



# An in-depth analysis of the relative strengths and weaknesses of students in Ireland in mathematics and science in **TIMSS 2019**

Gráinne McHugh, Aidan Clerkin,  
Rachel Cunningham and Rachel Perkins

EDUCATIONAL RESEARCH CENTRE 2024





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Foras Taighde ar  
**Oideachas**  
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# Acronyms and Abbreviations

|              |                                                                  |
|--------------|------------------------------------------------------------------|
| <b>NAMER</b> | National Assessments of Mathematics and English Reading          |
| <b>NCCA</b>  | National Council for Curriculum and Assessment                   |
| <b>PDST</b>  | Professional Development Service for Teachers (now part of Oide) |
| <b>PISA</b>  | Programme for International Student Assessment                   |
| <b>TCMA</b>  | Test-Curriculum Matching Analysis                                |
| <b>TIMSS</b> | Trends in International Mathematics and Science Study            |



# Chapter 1 - Introduction

This report is aimed at informing the work of teachers, school leaders, teacher educators, and curriculum developers in Ireland. It describes in detail the performance of Fourth Class (primary) and Second Year (post-primary) students<sup>1</sup> on a range of mathematics and science topics and test items. In interpreting the data presented here from the TIMSS 2019 study (the *Trends in International Mathematics and Science Study*), students' performance is discussed with reference to relevant aspects of the Irish curricula for mathematics and science, and to international comparisons of student performance.

The findings presented here build on the initial national report on TIMSS 2019 (Perkins & Clerkin, 2020), which described student performance in mathematics and science in terms of average achievement, distributions of achievement among higher- and lower-achieving students, gender differences, benchmarks of performance (Low, Intermediate, High, or Advanced), and high-level descriptions of performance on the TIMSS cognitive and content domains. This report expands on the latter aspect by providing a detailed examination of Fourth Class and Second Year students' performance on the TIMSS content domains and, in particular, on their constituent subdomains and topic areas.

## 1.1 TIMSS 2019 ASSESSMENT FRAMEWORK

The TIMSS 2019 Assessment Frameworks (Mullis & Martin, 2017) set out the structure and content of the TIMSS mathematics and science assessments which were administered to Grade 4 (in Ireland, Fourth Class) and Grade 8 (Second Year) students in 64 countries around the world. The frameworks describe the knowledge and skills that the assessment seeks to measure, and the extent of coverage of various content domains (for example, the proportion of the science assessment allocated to Biology or to Physics).

Both the TIMSS 2019 Mathematics Framework and the Science Framework encompass three cognitive domains: *Knowing*, *Applying*, and *Reasoning*. These cognitive dimensions are described in Mullis and Martin (2017; see also Perkins & Clerkin, 2020) but are not considered further here as the focus of this report is on the TIMSS content domains.

The content domains covered in Grade 4 mathematics are Number (comprising 50% of the assessment), Measurement & Geometry (30%), and Data (20%). At Grade 8, the corresponding domains are Number (30%), Algebra (30%), Geometry (20%), and Data & Probability (20%).

For science, the content domains assessed at Grade 4 are Life Science (45%), Physical Science (35%), and Earth Science (20%). The corresponding domains assessed at Grade 8 are Biology (35%), Physics (25%), Chemistry (20%), and Earth Science (20%). At both grades, Earth Science includes aspects such as geology and climate that may be taught outside science classes (e.g., as geography) in Ireland.

Perkins and Clerkin (2020) previously presented findings on student performance in Ireland, which was significantly above the TIMSS international average for both mathematics and science at both Fourth Class and Second Year. The performance of students in Ireland was notable both for the relatively strong performance of lower-achieving students in Ireland relative to lower-achieving

<sup>1</sup> In general, 'pupils' is the term used in this report when discussing children in Fourth Class (Grade 4) only, while 'students' is used when discussing young people attending Second Year (Grade 8) or when discussing both cohorts of young people together.

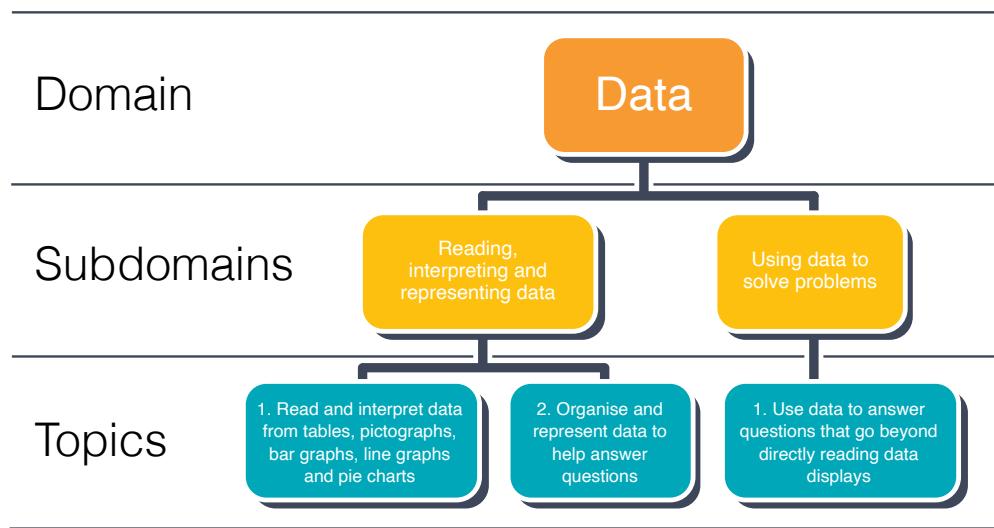
students in other countries with similar average levels of achievement, and also for the relative under-performance of higher-achieving students in Ireland (Perkins & Clerkin, 2020). This initial national report also presented patterns of relative strengths and weaknesses within Ireland for the high-level content domains, as shown in Table 1.1.

**Table 1.1: Summary of relative strengths and weaknesses in mathematics and science content domains (reproduced from Perkins & Clerkin, 2020)**

| Mathematics         |                                                  |                                | Science                                        |                                    |                                |                      |
|---------------------|--------------------------------------------------|--------------------------------|------------------------------------------------|------------------------------------|--------------------------------|----------------------|
|                     | Relative weakness                                | Similar to overall performance | Relative strength                              | Relative weakness                  | Similar to overall performance | Relative strength    |
| <b>Fourth Class</b> | <i>Measurement &amp; Geometry</i><br><i>Data</i> | -                              | <i>Number</i>                                  | <i>Physical Science</i>            | <i>Life Science</i>            | <i>Earth Science</i> |
| <b>Second Year</b>  | <i>Algebra</i><br><i>Geometry</i>                | -                              | <i>Number</i><br><i>Data &amp; Probability</i> | <i>Chemistry</i><br><i>Physics</i> | <i>Biology</i>                 | <i>Earth Science</i> |

However, the TIMSS 2019 Assessment Frameworks also specifies the content of the assessment at much more granular levels of detail than have previously been covered for Ireland. For example, the Grade 4 domain Data, as one part of the mathematics assessment at one grade level, can be further described in terms of two subdomains and three topics (Figure 1.1).

**Figure 1.1: Example of a Content Domain, Subdomains, and Topics (Grade 4, mathematics)**



The relevant subdomains and topics for each of the top-level content domains are described in further detail in the chapters that follow. Grade 4 mathematics is described in Chapter 2, with Grade 4 science in Chapter 3, Grade 8 mathematics in Chapter 4, and Grade 8 science in Chapter 5.

Throughout the report, for clarity of reading, we denote the different levels of analysis with the following stylistic presentation in text:

- **Domains** (such as Data in Figure 1.1) are presented with the first letter in all words capitalised.
- **Subdomains** (such as *Using data to solve problems* in Figure 1.1) are presented with the first letter capitalised and the entire subdomain name italicised.
- **Topics** (such as *organise and represent data to help answer questions* in Figure 1.1) are presented in grey font and italicised.

## 1.2 OVERVIEW OF THE CURRENT REPORT

The purpose of this report is to provide educators and policymakers in Ireland with a rich insight into the skills and knowledge that students in Ireland can demonstrate in two key areas of learning, mathematics and science, by drawing on the high-quality and nationally representative TIMSS data.

A similar exercise, at primary level only, was carried out over a decade ago following the administration of TIMSS 2011 in Ireland. Interested readers are referred to the chapters on mathematics (Close, 2013) and science (Murphy, 2013) which were presented at that point as part of a broader analysis of contextual data for Ireland (Eivers & Clerkin, 2013). The decade since those analyses has seen several noteworthy developments, including significant increases in observed performance at Fourth Class (Clerkin et al., 2016), the addition of detailed data on students' mathematics and science achievement at Second Year, which were unavailable in 2011 (Clerkin et al., 2016; Perkins & Clerkin, 2020), the introduction of a new Junior Cycle mathematics curriculum on a phased basis from September 2018<sup>2</sup>, and the development and introduction in September 2023 of a new primary mathematics curriculum (Department of Education, 2023; NCCA, 2022). In addition, in Ireland, performance in TIMSS has generally shown relatively consistent results from cycle to cycle (Clerkin et al., 2016; Eivers & Clerkin, 2012; Perkins & Clerkin, 2020) in terms of students' relative strengths and weaknesses across content areas. The current research aims to delve deeper into these content areas to identify, in more comprehensive and up-to-date detail, areas of relative strength and weakness within content areas to inform policy-making and subsequent teaching and learning.

It is therefore timely to re-assess in detail what can be learned about the mathematical and scientific skills and knowledge that pupils in Ireland can demonstrate at primary level, and to assess and report those skills for the first time at post-primary level, using TIMSS 2019 data. The findings of these analyses may be useful for providers of initial teacher education and teacher professional learning (or continuing professional development) in mathematics and science at both primary and Junior Cycle levels.

### *Interpreting the data in this report*

The analyses in the following chapters report percent correct scores for students in Ireland at all levels of the assessment (i.e., all of the mathematics and science content domains, subdomains, and topics), as well as a selection of individual items. A percent correct score is, simply, the percentage of students in Ireland answering each item (or an average for the items within a subdomain or topic) correctly.

2 <https://curriculumonline.ie/Junior-Cycle/Junior-Cycle-Subjects/Mathematics/>

Corresponding percent correct scores for the international average of the countries that administered TIMSS 2019 on paper (i.e., for *paperTIMSS* countries) are also calculated (Gonzalez, 2022).<sup>3</sup> In TIMSS 2019, about half of the participating countries, including Ireland, administered the assessment to students on paper, while the remainder administered the test in digital format (i.e., on computers or tablets) for the first time. As mode effects were found to be present in percent correct comparisons of scores between the two modes of administration (Fishbein et al., 2018) – that is, percent correct scores tended to differ slightly depending on whether the item was seen by a student on paper or on a digital device – the analyses and comparisons reported here are restricted only to the set of countries that administered TIMSS in the same mode as Ireland.<sup>4</sup> Where reference is made to the international average throughout this report, this refers to the average across the countries that administered the study on paper, and includes the score for Ireland.

Comparisons between the percent correct scores for Ireland and the international average are used as a benchmark to draw attention to areas where Fourth Class and Second Year students performed particularly strongly or less well within their strong overall performance on TIMSS 2019. For the purposes of this report, a subdomain or topic area where the percent correct score in Ireland fell below the international average – or those where Ireland's score was above but much closer to the international average compared to the difference observed at the overall content domain level – can be loosely considered areas where students in Ireland demonstrated a *relative weakness* (relative to their high overall performance compared to their peers internationally). Similarly, a subdomain or topic where students in Ireland demonstrated a larger advantage over their international peers than was found at the higher (e.g. domain) level can be loosely considered an area of *relative strength*.

These labels are not intended to be read definitively; rather, they are intended primarily to provoke reflection and consideration among educators and policymakers in Ireland by identifying areas of particular interest within the relatively strong overall performance of students in Ireland on the TIMSS international assessment. These comparisons are informed by the percent correct scores observed among students in Ireland and internationally but, following the descriptions above, the judgements of which areas are described as showing relative strength or weakness in Ireland also involve an element of subjectivity. Comparisons of Ireland's percent correct scores against the international average are used here as a tool to illustrate where differences between the performance of students in Ireland and other countries diverged in interesting or informative ways from the overall patterns. However, it should be noted that percent correct scores are a more limited indicator in some ways compared to the scale scores that are more commonly used for reporting the outcomes of TIMSS as, for example, the percent correct scores do not account for differences in the level of difficulty across the range of items. For this reason, scale scores should still be used when interpreting higher-level outcomes of TIMSS, such as those reported by Perkins and Clerkin (2020) and Mullis et al. (2020).

<sup>3</sup> 28 countries administered TIMSS 2019 on paper at Grade 4: Albania, Armenia, Australia, Azerbaijan, Bahrain, Belgium (Flemish), Bosnia and Herzegovina, Bulgaria, Cyprus, Iran, Ireland, Japan, Kazakhstan, Kosovo, Kuwait, Latvia, Montenegro, Morocco, New Zealand, North Macedonia, Northern Ireland, Oman, Pakistan, Philippines, Poland, Saudi Arabia, Serbia, and South Africa. 17 countries administered TIMSS 2019 on paper at Grade 8: Australia, Bahrain, Cyprus, Egypt, Iran, Ireland, Japan, Jordan, Kazakhstan, Kuwait, Lebanon, Morocco, New Zealand, Oman, Romania, Saudi Arabia, and South Africa.

<sup>4</sup> These mode effects were accounted for at the international level in subsequent statistical scaling of the data, which produced the scale scores (rather than percent correct scores) that are reported in Perkins and Clerkin (2020) and other international publications on TIMSS 2019.

## Presentation of released TIMSS items

Selected released items from the 2019 assessment are reproduced with permission<sup>5</sup> so that readers of this report can get a sense of what students see when they are taking the TIMSS assessment. These items are presented to illustrate particular areas of (relative) weakness in performance or to highlight items from the assessment that were unusually difficult or otherwise of interest with regard to students in Ireland. For each of these items, several additional points of information are provided:

- The item subdomain and topic.
- A short description of the item content.
- The TIMSS International Benchmark (Low, Intermediate, High or Advanced) corresponding to the difficulty level of the item.<sup>6</sup> More difficult items are associated with higher Benchmark levels.
- The percent correct score for Ireland.
- The percent correct score at the international average (*paper* TIMSS countries).

