taught. In fact, the performance of Irish pupils on a question which asked them to draw the line of symmetry on the picture of a kite (item ID code: M06_08, not shown here) was 74%, compared with an international mean of 47%.

Discussion and conclusions

Overall, Irish performance in mathematics in TIMSS could be said to be satisfactory, with a mean score of 527. This is significantly above the international scale centrepoint of 500 and significantly above the mean for 33 other countries, though significantly less than the mean score for 13 countries, including Northern Ireland (562). Another positive outcome is the significant reduction, since the TIMSS 1995 study, in the number of low achievers who fail to reach the Low Benchmark. Further analysis conducted as part of this chapter highlights more specific strengths and weaknesses of Irish pupils' performance.

In section two, the TIMSS framework and test for Fourth grade were compared with the Irish primary school mathematics curriculum (PSMC) for Fourth class in terms of content and cognitive process domains, with adjustments for differences in classification definitions. This analysis showed that the PSMC for Fourth class closely matched the content and cognitive processes tested by TIMSS 2011. The 13 items (of 175) identified as being on the TIMSS test but not on the PSMC for Fourth class related to the following topics – coordinates, rotational symmetry, volume of cuboids, millimetres, speed, factors and multiples, and ratio and proportion. Though not formally on the PSMC for Fourth class, pupils may have acquired some knowledge of these topics as part of classroom enrichment activities or through out of school experiences (e.g., in games and leisure activities). To check for the effects of performance on TIMSS items not covered in particular country curricula, countries were compared on performance based only on the items common to TIMSS and their own curriculum. Results showed that there was very little change in comparative performance across countries compared with performance when all items were included (Mullis, Martin, Foy, & Arora, 2012). This may be due to a number of factors – the general closeness of the TIMSS framework and test to the curricula of the participating countries (40 out 47 countries indicated that at least 75% of the TIMSS test items matched their country curricula); the large number of items used (175 items, or 184 score points considering items with full and partial credits); and the rotated booklet design which meant that different pupils took different item sets with some overlap across them for scaling purposes.

Section three compared Irish and international average performance at each of the four International Benchmarks in mathematics along with exemplar items for each Benchmark. Results show that the percentage of Irish pupils reaching the Advanced Benchmark (9%) is lower than would be expected from overall Irish performance, more so for girls (8%) than for boys (11%). This relatively poor performance of pupils at the upper end of the proficiency scale is mirrored in PISA mathematics with 15-year-olds (Cosgrove et al., 2005). Despite this, approximately 98% of Irish pupils were taught by teachers who, in responding to the TIMSS Teacher Questionnaire, said they were *very confident* or *somewhat confident* that they could provide challenging tasks to more capable pupils. This finding suggests that primary schools need to do more to challenge more mathematically able pupils, particularly girls, and to highlight this need among teachers and teacher educators.

When Irish performance at each Benchmark is broken down by content and cognitive domains it shows that performance at the four Benchmarks is relatively higher for Number (than for Geometric Shapes and Measures or Data Display), and for Knowing (than for Applying or Reasoning). The TIMSS teacher questionnaire revealed that, on average, Irish pupils have teachers who spend 56% of their time for mathematics on Number, compared with 22% on Geometric Shapes and Measures, 12% on Data Display and 10% on other topics. These data suggest that, despite the findings of the 2004 and 2009 National

Assessments of weaknesses in the content domains of Shape and Space, and Measures, and in the cognitive domain of Applying and Problem-solving, the main focus of the mathematics curriculum in Irish primary schools is on Number, when more time may be needed for teaching Geometric Shapes and Measures and problem-solving situations and strategies. These weaknesses persist to second-level as found in PISA (Cosgrove et al., 2005). These deficiencies were the subject of a recommendation in the recent DES policy document setting out a national strategy for literacy and numeracy (DES, 2011):

> Ensure that the curriculum contains additional guidance for teachers on the approaches to teaching and learning advocated in the curriculum in areas such as estimation, shape and space, measures, the use of cooperative group learning and problem-solving approaches (p. 56).

Analyses of a selection of released items in section four expand on the findings of the previous two sections. Among items in the Number domain Irish pupils scored particularly well on those in the topic area of Fractions and Decimals. In the area of Whole Numbers, consideration might be given to beginning formal work on factors and multiples, and on ratio and proportion, in Third and Fourth classes rather than waiting until Fifth and Sixth classes. TIMSS performance across countries on items relating to these areas suggests pupil readiness for learning these more complex concepts. The TIMSS results also suggest that gender appropriateness of contexts and situations used in teaching these topics should be addressed.

In the Geometric Shapes and Measures domain, the mixed performance of Irish pupils on Coordinates and the high relevance of the topic to everyday life suggest that this topic (and the related topic of describing movement between locations on plans and maps, etc.) should be introduced earlier in the mathematics curriculum. The mixed performance in this topic, and perhaps the "Trading Cards" items, reflects the influence of out of school experience on the learning of mathematics. There is a need to capitalise more on such experience in classroom teaching.

Another topic in this domain where mixed performance by Irish pupils was observed is that of symmetry and transformational geometry. Axial symmetry in the form of reflection is on the PSMC, but rotational symmetry is not. Many countries include both topics in their curriculum – as indicated in responses to the TIMSS Teacher Questionnaire. The PSMC is very specific in setting out what pupils in each grade level should learn. This level of detail and lack of practical contexts for the mathematics to be taught, though it may be beneficial for some aspects of curriculum and teaching, does not encourage teachers to use problem-based teaching in which mathematical concepts may be integrated and developed in applied or practical settings. There is a need for a repository of "good" tasks aligned with high quality professional development to support teachers in moving away from over-reliance on textbook activities. It is worth noting in this regard that approximately two-thirds of TIMSS assessment items are embedded in simple applied contexts.

Though Irish performance in mathematics on TIMSS 2011 at Fourth class can be considered to be satisfactory in general, there are some specific weaknesses which have been highlighted in this chapter. Addressing these weaknesses appropriately may not only help Irish pupils to demonstrate improvement in these areas in TIMSS 2015, but – more importantly – lead to a broader and deeper understanding of mathematics by Irish primary pupils than is currently found.

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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