Where relevant, reference will be made to the findings of a Test-Curriculum Matching Analysis (TCMA) which was carried out by subject experts, who examined each item individually, to assess the extent to which students in Ireland would be expected (based on the curriculum) to have been familiar with the content assessed in TIMSS.<sup>7</sup>

## Understanding TIMSS performance in the Irish context

To aid readers in interpreting the data presented in this report, we include tables for each content domain that draws linkages between specific elements of the TIMSS Assessment Frameworks and the closest corresponding elements of the mathematics and science curricula in Ireland. These tables make clear comparisons between the structure and content of the TIMSS Assessment Frameworks (domains, subdomains, topics) and the corresponding strands and topics in the Fourth Class and Junior Cycle (for Second Year) mathematics and science curricula in Ireland. (The mathematics specifications for Fourth Class are specific to Fourth Class, whereas the science specifications refer to Third/Fourth Class together.)

In addition, responses from the TIMSS Teacher Questionnaire are included, where relevant, which provide teachers' reports of whether particular topics had been taught to their Fourth Class or Second Year students mostly before the year of the assessment, mostly during that year, or if they had not yet been taught or were just introduced. Including teachers' reports of their classroom practice in this way adds a valuable perspective against which to interpret the intended content of the Irish curriculum.

5 Following the completion of a study cycle, a subset of the items used in the assessment are made available for release as they are replaced by newer items for subsequent cycles of TIMSS. Permission to report these items from the 2019 cycle was granted by the IEA (International Association for the Evaluation of Educational Achievement), the international body that sponsors TIMSS.

6 Items were classified internationally as being indicative of a particular Benchmark on the basis of a classification exercise conducted by Boston College which distinguished items that were likely to be answered correctly by a student reaching a certain Benchmark (e.g., Intermediate), but not lower Benchmarks (e.g., Low), from items that were likely to be answered correctly only by students reaching a higher Benchmark (e.g., High). For example, an item 'anchored at' the Intermediate Benchmark (475 points) is one that at least 65% of students with scores between 470-480 answered correctly and that fewer than 50% of students at the Low Benchmark answered correctly. For more on these classifications, readers are referred to Mullis and Fishbein (2020). For more on interpreting the Benchmarks generally, please see Chapter 5 of Perkins and Clerkin (2020).

7 The results of the TCMA are described in more detail in Chapter 8 of Perkins and Clerkin (2020).

These additional pieces of contextual information are particularly helpful for Second Year mathematics and science (Chapter 3 and Chapter 5) given that the curriculum for Junior Cycle covers the span from First Year to Third Year, whereas students participating in TIMSS are assessed partway through that cycle near the end of Second Year. These analyses add further valuable nuance to the interpretation of the TIMSS data by identifying areas of overlap between the Irish curricula and the international assessment, aspects that appear only on the Irish curricula but not in TIMSS, and aspects that appear in TIMSS but not on the curricula as well as possible gaps between the intended Irish curricula on paper and what actually occurs in classroom practice as informed by teachers' perspectives.

Next, Chapters 2-5 present findings from the subdomain-, topic-, and item-level analyses of TIMSS mathematics and science data for Fourth Class and Second Year. The final chapter, Chapter 6, draws together the main insights and conclusions of the analysis, and presents discussion of these findings aimed at educators and policymakers in Ireland.

Readers are reminded that the international comparisons in this report differ from those presented in the initial national report for TIMSS 2019 (Perkins & Clerkin, 2020) and other TIMSS 2019 reporting, as the analyses shown here are restricted only to the set of countries that administered TIMSS 2019 in the same mode as Ireland – i.e., on paper. This means that references to the ***international average*** in this report refer to *the average across the countries that administered the study on paper*, and include the score for Ireland. Footnote 3 (p.4) provides the full list of *paper*TIMSS countries at both grade levels.

Where differences between the percent correct scores of Ireland and the international average are described as being ***(statistically) significant***, this indicates that a statistical test has been carried out and that the probability of magnitude of that difference being observed by chance is less than 5%. Nonetheless, readers are reminded that a statistically significant difference may not be significant in the everyday sense (i.e., not all statistically significant differences are meaningful or important).

Throughout this report, we provide information on the ***relative performance of boys and girls in Ireland in mathematics and science***. In most cases, the differences between boys and girls are very small (often ranging from less than one to three percentage points, sometimes in favour of boys and sometimes in favour of girls) and should be interpreted with some caution.

Additional statistical detail on the data provided in figures, tables, and in text in this report is available from the accompanying e-appendix: <https://doi.org/10.70092/2091319.0724>

# Chapter 2 - Fourth Class Mathematics

## 2.1 INTRODUCTION

As outlined in Chapter 1, the TIMSS mathematics assessment has three content domains at Grade 4 (in Ireland, Fourth Class): Number, Measurement & Geometry, and Data. Each of the content domains contributes a different proportion of the assessment, which are outlined in detail in the TIMSS 2019 Assessment Framework (Mullis & Martin, 2017). Number was planned to account for half of the mathematics assessment (50%) as it is seen as providing the foundation of mathematics in primary school (Mullins & Martin, 2017), while Measurement & Geometry was planned to account for 30% of the assessment and Data for the remaining 20%. Perkins and Clerkin (2020) reported that the final distribution of items across the three content domains (Number, Measurement & Geometry and Data) were similar to these planned distributions at 47%, 31% and 23% respectively.

The content domains differ somewhat between Grade 4 and Grade 8 to reflect the mathematics widely taught at each level across the range of TIMSS countries. At Grade 4, Algebra content is included as part of Number while at Grade 8 it is a separate content domain. Measurement & Geometry is a content domain for Grade 4, but the corresponding domain at Grade 8 is Geometry. However, it is important to note that the Grade 8 domain of Geometry also includes measurements, such as area and volume. Finally, the Data domain at Grade 4 does not include any probability, while the content domain is framed as Data & Probability for Grade 8.

This chapter presents the percent correct scores at the content domain, subdomain and topic levels for Ireland, and on average internationally, for Grade 4. Comparisons to the international average for each topic and subdomain are used as a basis for identifying areas of relative strength and weakness in Ireland because, as noted in Chapter 1, percent correct scores do not take relative item difficulty across topics or subdomains into consideration.

As part of the Teacher Questionnaire, teachers were asked to indicate whether various concepts were *mostly taught before this year*, *mostly taught this year*, or *not yet taught or just introduced*. The contextual information collected from teachers is used for further interpretation of the findings. It should be noted that the wording of the concepts in the Teacher Questionnaire and the subdomains or topics in the Assessment Framework are not identical, but are generally broadly similar. For example, one set of concepts listed in the Teacher Questionnaire is “adding, subtracting, multiplying and dividing with whole numbers” which corresponds to two topics within the assessment framework: *add or subtract (up to 4-digit numbers), including computation in simple contextual problems* and *multiply (up to 3-digit by 1-digit and 2-digit by 2-digit numbers) and divide (up to 3-digit by 1-digit numbers), including computation in simple contextual problems*.

Released items are also presented for each subdomain (one item per subdomain). This is to provide examples of the types of items used in TIMSS. Items are classified as being indicative of the *Low International Benchmark (400)*, the *Intermediate International Benchmark (475)*, the *High International Benchmark (550)*, the *Advanced International Benchmark (625)*, or as being *Above the Advanced International Benchmark (625+)*. Table 2.1 below is adapted from Exhibit 1.7 in the TIMSS 2019 International Report (Mullis et al., 2020) and summarises what Grade 4 pupils who reached each of the International Benchmarks can do in mathematics.

**Table 2.1: Summary of the TIMSS 2019 International Benchmarks of Grade 4 Mathematics Achievement (adapted from Mullis et al., 2020)**

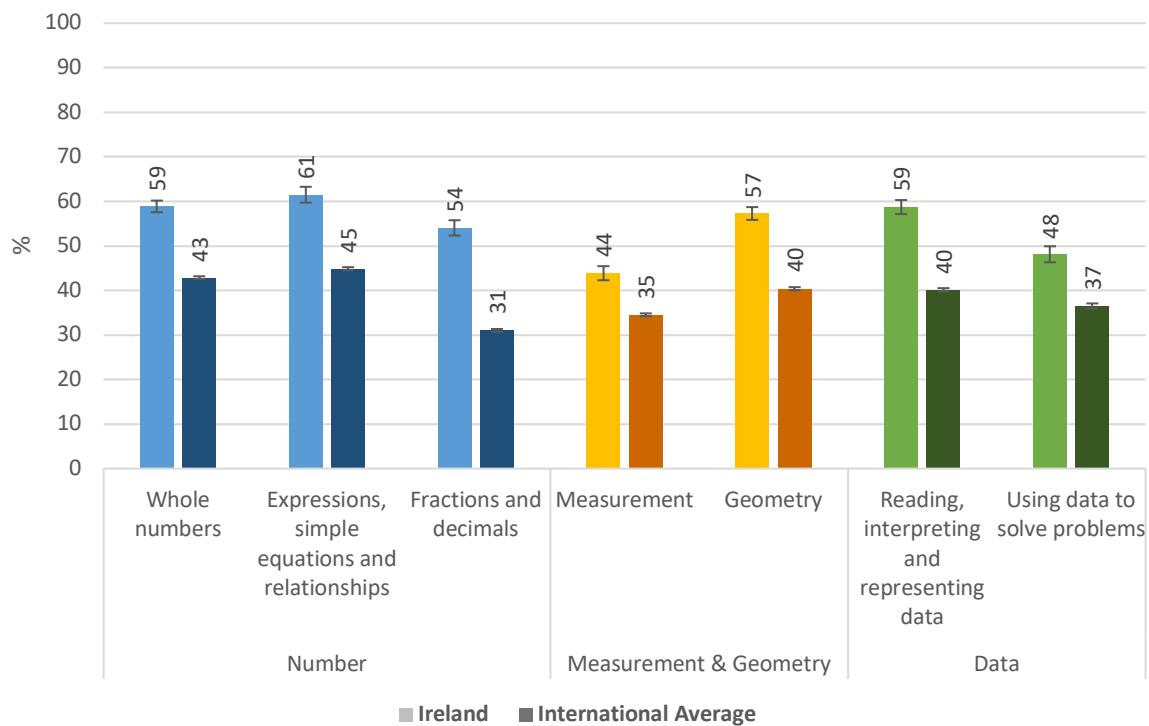
| International Benchmarks                    | Scale Score | Summary                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|---------------------------------------------|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Advanced International Benchmark</b>     | <b>625</b>  | Pupils can apply their understanding and knowledge in a variety of relatively complex situations and explain their reasoning. Pupils can solve a variety of multistep word problems involving whole numbers and show an understanding of fractions and decimals. They can apply knowledge of two- and three-dimensional shapes in a variety of situations. Pupils can interpret and represent data to solve multistep problems.                                                                        |
| <b>High International Benchmark</b>         | <b>550</b>  | Pupils apply conceptual understanding to solve problems. They can apply conceptual understanding of whole numbers to solve two-step word problems. They show understanding of the number line, multiples, factors, and rounding numbers, and operations with fractions and decimals. Pupils can solve simple measurement problems. They demonstrate understanding of geometric properties of shapes and angles. Pupils can interpret and use data in tables and a variety of graphs to solve problems. |
| <b>Intermediate International Benchmark</b> | <b>475</b>  | Pupils can apply basic mathematical knowledge in simple situations. They can compute with three- and four-digit whole numbers in a variety of situations. They have some understanding of decimals and fractions. Pupils can identify and draw shapes with simple properties. They can read, label, and interpret information in graphs and tables.                                                                                                                                                    |
| <b>Low International Benchmark</b>          | <b>400</b>  | Pupils have some basic mathematical knowledge. They can add, subtract, multiply, and divide one- and two-digit whole numbers. They can solve simple word problems. They have some knowledge of simple fractions and common geometric shapes. Pupils can read and complete simple bar graphs and tables.                                                                                                                                                                                                |

For each of the content domains (Number, Measurement & Geometry, and Data), Ireland was above the international average among the 17 countries that participated in *paperTIMSS* and the 11 countries that participated in *paperTIMSS Less Difficult*<sup>8</sup> (Appendix Table F.1, Mullis et al., 2020).

Figure 2.1 presents the percent correct score of each of the subdomains in Ireland (lighter bars) and internationally (darker bars). In each of these subdomains, Ireland's percent correct score was significantly above the average for the 28 countries<sup>9</sup> (Appendix Table A2.1).

<sup>8</sup> Introduced in the 2015 cycle, *TIMSS less difficult* is a less difficult mathematics assessment at Grade 4. The purpose of including less difficult items was to extend the TIMSS mathematics scale at Grade 4 to improve the measurement at the lower end of the scale (Mullins et al., 2017).

<sup>9</sup> Albania, Armenia, Australia, Azerbaijan, Bahrain, Belgium (Flemish), Bosnia and Herzegovina, Bulgaria, Cyprus, Iran, Ireland, Japan, Kazakhstan, Kosovo, Kuwait, Latvia, Montenegro, Morocco, Oman, New Zealand, North Macedonia, Northern Ireland, Pakistan, Philippines, Poland, Saudi Arabia, Serbia, and South Africa.

**Figure 2.1: Percent correct scores by subdomain in Ireland and on average internationally**

See Appendix Table A2.1.

Note. Due to rounding, some differences may appear inconsistent with those reported in text.

Number is made up of three subdomains: *Whole numbers*; *Expressions, simple equations and relationships*; and *Fractions and decimals*. As noted above, comparisons between Ireland and the international average are used as a benchmark for highlighting areas of relative strength and weakness. Applying this here, within Number, *Fractions and decimals* was found to be an area of relative strength in Ireland as the difference between Ireland and the international average was larger than at the domain level (these differences, and those for the other content domains, are discussed further below).

Measurement & Geometry has two subdomains, *Measurement* and *Geometry*. *Measurement* was an area where Ireland performed relatively less well, as the difference between Ireland and the international average was nine percentage points, which is a smaller difference than that observed for *Geometry* (17 percentage points).

Data has two subdomains: *Reading, interpreting and representing data* and *Using data to solve problems*. There was a difference of 12 percentage points between Ireland and the international average for *Using data to solve problems*, indicating that this was an area of relative weakness for Ireland in comparison to the other subdomain (*Reading, interpreting and representing data*) where Ireland had an advantage of 19 percentage points.

The following sections describe the patterns of performance within each content domain for Ireland in more detail, and how the TIMSS subdomains relate to the primary school curriculum in Ireland. Examples of TIMSS items are also presented to illustrate how the subdomains and topic areas are assessed in TIMSS.

## 2.2 NUMBER

In TIMSS 2019, Number accounted for almost half of the items. At Grade 4, this content domain includes pre-algebra topics while, at Grade 8, Algebra is a separate domain.

Table 2.2 presents the connections between the Fourth Class 1999 primary school mathematics curriculum and the Number content domain within the TIMSS Framework.<sup>10</sup> Within the TIMSS Framework, the content domain of Number relates to both the Number and Algebra strands in the Fourth Class curriculum. All areas of the TIMSS Framework for Grade 4 mathematics link with an aspect of the Irish curriculum.

**Table 2.2: Primary School Curriculum: Mathematics (Department of Education and Science, 1999b) linked to TIMSS 2019 Framework**

|        | Fourth Class Curriculum: Number and Algebra                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | TIMSS Framework                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|--------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Number | <p><b>Place Value</b></p> <ul style="list-style-type: none"> <li>Explore and identify place value in whole numbers 0-9999.</li> <li>Read, write and order four-digit numbers and solve simple problems</li> <li>Round whole numbers to the nearest thousand</li> <li>Explore and identify place value in decimal numbers to two places of decimals</li> </ul> <p><b>Operations</b></p> <p><i>Addition and Subtraction</i></p> <ul style="list-style-type: none"> <li>Add and subtract, without and with renaming, within 9999</li> <li>Know and recall addition and subtraction facts</li> <li>Solve word problems involving addition and subtraction</li> </ul> <p><i>Multiplication</i></p> <ul style="list-style-type: none"> <li>Develop an understanding of multiplication as repeated addition and vice versa</li> <li>Explore, understand and apply the zero, commutative, distributive and associative properties of multiplication</li> <li>Develop and recall multiplication facts within 100</li> <li>Multiply a two-digit or three-digit number by a one or two-digit number</li> <li>Use a calculator to check estimates</li> <li>Solve and complete practical tasks and problems involving multiplication of whole numbers</li> </ul> <p><i>Division</i></p> <ul style="list-style-type: none"> <li>Develop an understanding of division as sharing and as repeated subtraction without and with remainders</li> <li>Develop and/or recall division facts within 100</li> <li>Divide a three-digit number by a one-digit number without and with remainders</li> <li>Use calculator to check estimates</li> <li>Solve and complete practical tasks and problems involving division of whole numbers</li> </ul> | <p><b>Whole Numbers</b></p> <p><b>1.</b> Demonstrate knowledge of place value (2-digit to 6-digit numbers); represent whole numbers with words, diagrams, number lines, or symbols; order numbers.</p> <p><b>Whole Numbers</b></p> <p><b>2.</b> Add and subtract (up to 4-digit numbers), including computation in simple contextual problems</p> <p><b>3.</b> Multiply (up to 3-digit by 1-digit and 2-digit by 2-digit numbers) and divide (up to 3-digit by 1-digit numbers), including computation in simple contextual problems.</p> <p><b>4.</b> Solve problems involving odd and even numbers, multiples and factors of numbers, rounding numbers (up to nearest ten thousand) and making estimates.</p> <p><b>5.</b> Combine two or more properties of numbers or operations to solve problems in context.</p> |

<sup>10</sup> Pupils who completed the TIMSS assessment in 2019 engaged with the 1999 Primary School Curriculum: Mathematics (Department of Education and Science, 1999b).

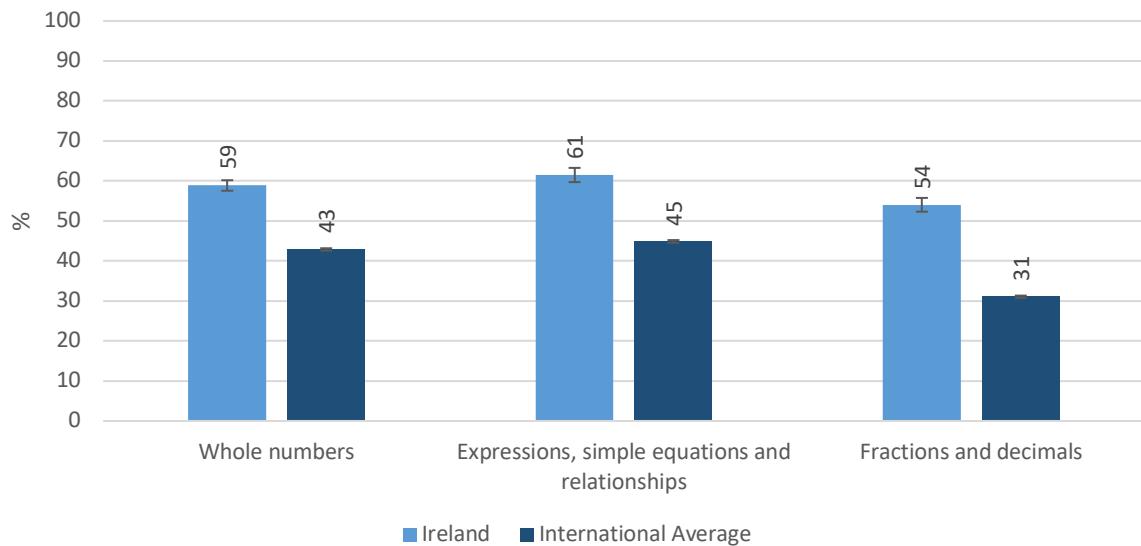
|               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|---------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Number</b> | <p><b>Fractions</b></p> <ul style="list-style-type: none"> <li>Identify fractions and equivalent forms of fractions with denominators 2, 3, 4, 5, 6, 8, 9, 10 and 12</li> <li>Compare and order fractions with appropriate denominators and position on the number line</li> <li>Calculate a fraction of a set using concrete materials</li> <li>Calculate a number given a multiple fraction of the number</li> <li>Express one number as a fraction of another number</li> <li>Solve and complete practical tasks and problems involving fractions</li> </ul> <p><b>Decimals</b></p> <ul style="list-style-type: none"> <li>Express tenths and hundredths as fractions &amp; decimals</li> <li>Identify place value of whole numbers and decimals to two places and write in expanded form</li> <li>Order decimals on the number line</li> <li>Add and subtract whole numbers and decimals up to two places</li> <li>Multiply and divide a decimal number up to two places by a single-digit whole number</li> <li>Solve problems involving decimals</li> </ul> | <p><b>Fractions &amp; decimals</b></p> <p>1. Recognise fractions as parts of wholes or collections; represent fractions using words, numbers or models; compare and order simple fractions; add and subtract simple fractions, including those set in problem situations (fractions may have denominators of 2,3,4,5,6,8,10,12 or 100.)</p> <p><b>Fractions &amp; decimals</b></p> <p>2. Demonstrate knowledge of decimal place value including representing decimals using words, numbers or models; compare, order and round decimals; add and subtract decimals, including those set in problem situations. (Decimals may have one or two decimal places, allowing for computations with money.)</p> |
|               | <p><b>Number patterns and sequences</b></p> <ul style="list-style-type: none"> <li>Explore, recognise, and record patterns in number, 0-9999</li> <li>Explore, extend, and describe sequences</li> <li>Use patterns as an aid in the memorisation of number facts</li> </ul> <p><b>Number sentences</b></p> <ul style="list-style-type: none"> <li>Translate an addition, subtraction, multiplication, or division number sentence with a frame into a word problem</li> <li>Translate a one-step word problem into a number sentence</li> <li>Solve one-step number sentences</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <p><b>Expressions, Simple Equations and Relationships</b></p> <p>3. Identify and use relationships in a well-defined pattern (e.g., describe the relationship between adjacent terms and generate pairs of whole numbers given a rule).</p> <p><b>Expressions, Simple Equations and Relationships</b></p> <p>1. Find the missing number or operation in a number sentence (e.g., <math>17 + w = 29</math>).</p> <p>2. Identify or write expressions or number sentences to represent problem situations that may involve unknowns.</p>                                                                                                                                                                  |

While Figure 2.1 presented the percent correct scores for each of the subdomains, Figure 2.2 presents a closer focus on the percent correct scores for the subdomains of Number only. As shown, Ireland performed significantly above the international average in each of the subdomains with differences of 23 percentage points for *Fractions and decimals*, 17 percentage points for *Expressions, simple equations and relationships*, and 16 percentage points for *Whole numbers* (Appendix Table A2.1). As previously mentioned, this indicates that *Fractions and decimals* was an area of relative strength for Ireland within Number. Boys had a slightly higher percent correct score than girls for *Fractions and decimals* (by 4%) and *Expressions, simple equations, and relationships* (by 2%) (Appendix Table A2.2). However, it should be noted that there were no significant gender differences in Number or in any of the content domains in Ireland (Perkins & Clerkin, 2020).

Looking at the concepts relating to Number in the Teacher Questionnaire, teachers reported that in almost all cases more than 90% of pupils had been taught the topics either before Fourth Class or

during Fourth Class (Appendix Table A2.6). The only exception to this related to concepts of fractions (e.g., comparing and ordering, adding and subtracting simple fractions), where 14% of pupils had not yet been taught or had just been introduced to the topic.

**Figure 2.2: Percent correct score for the subdomains of Number in Ireland and on average internationally**



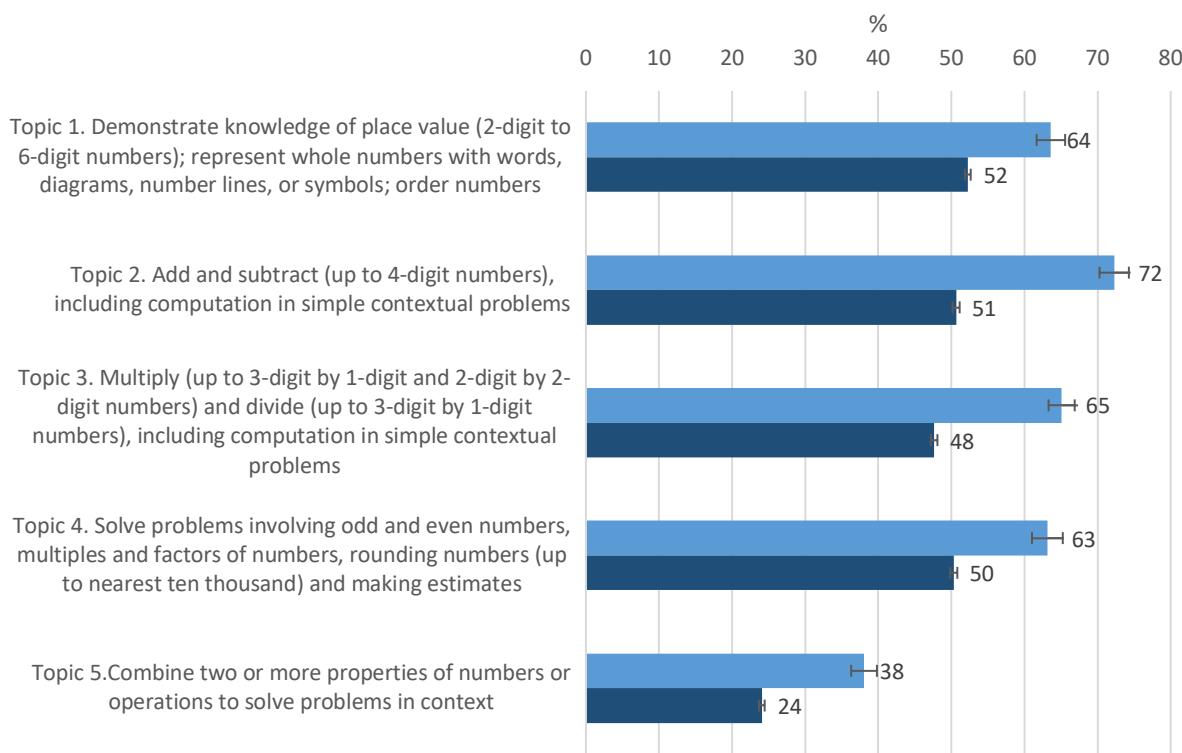
See Appendix Table A2.1.

*Note.* The figure is an amended version of Figure 2.1 with only the subdomains of Number represented. Due to rounding, some differences may appear inconsistent with those reported in text.

### Number Subdomain 1: Whole Numbers

The first subdomain of *Whole numbers* includes five topics. Looking at the curriculum in Ireland, each of the topics of *Whole numbers* relate to the strand units of 'place value' and 'operations' within the Number strand of the curriculum. Figure 2.3 presents the percent correct score at the topic level in Ireland and on average internationally. Comparing Ireland with the international average, the largest difference was for Topic 2 and the smallest difference for Topic 1. The fifth and final topic had the largest gender difference in Ireland, as boys had a percent correct score which was 6% higher than girls. In the other topics, there were small gender differences, no greater than 2% (Appendix Table A2.4).

**Figure 2.3: Percent correct scores at the topic level for the subdomain *Whole numbers* in Ireland and on average internationally**



See Appendix Table A2.3.

*Note.* Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

As previously mentioned in Chapter 1, selected items are released after each cycle of TIMSS. Table 2.3 presents a released item relating to *Whole numbers*. This item related to Topic 5 (*combine two or more properties of numbers or operations to solve problems in context*), for which pupils both in Ireland and internationally had the lowest percent correct score. This released item was categorised as *Above the Advanced International Benchmark (625+)*. In this item, Ireland (12%) scored significantly below the international average (15%).

This question asks pupils to solve a multi-step word problem involving unit price. Pupils need to use the information provided in the question to find the cost of the items together and one separately. Pupils are presented with two statements about the cost of a mixture of bananas and plums. From this, pupils are asked to work out the cost of a banana and plum and subsequently, a plum on its own. While this item is categorised under the subdomain of *Whole numbers*, it should be noted that some pupils may have used algebraic methods as part of their solution strategy.

**Table 2.3: Released item for *Whole numbers***

|                       |                                                                                      |                           |
|-----------------------|--------------------------------------------------------------------------------------|---------------------------|
| Whole numbers         | Combine two or more properties of numbers or operations to solve problems in context |                           |
| Item Description      | Solves a multi-step word problem involving unit price                                |                           |
| Benchmark             | Item Above Advanced International Benchmark (625+)                                   |                           |
| Percent Correct Score | Ireland 12%                                                                          | International Average 15% |
| Reason for Inclusion  | Ireland significantly lower than international average                               |                           |



How much do a and a cost together?

Answer: \_\_\_\_\_ zeds

How much does a cost?

Answer: \_\_\_\_\_ zeds

**Solutions:** A. 9

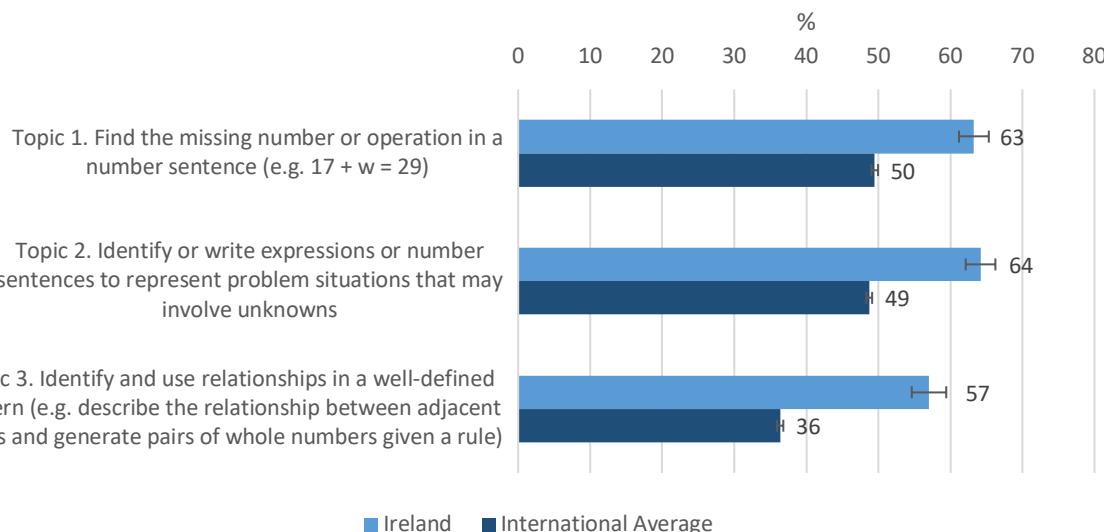
**B. 2**

See Appendix Table A2.5

### **Number Subdomain 2: Expressions, Simple Equations and Relationships**

The second subdomain within Number for Fourth Class is *Expressions, simple equations and relationships*. This includes three topics, as listed in Figure 2.4 below. Each of these topics relate to the Algebra strand in the 1999 curriculum. Comparing Ireland and the international average, Figure 2.4 shows that Topic 3 was a topic of relative strength within this subdomain as the difference between the percent correct score in Ireland and on average internationally is greater than for the other topics in this subdomain. In terms of gender differences in Ireland, there was a difference of four percentage points in favour of girls for Topic 3, while boys had a higher score by two percentage points for the other two topics (Appendix Table A2.4).

**Figure 2.4: Percent correct scores by topic for the subdomain *Expressions, simple equations and relationships* in Ireland and on average internationally**



See Appendix Table A2.3

*Note.* Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

A released item is presented in Table 2.4 which relates to Topic 2 (*identify or write expressions or number sentences to represent problem situations that may involve unknowns*). This topic relates to the strand unit of 'number sentences' within the strand of Algebra in the Fourth Class mathematics curriculum.

In this question, pupils are presented with a word problem and are asked to choose which option best represents the situation. This involves the translation of a word problem into a number sentence. Pupils are asked to choose from four answer options. They must understand the use of brackets and the order of operations. Over three-fifths (61%) of pupils in Ireland answered this item correctly, which was significantly higher than on average internationally (55%). Regarding the incorrect responses, over 15% of pupils chose (b) which may indicate that some pupils did not understand that both people are adding to the same tank. Over 12% chose (a) and less than 10% chose option (c).

**Table 2.4: Released Item for *Expressions, simple equations and relationships***

|                                                 |                                                                                                             |                            |
|-------------------------------------------------|-------------------------------------------------------------------------------------------------------------|----------------------------|
| Expressions, simple equations and relationships | Identify or write expressions or number sentences to represent problem situations that may involve unknowns |                            |
| Item Description                                | Identify an expression that represents a situation                                                          |                            |
| Benchmark                                       | Item at High International Benchmark (550)                                                                  |                            |
| Percent Correct Score                           | Ireland: 61%                                                                                                | International Average: 55% |
| Reason for Inclusion                            | Word problem with multiple-choice answers                                                                   |                            |

There were 12 litres of water in the tank.

Ravi then poured 3 litres of water into the tank and Indira poured another 3 litres of water into the tank.



How can the amount of water in the tank be calculated?

- (a)  $12 + (2 + 3)$
- (b)  $(12 + 3) + (12 + 3)$
- (c)  $(12 + 2) \times 3$
- (d)  $12 + (2 \times 3)$

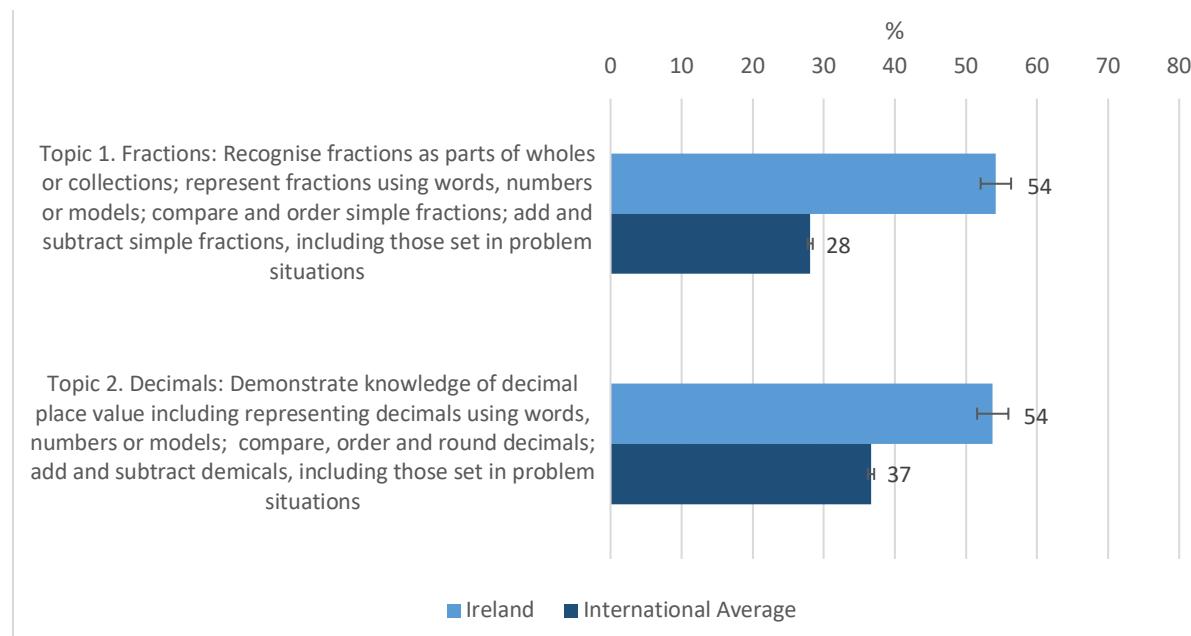
**Solution: (d)  $12 + (2 \times 3)$**

See Appendix Table A2.5

### Number Subdomain 3: Fractions and Decimals

The final subdomain within Number is *Fractions and decimals*. Each of the topics in this subdomain relate to the strand units on ‘fractions’ and ‘decimals’ within the strand of Number of the Fourth Class mathematics curriculum.

Figure 2.5 presents the two topics which make up *Fractions and decimals* and their respective percent correct scores in Ireland and internationally. Pupils in Ireland achieved scores that were 26 percentage points higher than the international average for the first topic, *fractions*, and 17 percentage points higher for the second topic, *decimals*. The topic of *fractions* therefore appears to be one where Ireland performed particularly well in comparison to the international average. Boys achieved percent correct scores that were four percentage points higher than girls for both topics (Appendix Table A2.4).

**Figure 2.5: Percent correct scores by topic for the subdomain *Fractions and decimals***

See Appendix Table A2.3.

*Note.* Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

Table 2.5 presents a released item which relates to Topic 1 (*fractions*) in Figure 2.5. This item relates to the ‘fractions’ strand unit within the Number strand of the Fourth Class mathematics curriculum. Two-fifths of pupils (40%) in Ireland answered this question correctly. This was above the average internationally (32%). This item was categorised as at the *Advanced International Benchmark* (625). It requires pupils to recognise that they will need to add three quarters (or nine squares) to complete the chocolate bar. For a correct response, pupils must draw a rectangle which is  $2 \times 6$  units or  $3 \times 4$  units (in either orientation).

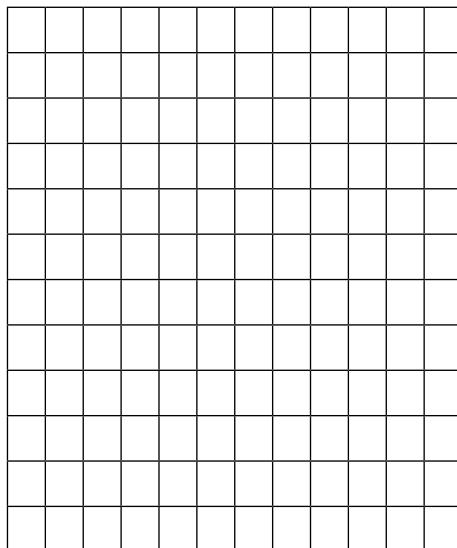
**Table 2.5: Released Item for *Fractions and decimals***

|                        |                                                                                                                                                                                                                                                                                                     |
|------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Fractions and decimals | Recognise fractions as parts of wholes or collections; represent fractions using words, numbers, or models; compare and order simple fractions; add and subtract simple fractions, including those set in problem situations. (Fractions may have denominators of 2, 3, 4, 5, 6, 8, 10, 12 or 100.) |
| Item Description       | Draws a complete shape on a grid given a picture of a fraction of the shape                                                                                                                                                                                                                         |
| Benchmark              | Item at Advanced International Benchmark (625)                                                                                                                                                                                                                                                      |
| Percent Correct Score  | Ireland: 40%      International Average: 32%                                                                                                                                                                                                                                                        |
| Reason for Inclusion   | Fractions was an area of relative strength for Ireland                                                                                                                                                                                                                                              |

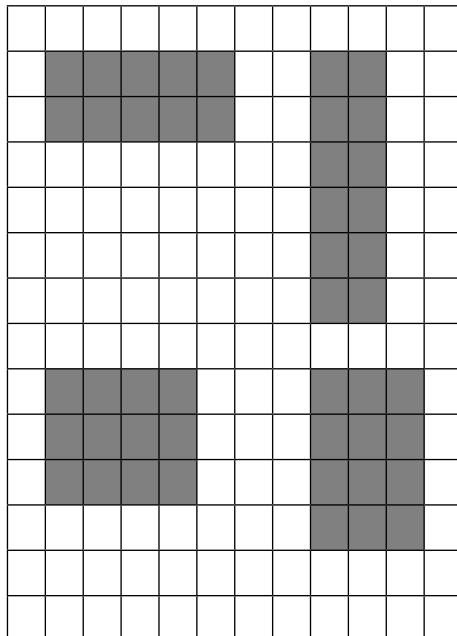
A chocolate bar is in the shape of a rectangle. One-quarter of it is shown below.



Draw the complete chocolate bar on the grid.



**Solution: Rectangle: 2 X 6 or 3 X 4**



See Appendix Table A2.5

## 2.3 MEASUREMENT & GEOMETRY

In TIMSS 2019, the Measurement & Geometry domain accounted for approximately one-third of the items. Table 2.6 presents the linking of the Fourth Class primary school mathematics curriculum to the Measurement & Geometry content domain of the TIMSS framework. Measurement & Geometry is made up of two subdomains – *Measurement* and *Geometry*. Table 2.6 shows that the subdomain of *Geometry* links to the Shape & Space strand in the curriculum, while *Measurement* links to Measures. All aspects of the TIMSS Measurement & Geometry domain can be linked to these elements of the curriculum.

**Table 2.6: Primary School Curriculum: Mathematics (Department of Education and Science, 1999b) linked to TIMSS 2019 Framework**

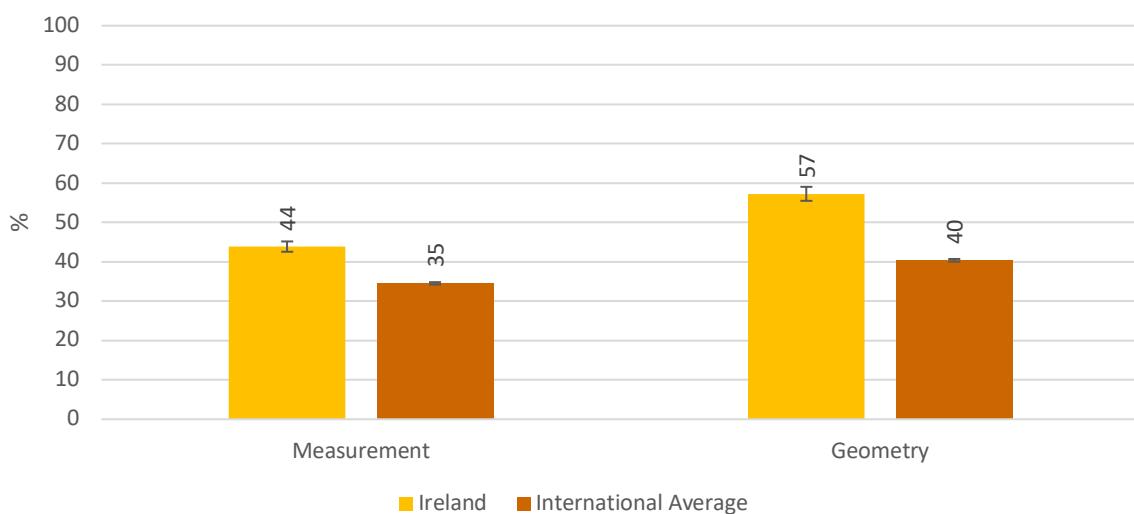
|                 | Fourth Class Curriculum: Shape and Space & Measures                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | TIMSS Framework                                                                                                                                                                                                                                                                           |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Shape and Space | <p><b>2-D Shapes</b></p> <ul style="list-style-type: none"> <li>Identify, describe and classify 2-D shapes: equilateral, isosceles and scalene triangles, parallelogram, rhombus, pentagon, octagon</li> <li>Explore, describe and compare the properties (sides, angles, parallel and non-parallel lines) of 2-D shapes</li> <li>Construct and draw 2-D shapes</li> <li>Combine, tessellate and make patterns with 2-D shapes</li> <li>Identify the use of 2-D shapes in the environment</li> <li>Solve and complete practical tasks and problems using 2-D shapes</li> </ul> | <p><b>Geometry</b></p> <p><b>2.</b> Use elementary properties, including line and rotational symmetry to describe, compare and create common 2-D shapes</p>                                                                                                                               |
|                 | <p><b>3-D Shapes</b></p> <ul style="list-style-type: none"> <li>Identify, describe and classify 3-D shapes including cube, cuboid, cylinder, cone, sphere, triangular prism, pyramid</li> <li>Establish and appreciate that when prisms are sliced through (in the same direction) each face is equal in shape and size</li> <li>Explore and describe the relationship of 3-D shapes with constituent 2-D shapes</li> <li>Construct 3-D shapes</li> <li>Solve and complete practical tasks and problems involving 2-D and 3-D shapes</li> </ul>                                | <p><b>Geometry</b></p> <p><b>3.</b> Use elementary properties to describe and compare 3-D shapes and relate these with their 2-D representations</p>                                                                                                                                      |
|                 | <p><b>Symmetry</b></p> <ul style="list-style-type: none"> <li>Identify line symmetry in the environment</li> <li>Identify lines of symmetry as horizontal, vertical or diagonal</li> <li>Use understanding of line symmetry to complete missing half of a shape, picture or pattern</li> </ul>                                                                                                                                                                                                                                                                                 | <p><b>Geometry</b></p> <p><b>2.</b> Use elementary properties, including line and rotational symmetry to describe, compare and create common 2-D shapes</p> <p><b>3.</b> Use elementary properties to describe and compare 3-D shapes and relate these with their 2-D representations</p> |
|                 | <p><b>Lines and angles</b></p> <ul style="list-style-type: none"> <li>Identify, describe and classify oblique and perpendicular lines</li> <li>Draw, discuss and describe intersecting lines and their angles</li> <li>Classify angles as greater than, less than or equal to a right angle</li> <li>Solve problems involving lines and angles</li> </ul>                                                                                                                                                                                                                      | <p><b>Geometry</b></p> <p><b>1.</b> Identify and draw parallel and perpendicular lines; identify and draw right angles and angles smaller or larger than a right angle; compare angles by size</p>                                                                                        |

|                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                              |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Measures</b> | <p><b>Length</b></p> <ul style="list-style-type: none"> <li>Estimate, compare, measure and record lengths of a wide variety of objects using appropriate metric units, and selecting suitable instruments of measurement</li> <li>Rename units of length using decimal or fraction form</li> <li>Understand estimate and measure the perimeter of regular 2-D shapes</li> <li>Solve and complete practical tasks and problems involving the addition, subtraction, multiplication and simple division of units of length (m, cm, km)</li> </ul>                                                        | <p><b>Measurement</b></p> <ol style="list-style-type: none"> <li>Measure and estimate lengths (mm, cm, m, km); solve problems involving lengths</li> <li>Solve problems involving perimeters of polygons, areas of rectangles, areas of shapes covered with squares or partial squares and volumes filled with cubes</li> </ol>                                                                              |
|                 | <p><b>Area</b></p> <ul style="list-style-type: none"> <li>Estimate, compare and measure the area of regular and irregular shapes</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                            | <p><b>Measurement</b></p> <ol style="list-style-type: none"> <li>Solve problems involving perimeters of polygons, areas of rectangles, areas of shapes covered with squares or partial squares and volumes filled with cubes</li> </ol>                                                                                                                                                                      |
|                 | <p><b>Weight</b></p> <ul style="list-style-type: none"> <li>Estimate, compare, measure and record the weight of a wide variety of objects using appropriate metric units (kg, g) and selecting suitable instruments of measurement</li> <li>Rename units of weight in kg and g</li> <li>Rename units of weight using decimal or fraction form</li> <li>Solve and complete practical tasks and problems involving the addition, subtraction, multiplication and simple division of units of weight (kg and g)</li> </ul>                                                                                | <p><b>Measurement</b></p> <ol style="list-style-type: none"> <li>Solve problems involving mass (g and kg), volume (mm and litre) and time (minutes and hours); identify appropriate types and sizes of units and read scales</li> </ol>                                                                                                                                                                      |
|                 | <p><b>Capacity</b></p> <ul style="list-style-type: none"> <li>Estimate, compare, measure and record capacity using appropriate metric units (l, ml) and selecting suitable instruments of measurement</li> <li>Rename units of capacity in l and ml</li> <li>Rename units of capacity using decimal and fraction form</li> <li>Solve and complete practical tasks and problems involving the addition, subtraction, multiplication and simple division of units of capacity (l, ml)</li> </ul>                                                                                                         | <p><b>Measurement</b></p> <ol style="list-style-type: none"> <li>Solve problems involving mass (g and kg), volume (mm and litre) and time (minutes and hours); identify appropriate types and sizes of units and read scales</li> <li>Solve problems involving perimeters of polygons, areas of rectangles, areas of shapes covered with squares or partial squares and volumes filled with cubes</li> </ol> |
|                 | <p><b>Time</b></p> <ul style="list-style-type: none"> <li>Consolidate and develop further a sense of time passing</li> <li>Read time in one-minute intervals on analogue and digital clock (12-hour)</li> <li>Express digital time as analogue time and vice versa</li> <li>Read and interpret simple timetables</li> <li>Rename minutes as hours and hours as minutes</li> <li>Read dates from calendars and express weeks as days and vice versa</li> <li>Solve and complete practical tasks and problems involving times and dates and the addition and subtraction of hours and minutes</li> </ul> | <p><b>Measurement</b></p> <ol style="list-style-type: none"> <li>Solve problems involving mass (g and kg), volume (mm and litre) and time (minutes and hours); identify appropriate types and sizes of units and read scales</li> </ol>                                                                                                                                                                      |
|                 | <p><b>Money</b></p> <ul style="list-style-type: none"> <li>Rename amounts of money as euro or cents and record using € symbol and decimal point</li> <li>Solve and complete practical one-step and two-step problems and tasks involving the addition, subtraction, multiplication and simple division of money</li> </ul>                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                              |

Figure 2.6 presents the percent correct scores for the two subdomains of *Measurement* and *Geometry* in Ireland and on average internationally. Comparing Ireland with the international average, there was a 17 percentage point difference for *Geometry* and a nine percentage point difference for *Measurement*. This could be interpreted as indicating that, relative to Ireland's strong overall performance on TIMSS mathematics, the subdomain *Measurement* was an area of relative weakness for Ireland (i.e., the difference between Ireland and the international average in favour of Ireland was smaller than for many other subdomains). Boys outperformed girls by four percentage points in *Geometry*, while girls' mean score was two percentage points higher in *Measurement* (Appendix Table A2.2).

Looking at the Teacher Questionnaire, teachers reported that, in comparison to Number, higher proportions of pupils had not yet been taught or had just been introduced to the topics within *Measurement & Geometry*. Approximately one-third of pupils had not yet been taught or had just been introduced to "solving problems involving mass, volume & time"; "finding and estimating perimeter, area and volume"; and "comparing and drawing angles" (Appendix Table A2.6).

**Figure 2.6: Percent correct score for the subdomains of Measurement & Geometry in Ireland and on average internationally**



See Appendix Table A2.1.

Note. The figure is an amended version of Figure 2.1 with only the subdomains of Measurement & Geometry represented. Due to rounding, some differences may appear inconsistent with those reported in text.

### **Measurement & Geometry Subdomain 1: Measurement**

The first subdomain of Measurement & Geometry is *Measurement*, which includes three topics. As mentioned above, the subdomain of *Measurement* relates to the Measures strand of the Fourth Class mathematics curriculum.

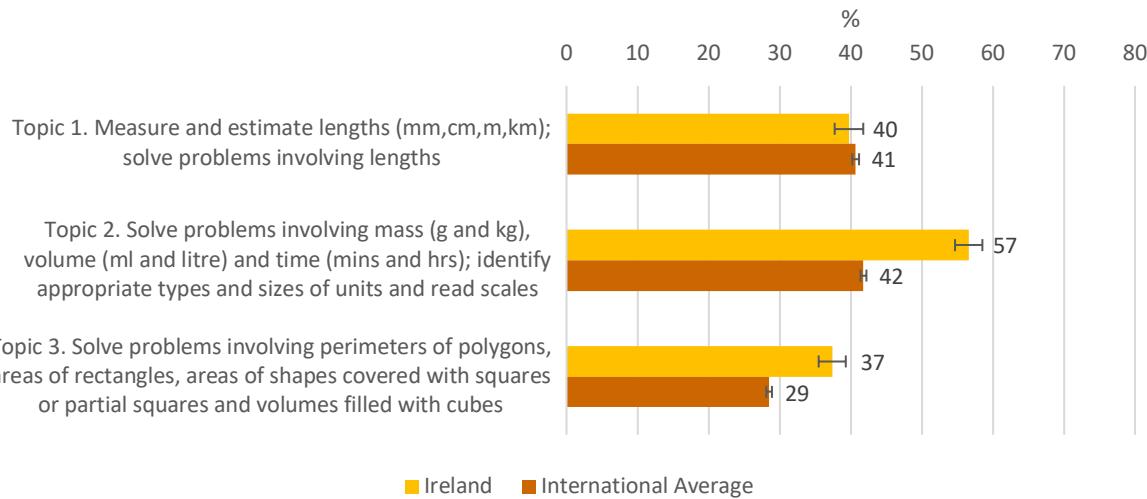
Figure 2.7 presents the percent correct scores at the topic level in Ireland and on average internationally. Comparing these scores, there was a 15 percentage point difference for Topic 2 in favour of Ireland, and a nine percentage point difference for Topic 3.

The first topic was the only topic in this subdomain, and in Grade 4 mathematics as a whole, where Ireland's percent correct score (40%) was below the international average (41%). Although this difference is marginal and not statistically significant, in the context of Ireland's strong overall performance on TIMSS mathematics it suggests that Topic 1 could be considered a topic of relative

weakness in Ireland. It should be noted here that teachers of 90% of pupils reported covering this topic either before or during Fourth Class (Appendix Table A2.6).

Boys had a higher percent correct score in each of the topics, with the largest difference between boys and girls (7%) observed for Topic 2 (Appendix Table A2.4).

**Figure 2.7: Percent correct scores at the topic level for the subdomain of *Measurement* in Ireland and on average internationally**



See Appendix Table A2.3

*Note.* For Topic 1, Ireland's percent correct score was not significantly different from the international average. For the other topic levels, Ireland's score was significantly above the international average.

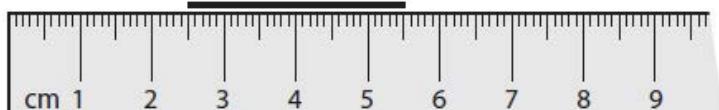
Due to rounding, some differences may appear inconsistent with those reported in text.

A released item is presented in Table 2.7. This item relates to the only topic in the subdomain, and in Grade 4 mathematics as a whole, where Ireland was below the international average: *measure and estimate lengths (mm, cm, m, km); solve problems involving lengths*. This released item was categorised as being at the *Advanced International Benchmark (625)*. Ireland had a percent correct score (39%) which was significantly below the international average (46%). In this item, pupils are asked to read a ruler and find the length of the line segment. The line segment begins at 2.5cm and ends at 5.5cm on the ruler. Pupils are provided with four options and asked to choose the correct answer. Although 39% of Fourth Class pupils answered this item correctly, a very similar proportion (37%) chose the incorrect response option (c) (3.5cm). By contrast, response option (b) was chosen by 15% of pupils and response option (a) by approximately 6% of pupils.

**Table 2.7: Released Item for *Measurement***

|                       |                                                                                                                                   |                            |
|-----------------------|-----------------------------------------------------------------------------------------------------------------------------------|----------------------------|
| Measurement           | Measure and estimate lengths (mm, cm, m, km); solve problems involving lengths                                                    |                            |
| Item Description      | Reads a ruler to find the length of a line segment beginning and ending at half-units                                             |                            |
| Benchmark             | Item at Advanced International Benchmark (625)                                                                                    |                            |
| Percent Correct Score | Ireland: 39%                                                                                                                      | International Average: 46% |
| Reason for Inclusion  | Topic where Ireland was below the international average and item where Ireland significantly lower than the international average |                            |

How long is this line in centimetres?



- (a) 7
- (b) 5.5
- (c) 3.5
- (d) 3

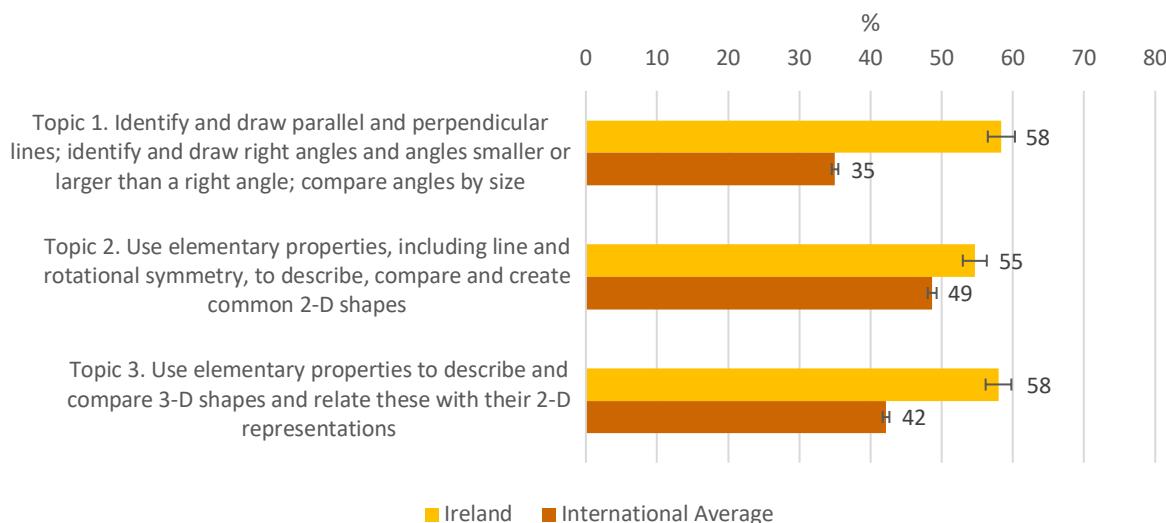
**Solution: (d) 3**

See Appendix Table A2.5.

### **Measurement & Geometry Subdomain 2: Geometry**

The second of the two subdomains within Measurement & Geometry is *Geometry*. This subdomain includes three topics, listed in Figure 2.8. Comparing Ireland and the international average, the first topic was an area where pupils in Ireland performed relatively well as there was a 23 percentage point difference in the percent correct score for Ireland and on average internationally. Topic 2 was an area of relative weakness, with a difference of only six percentage points between Ireland and the TIMSS average. Boys had a score that was three percentage points higher for the first two topics listed in Figure 2.8, with almost no difference between boys and girls in the third topic (Appendix Table A2.4).

**Figure 2.8: Percent correct scores at the topic level for the subdomain of *Geometry* in Ireland and on average internationally**



See Appendix Table A2.3.

*Note.* Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

Table 2.8 presents a released item relating to the *Geometry* subdomain. The item was categorised as at the *Advanced International Benchmark* (625). In Ireland, two in five pupils (40%) answered this item correctly, while internationally only one in four pupils answered the item correctly (26%). In this item, pupils are asked to determine the number of square and triangular faces needed to make up various three-dimensional shapes including a square-based pyramid, a triangular-based pyramid, a cube, and a triangular prism.

**Table 2.8: Released Item for *Geometry***

|                       |                                                                                                               |                            |
|-----------------------|---------------------------------------------------------------------------------------------------------------|----------------------------|
| Measurement           | Use elementary properties to describe and compare 3-D shapes and relate these with their 2-D representations. |                            |
| Item Description      | Determines the number of square and triangular faces of three-dimensional shapes                              |                            |
| Benchmark             | Item at Advanced International Benchmark (625)                                                                |                            |
| Percent Correct Score | Ireland: 40%                                                                                                  | International Average: 26% |
| Reason for Inclusion  | Ireland was significantly above the international average                                                     |                            |

Justin has many of these triangle and square panels that fit together to make three-dimensional shapes.



Justin makes each of the shapes shown below.

Fill in the table. The first one has been done for you.

| Three-dimensional shape | Number of triangles | Number of squares |
|-------------------------|---------------------|-------------------|
|                         | 4                   | 1                 |
|                         |                     |                   |
|                         |                     |                   |
|                         |                     |                   |

**Solution:**

| Three-dimensional shape | Number of triangles | Number of squares |
|-------------------------|---------------------|-------------------|
|                         | 4                   | 1                 |
|                         | 4                   | 0 or blank        |
|                         | 0 or blank          | 6                 |
|                         | 2                   | 3                 |

The first row is pre-filled. Pupils get full credit if they fill in all six remaining values in the table correctly. They receive partial credit if they complete five values in the table correctly.

See Appendix Table A2.5.

## 2.4 DATA

The final content domain for Grade 4 mathematics is Data. This accounts for one-fifth of the items on the TIMSS assessment. Table 2.9 presents the linking of the Fourth Class primary school mathematics curriculum to the content domain of Data in the TIMSS framework. This content domain relates to the Data strand of the Irish curriculum. While the concept of chance features in the Irish curriculum, probability or chance are not included in the TIMSS framework for Grade 4 mathematics. (Probability is, however, included in the TIMSS framework for Grade 8 mathematics.) All of the topics within the TIMSS framework for Data relate to the strand unit of 'representing and interpreting data' in the Fourth Class curriculum. Conversely, the Irish curriculum includes a strand unit on 'chance' which is not part of the TIMSS framework at this grade level.

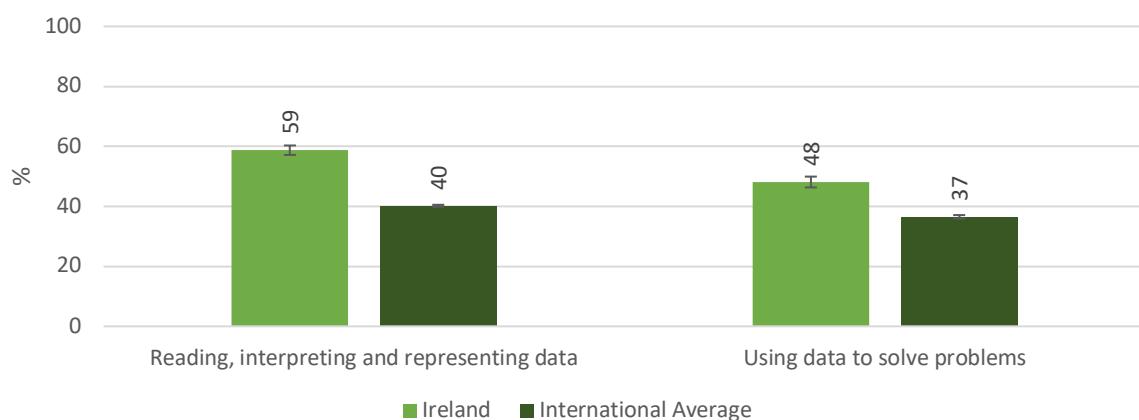
**Table 2.9: Primary School Curriculum: Mathematics (Department of Education and Science, 1999b) linked to TIMSS 2019 Framework**

|      | Fourth Class Curriculum: Data                                                                                                                                                                                                                                                                                                                                                                                                                    | TIMSS Framework                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Data | <p><b>Representing and interpreting data</b></p> <ul style="list-style-type: none"> <li>• Collect, organise and represent data using pictograms, block graphs, bar charts and bar-line graphs incorporating the scales 1:2, 1:5, 1:10 and 1:100</li> <li>• Read and interpret bar-line graphs and simple pie charts involving the use of 1/2, 1/3 and 1/4</li> <li>• Use data sets to solve and complete practical tasks and problems</li> </ul> | <p><b>Reading, Interpreting and Representing Data</b></p> <ol style="list-style-type: none"> <li>1. Read and interpret data from tables, pictographs, bar graphs, line graphs and pie charts</li> <li>2. Organise and represent data to help answer questions</li> </ol> <p><b>Using Data to Solve Problems</b></p> <ol style="list-style-type: none"> <li>1. Use data to answer questions that go beyond directly reading data displays (e.g., solve problems and perform computations using data, combine data from two or more sources, draw conclusions based on data)</li> </ol> |
|      | <p><b>Chance</b></p> <ul style="list-style-type: none"> <li>• Use vocabulary of uncertainty and chance: chance, likely, unlikely, never, definitely</li> <li>• Order events in terms of likelihood of occurrence</li> <li>• Identify and record outcomes of simple random processes</li> </ul>                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

Figure 2.9 presents the percent correct score for the subdomains of Data in Ireland and on average internationally. For *Reading, interpreting and representing data*, pupils in Ireland had a 19 percentage point advantage over the international average while for *Using data to solve problems*, pupils in Ireland had a 12 percentage point advantage over the international average. Boys and girls performed very similarly on these subdomains. Boys' score for *Using data to solve problems* was two percentage points higher than girls', and one percentage point higher for *Reading, interpreting and representing data* (Appendix Table A2.2).

Teachers' responses to the Teacher Questionnaire indicated that, for the concepts relating to Data, approximately 90% of pupils had covered them either before or during Fourth Class (Appendix Table A2.6).

**Figure 2.9: Percent correct score for the subdomains of Data in Ireland and on average internationally**



See Appendix Table A2.1.

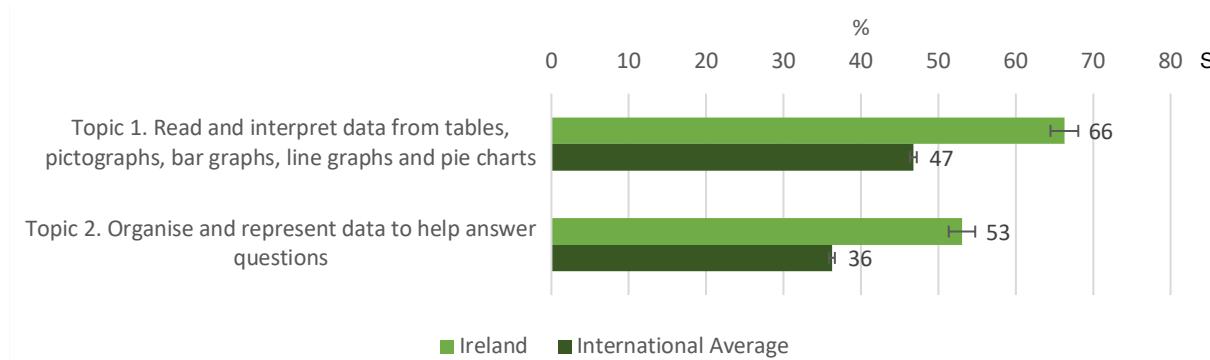
*Note.* The figure is an amended version of Figure 2.1 with only the subdomains of Data represented. Due to rounding, some differences may appear inconsistent with those reported in text.

### ***Data Subdomain 1: Reading, Interpreting and Representing Data***

The first subdomain of Data (*Reading, interpreting and representing data*) has two topics. This relates to the ‘representing and interpreting data’ strand unit in the Fourth Class curriculum. Figure 2.10 presents the percent correct scores at the topic level in Ireland and internationally. On Topic 1, pupils in Ireland had a percent correct score which was well above the international average (by 19 percentage points). For the second topic, *organise and represent data to help answer questions*, there was a 17 percentage point difference between Ireland and the international average (in favour of Ireland). Boys had a slightly higher percent correct score than girls for the first topic (by 3 percentage points) while for the second topic, boys and girls had broadly similar percent correct scores (Appendix Table A2.4).

Both of these topics were reported by teachers to have been well-covered, with more than 90% of pupils reported to have covered the topics before or during Fourth Class (Appendix Table A2.6).

**Figure 2.10: Percent correct scores at the topic level for the subdomain *Reading, interpreting and representing data* in Ireland and on average internationally**



See Appendix Table A2.3.

*Note.* Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

Table 2.10 presents an item relating to *Reading, interpreting and representing data*. It was categorised as at the *Advanced International Benchmark* (625). Almost half of pupils in Ireland (47%) answered this item correctly, which was 12% higher than the average internationally. In this question, pupils must use the information in the table to decide which numbers to place on the y-axis. The values for both Tuesday and Thursday are on one of the horizontal lines of the graph and pupils need this information to infer that the lines represent five and 10. Using this information, they will be able to deduce that the final box must be 15, to ensure that the y-axis labels increase by the same number of units.

**Table 2.10: Released Item for *Reading, interpreting and representing data***

|                                             |                                                                                       |                            |
|---------------------------------------------|---------------------------------------------------------------------------------------|----------------------------|
| Reading, interpreting and representing data | Organise and represent data to help answer questions                                  |                            |
| Item Description                            | Determines the y-axis scale for a bar graph given the data in a table                 |                            |
| Benchmark                                   | Item at Advanced International Benchmark (625)                                        |                            |
| Percent Correct Score                       | Ireland: 47%                                                                          | International Average: 35% |
| Reason for Inclusion                        | Pupils in Ireland did relatively less well on this item compared to the overall topic |                            |

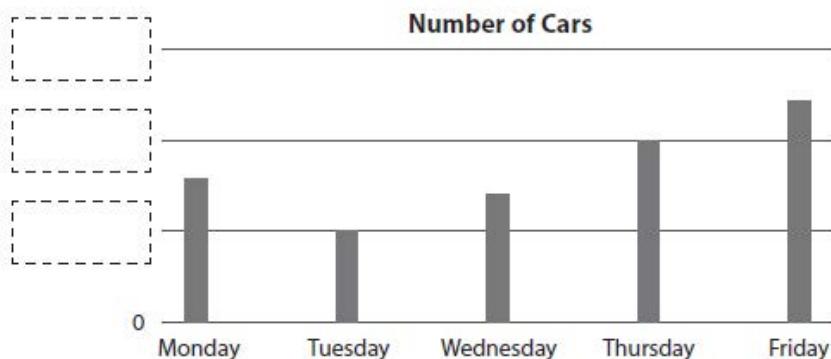
Sharon recorded the number of cars that travelled along her street each morning.

| Day       | Number of Cars |
|-----------|----------------|
| Monday    | 8              |
| Tuesday   | 5              |
| Wednesday | 7              |
| Thursday  | 10             |
| Friday    | 12             |

She started making a graph of her data.

What numbers should Sharon use to label the horizontal lines on her graph?

Put the numbers in the boxes on Sharon's graph.



**Solution:**

**Top Box – 15**

**Middle Box – 10**

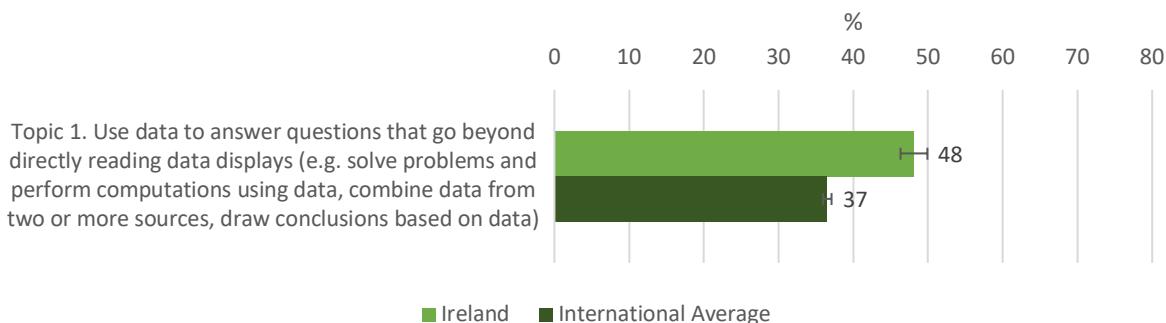
**Bottom Box – 5**

See Appendix Table A2.5

## Data Subdomain 2: Using Data to Solve Problems

The second subdomain within Data is *Using data to solve problems*. Similar to the previous subdomain, this subdomain relates to the ‘representing and interpreting data’ strand unit in the Data strand. Figure 2.11 presents the percent correct score at the topic level for this subdomain in Ireland and on average internationally. There is only one topic in this subdomain. Ireland’s score was 11 percentage points higher than the average internationally. In Ireland, boys’ score was two percentage points higher than girls’ for this topic (Appendix Table A2.4).

**Figure 2.11: Percent correct scores at the topic level for the subdomain *Using data to solve problems* in Ireland and on average internationally**



See Appendix Table A2.3.

*Note.* Ireland’s percent correct score was significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

There were no released items from 2019 relating to this topic.

# Chapter 3 - Fourth Class Science

## 3.1 INTRODUCTION

As outlined in Chapter 1, the TIMSS science assessment has three content domains at Grade 4: Life Science, Physical Science, and Earth Science. Each of the content domains contributes a different proportion to the assessment. Specifically, Life Science was planned to account for 45%, Physical Science for 35%, and Earth Science for the remaining 20% of the science assessment (Mullis & Martin, 2017). Perkins and Clerkin (2020) reported that the final distribution of items across the three content domains (Life Science, Physical Science and Earth Science) were similar to these planned distributions at 46%, 35% and 19% respectively.

The content domains differ somewhat between Grade 4 and Grade 8 to reflect the science widely taught at each level across the range of TIMSS countries. At Grade 4, Physics and Chemistry content is included as part of Physical Science while at Grade 8 they are separate content domains. Life Science is a content domain for Grade 4, but the corresponding domain at Grade 8 is Biology.

Each content domain is composed of a number of subdomains and topics, as outlined in Chapter 1. This chapter presents the percent correct scores in science at the content domain, subdomain and topic levels for Ireland, and on average internationally, for Grade 4. Comparisons to the international average are used as a basis for identifying areas where pupils in Ireland perform particularly strongly or do relatively less well, as percent correct scores do not take relative item difficulty across subdomains or topics into consideration.

As part of the Teacher Questionnaire, teachers were asked to indicate whether various concepts were *mostly taught before this year*, *mostly taught this year*, or *not yet taught or just introduced*. The wording of the concepts in the Teacher Questionnaire and the subdomains or topics in the Assessment Framework are not identical, but are broadly similar. For example, one concept listed in the Teacher Questionnaire is “interactions between organisms and their environment”, which relates to two topics on the pupil assessment: *physical features or behaviours of living things that help them survive in the environment* and *responses of living things to environmental conditions*.

Released items are also presented for each subdomain, where available. This is to provide examples of the types of items used in TIMSS. Items are classified as being indicative of the *Low International Benchmark (400)*, the *Intermediate International Benchmark (475)*, the *High International Benchmark (550)*, the *Advanced International Benchmark (625)*, or as being *Above the Advanced International Benchmark (625+)*. Table 3.1 is adapted from Exhibit 2.7 in the TIMSS 2019 International Report and summarises the skills that Grade 4 pupils who reached each of the International Benchmarks can demonstrate in science (Mullis et al., 2020).

**Table 3.1: Summary of the TIMSS 2019 International Benchmarks of Grade 4 Science Achievement (adapted from Mullis et al., 2020)**

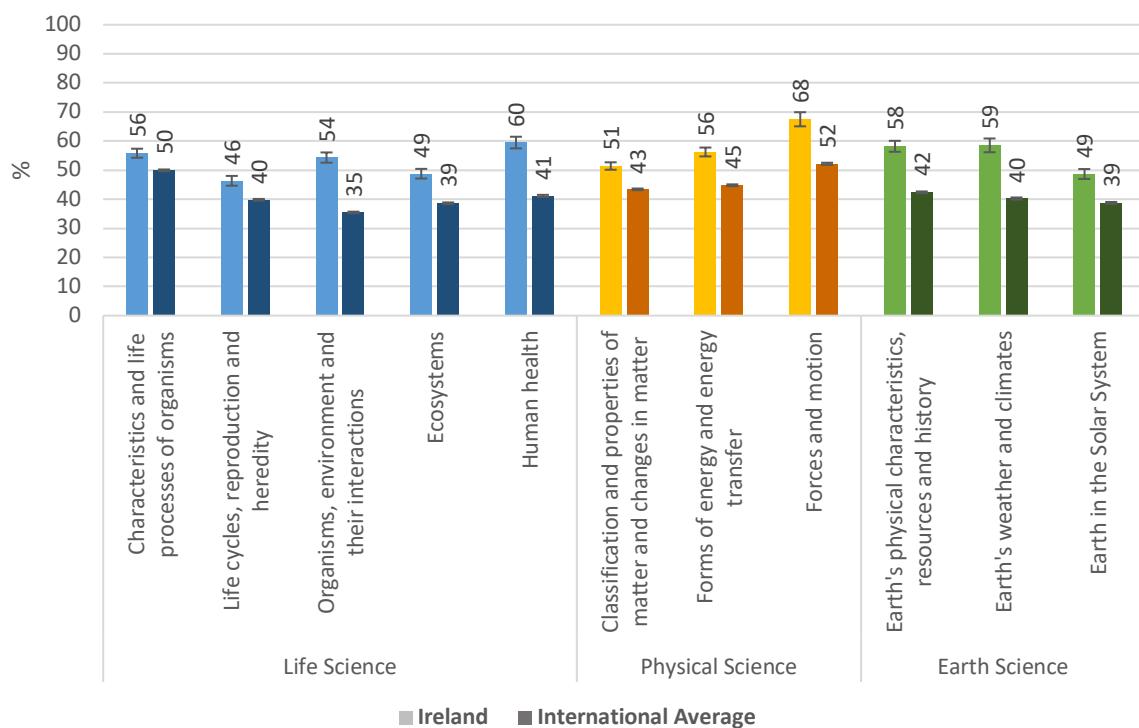
| International Benchmarks                    | Scale Score | Summary                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|---------------------------------------------|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Advanced International Benchmark</b>     | <b>625</b>  | Pupils communicate their understanding of life, physical, and Earth sciences and demonstrate some knowledge of the process of scientific inquiry. Pupils demonstrate knowledge of characteristics and life processes of a variety of organisms. They can communicate understanding of relationships in ecosystems and interactions between organisms and their environment. They communicate understanding of properties and states of matter and physical and chemical changes. Pupils communicate understanding of Earth's physical characteristics, processes, and history and show knowledge of Earth's revolution and rotation. |
| <b>High International Benchmark</b>         | <b>550</b>  | Pupils communicate and apply knowledge of life, physical, and Earth sciences. Pupils communicate knowledge of characteristics of plants, animals, and their life cycles, and apply knowledge of ecosystems and of humans' and organisms' interactions with their environment. Pupils demonstrate knowledge of states and properties of matter and of energy transfer in practical contexts, and show some understanding of forces and motion. Pupils know various facts about the Earth's physical characteristics and show basic understanding of the Earth-Moon-Sun system.                                                        |
| <b>Intermediate International Benchmark</b> | <b>475</b>  | Pupils show knowledge and understanding of some aspects of science. Pupils demonstrate some basic knowledge of plants and animals. They demonstrate knowledge about some properties of matter and some facts related to electricity, and can apply elementary knowledge of forces and motion. They show some understanding of Earth's physical characteristics.                                                                                                                                                                                                                                                                      |
| <b>Low International Benchmark</b>          | <b>400</b>  | Pupils show limited understanding of scientific concepts and limited knowledge of foundational science facts.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |

Fourth Class pupils in Ireland had percent correct scores which were above the international average for each of the content domains among the 28 countries that participated in *paper TIMSS* at Grade 4<sup>11</sup> (Appendix Table F.1, Mullis et al., 2020). Ireland was 14 percentage points above the international average in Earth Science and 12 percentage points above for Life Science. The difference was 10 percentage points in favour of Ireland for Physical Science. This pattern of results across content areas reflects those described in Perkins and Clerkin (2020), where student performance across content areas was described in terms of scale scores which take the difficulty level of items into account.

Figure 3.1 presents the percent correct score on each of the subdomains in Ireland (lighter bars) and internationally (darker bars). In each of these subdomains, Ireland's percent correct score was significantly above the average of the 28 countries (Appendix Table A3.1).

<sup>11</sup> Albania, Armenia, Australia, Azerbaijan, Bahrain, Belgium (Flemish), Bosnia and Herzegovina, Bulgaria, Cyprus, Iran, Ireland, Japan, Kazakhstan, Kosovo, Kuwait, Latvia, Montenegro, Morocco, New Zealand, North Macedonia, Northern Ireland, Oman, Pakistan, Philippines, Poland, Saudi Arabia, Serbia and South Africa.

Figure 3.1: Percent correct scores by subdomain in Ireland and on average internationally



See Appendix Table A3.1.

Note. Due to rounding, some differences may appear inconsistent with those reported in text.

Life Science includes five subdomains: *Characteristics and life processes of organisms*; *Life cycles, reproduction and heredity*; *Organisms, environment and their interactions*; *Ecosystems*; and *Human health*. As noted above, comparisons between Ireland and the international average are used as a point of reference for highlighting areas of relative strength and weakness.

Applying this here, within Life Science, *Organisms, environment and their interactions* and *Human health* were areas where pupils in Ireland performed relatively well, as the difference between Ireland and the international average was larger than at the overall domain level (these differences, and those for the other content domains, are discussed further below). Conversely, areas where pupils in Ireland performed relatively less well within Life Science include *Characteristics and life processes of organisms* and *Life cycles, reproduction and heredity*.

Physical Science has three subdomains: *Classification and properties of matter and changes in matter*; *Forms of energy and energy transfer*; and *Forces and motion*. *Forces and motion* was a subdomain where Ireland performed well relative to the other subdomains, while *Classification and properties of matter and changes in matter* was the subdomain where pupils in Ireland had the smallest advantage over the international average.

Earth Science also has three subdomains: *Earth's physical characteristics, resources and history*; *Earth's weather and climates*; and *Earth in the Solar System*. There was a difference of 10 percentage points between Ireland and the international average for *Earth in the Solar System*, indicating that this was an area of relative weakness for Ireland. In contrast, the subdomain of *Earth's weather and climates* was an area of relative strength for Ireland, with an 18 percentage point advantage over the international average.

The following sections describe the patterns of performance within each content domain for Ireland in more detail, and how the TIMSS subdomains relate to the primary school curriculum.

### 3.2 LIFE SCIENCE

In TIMSS 2019, Life Science accounted for 45% of the items. Table 3.2 presents the connections between the Third/Fourth Class primary school science curriculum and the Life Science content domain within the TIMSS Framework. In general, this aspect of the TIMSS Framework relates to the Living Things strand in the Third/Fourth Class curriculum. One exception is the topic of *the impact of humans on the environment* within the subdomain *Organisms, environment and their interactions*. This topic links with the strand unit ‘environmental awareness’, which is part of the Environmental Awareness and Care strand.

The Third/Fourth Class science curriculum does not map directly onto the TIMSS Framework and there are some topics which are not covered as part of the Irish curriculum at this level. Within the TIMSS subdomain of *Characteristics and life processes of organisms*, one topic is the *functions of major structures in living things*. Within this topic, the basic life processes of animals are included in the Third/Fourth Class curriculum, while the basic life processes of plants are not introduced until later in primary school (Fifth/Sixth Class).

Similarly, within *Life cycles, reproduction and heredity*, one topic is the *stages of life cycles and differences among the life cycles of common plants and animals*. The Third/Fourth Class curriculum includes the stages of life cycles in relation to animals, but the reproduction of plants and animals is not introduced in science until the Fifth/Sixth Class curriculum. The second topic within this subdomain is *inheritance and reproduction strategies*, which is not explicitly mentioned on the primary science curriculum.

Within the subdomain of *Ecosystems*, two topics are not introduced on the curriculum until Fifth/Sixth Class: *common ecosystems* and *competition in ecosystems*.

Within Human health, the *transmission, prevention, and symptoms of communicable diseases* is not part of the primary science curriculum, although it is mentioned in the Third/Fourth Class Social Personal and Health Education (SPHE) curriculum in the ‘taking care of my body’ strand unit in the Myself strand<sup>12</sup>.

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<sup>12</sup> Pupils would now also have an increased awareness of this topic due to the COVID-19 pandemic. However, the data collection for TIMSS 2019 took place prior to the pandemic.

**Table 3.2: Primary School Curriculum: Science (Department of Education and Science, 1999c) linked to TIMSS 2019 Framework**

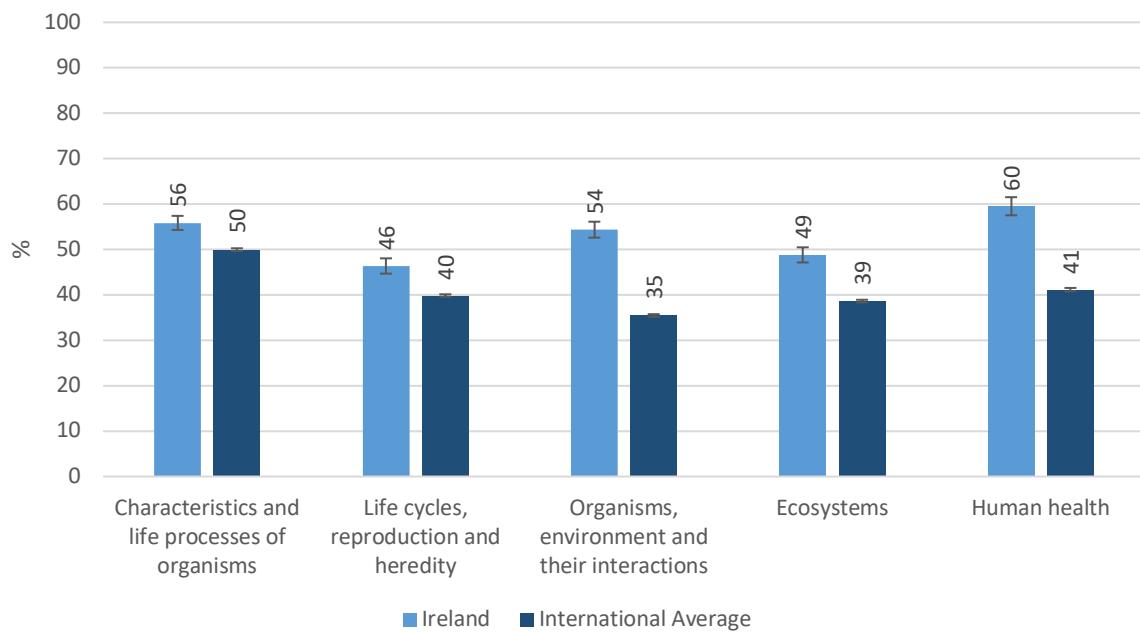
|               | Third/Fourth Class Curriculum: Living Things                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | TIMSS Framework                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Living Things | <p><b>Human Life</b><br/> <i>Variety and characteristics of humans</i> <ul style="list-style-type: none"> <li>• Become aware of the names and structure of some of the body's major external and internal organs</li> </ul> <p><i>Human Life Processes</i></p> <ul style="list-style-type: none"> <li>• Develop an awareness of the importance of food for energy and growth</li> <li>• Understand the physical changes taking place in both male and female during growth to adulthood</li> <li>• Become aware of and investigate breathing</li> <li>• Explore and investigate how people move</li> </ul> <p><b>Plant and animal life</b><br/> <i>Variety and characteristics of living things</i></p> <ul style="list-style-type: none"> <li>• Observe, identify and investigate the animals and plants that live in local environments</li> <li>• Develop an increasing awareness of plants and animals from wider environments</li> <li>• Observe and explore some ways in which plant and animal behaviour is influenced by, or adapted to, environmental conditions</li> <li>• Sort and group living things into sets according to observable features</li> <li>• Use simple keys to identify common species of plants and animals</li> <li>• Understand that plants use light energy from the sun</li> <li>• Come to appreciate that animals depend on plants and indirectly on the sun for food</li> <li>• Discuss simple food chains</li> </ul> <p><b>Processes of life</b></p> <ul style="list-style-type: none"> <li>• Become aware of some of the basic life processes in animals</li> <li>• Investigate the factors that affect plant growth</li> </ul> </p> | <p><b>Human Health</b><br/> 2. Ways of maintaining good health</p> <p><b>Characteristics and Life Processes of Organisms</b></p> <ol style="list-style-type: none"> <li>1. Differences between living and non-living things and what living things require to live</li> <li>2. Physical and behavioural characteristics of major groups of living things</li> <li>3. Functions of major structures in living things</li> </ol> <p><b>Life Cycles, Reproduction, and Heredity</b></p> <ol style="list-style-type: none"> <li>1. Stages of life cycles and differences among the life cycles of common plants and animals</li> <li>2. Inheritance and reproduction strategies</li> </ol> <p><b>Organisms, Environment, and Their Interactions</b></p> <ol style="list-style-type: none"> <li>1. Physical features or behaviours of living things that help them survive in their environment</li> <li>2. Responses of living things to environmental conditions</li> </ol> <p><b>Ecosystems</b></p> <ol style="list-style-type: none"> <li>2. Relationships in simple food chains</li> </ol> |
|               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

While Figure 3.1 (above) presented the percent correct scores for each of the subdomains, Figure 3.2 (below) presents a focus on the percent correct scores for the subdomains of Life Science only. As shown, Ireland performed significantly above the international average in each of the subdomains with differences ranging from six percentage points for *Characteristics and life processes of organisms* to 19 percentage points for *Organisms, environment, and their interactions* (Appendix Table A3.1). As previously mentioned, these differences indicate that *Organisms, environment and their interactions* and *Human health* were areas of relative strength for Ireland while *Characteristics and life processes of organisms* and *Life cycles* were areas where pupils in Ireland performed less well. Girls had a higher percent correct score than boys for *Human health* (by seven percentage points) while gender differences for the other subdomains were three percentage points or less (Appendix Table A3.2).

Responses to the Teacher Questionnaire indicated substantial variation across the Life Science concepts in terms of whether they had been *mostly taught before this year, mostly taught this year, or not yet taught or just introduced* (Appendix Table A3.6). Some concepts such as the “physical and behavioural characteristics of living things” or “life cycles of common plants and animals” were more

commonly taught before Fourth Class, while over half of pupils had not covered “characteristics of plants and animals that are inherited”. On the latter point, it may be noted that this topic is not included as part of the primary science curriculum.

**Figure 3.2: Percent correct score for the subdomains of Life Science in Ireland and on average internationally**



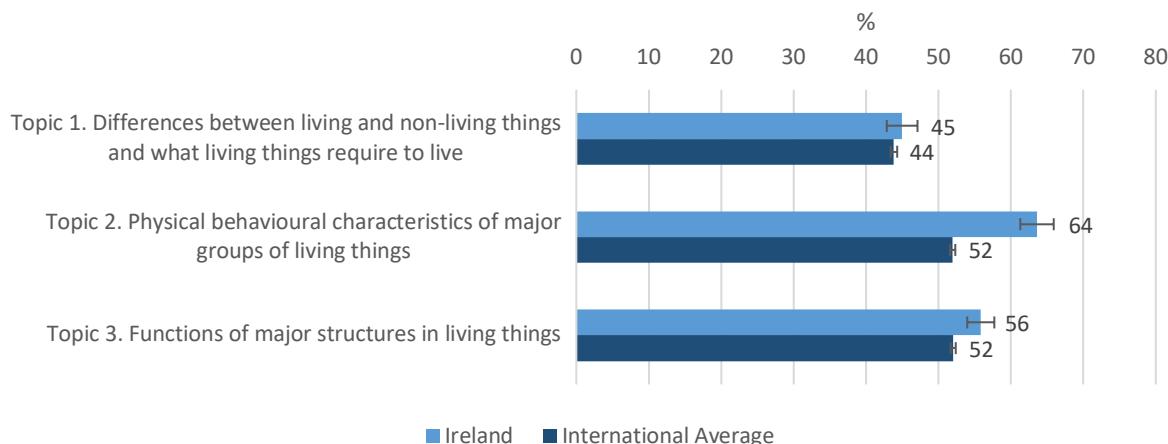
See Appendix Table A3.1.

*Note.* The figure is an amended version of Figure 3.1 with only the subdomains of Life Science represented. Due to rounding, some differences may appear inconsistent with those reported in text.

### ***Life Science Subdomain 1: Characteristics and Life Processes of Organisms***

The first subdomain of *Characteristics and life processes of organisms* includes three topics. Looking at the curriculum in Ireland, each of the TIMSS topics relate to the strand unit of ‘plant and animal life’ within the Living Things strand of the curriculum. However, while the Third/Fourth Class curriculum includes the basic life processes of animals, the basic life processes of plants are not introduced until Fifth/Sixth Class. Figure 3.3 presents the percent correct score at the topic level in Ireland and on average internationally. Comparing Ireland with the international average, the largest difference (12 percentage points) was for Topic 2 and the smallest difference (one percentage point) for Topic 1. Topic 1 could therefore be considered an area of relative weakness for pupils in Ireland. The magnitude of gender differences were small and ranged from one to three percentage points (Appendix Table A3.4).

**Figure 3.3: Percent correct scores at the topic level for the subdomain *Characteristics and life processes of organisms* in Ireland and on average internationally**



See Appendix Table A3.3.

*Note.* Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

As noted in Chapter 1, selected items are released after each cycle of TIMSS. Table 3.3 presents an item relating to this subdomain. This item relates to the topic of *differences between living and non-living things and what living things require to live*, the topic which had the smallest difference between Ireland and the international average of all topics in Grade 4 science. This topic connects to the strand unit of 'plant and animal life', in the Living Things strand of the Third/Fourth Class science curriculum. This released item was categorised as being at the *High International Benchmark (550)* (see Table 3.1). Pupils in Ireland achieved 35% correct on this item, which was significantly below the international average of 45%.

There are five parts to this item, in which pupils are asked to indicate whether certain characteristics relate to both a toy duck and a living duck, or only a living duck. The percent correct scores of each of the individual parts show that Ireland was either significantly above or not significantly different to the international average for all parts except for part (e), where Ireland was significantly below the international average (with a difference of 18 percentage points). One possible explanation is that, as reproduction of plants and animals is not introduced in the science curriculum until Fifth/Sixth Class, pupils may not have been familiar with the term 'reproduce'.

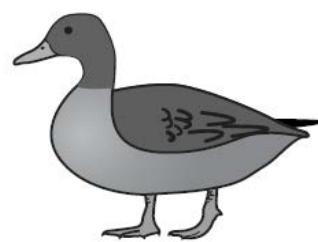
**Table 3.3: Released item for *Characteristics and life processes of organisms***

|                                                 |                                                                                                                        |                                                                                         |
|-------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| Characteristics and life processes of organisms | Differences between living and non-living things and what living things require to live                                |                                                                                         |
| Item Description                                | Identifies characteristics that describe either a toy duck and a living duck or only a living duck                     |                                                                                         |
| Benchmark                                       | Item at High International Benchmark (550)                                                                             |                                                                                         |
| Percent Correct Score                           | Ireland: Overall 35%<br>Part (a) 86%; (b) 89%; (c) 90%; (d) 64%; (e) 62%.                                              | International Average: Overall 45%<br>Part (a) 87%; (b) 86%; (c) 88%; (d) 60%; (e) 80%. |
| Reason for Inclusion                            | Ireland significantly lower than international average on this item; topic is an area of relative weakness for Ireland |                                                                                         |

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



toy duck



living duck

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

Tick one circle for each characteristic.

|                         | Toy duck and living duck | Only living duck |
|-------------------------|--------------------------|------------------|
| (a) needs water -----   | A                        | B                |
| (b) needs air -----     | A                        | B                |
| (c) can grow -----      | A                        | B                |
| (d) can move -----      | A                        | B                |
| (e) can reproduce ----- | A                        | B                |

### Solution

- (a) B
- (b) B
- (c) B
- (d) A
- (e) B

See Appendix Table A3.5

### Life Science Subdomain 2: Life Cycles, Reproduction and Heredity

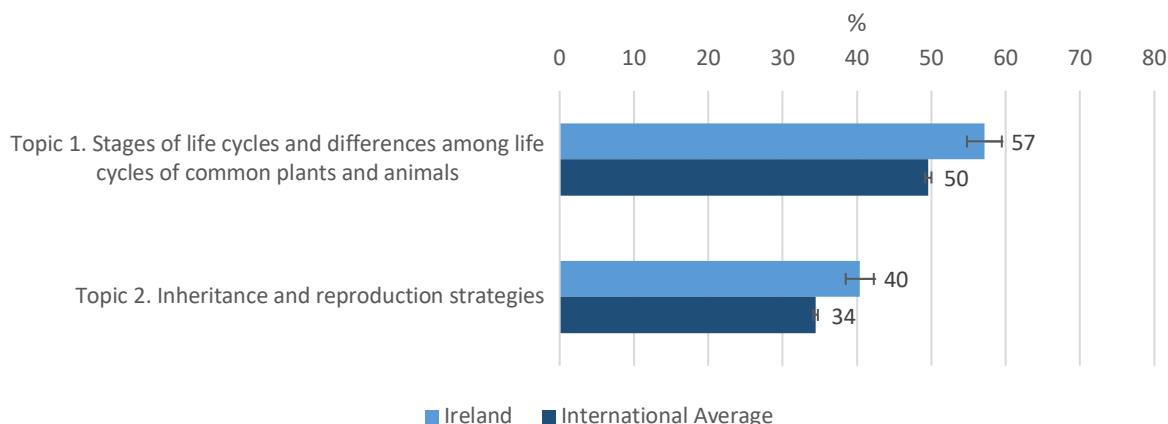
The second subdomain within Life Science is *Life cycles, reproduction and heredity*. This includes two topics (see Figure 3.4). Both of these topics relate to the Living Things strand in the Third/Fourth

Class science curriculum. Looking at the linking of these topics to the Irish curriculum, stages of life cycles of animals is included for Third/Fourth Class, while stages of life cycles of plants is not introduced until Fifth/Sixth Class. Similarly, reproduction of plants and animals is not introduced in the science curriculum until Fifth/Sixth Class.

Figure 3.4 presents percent correct scores at the topic level for the subdomain *Life cycles, reproduction and heredity*. The differences between Ireland and the international average were broadly similar for both topics (6% and 8% respectively). Gender differences were small and in favour of girls, with a three percentage point difference for the first topic and a one percentage point difference for the second topic (Appendix Table A3.4).

There were no released items relating to this subdomain.

**Figure 3.4: Percent correct scores by topic for the subdomain *Life cycles, reproduction and heredity* in Ireland and on average internationally**



See Appendix Table A3.3

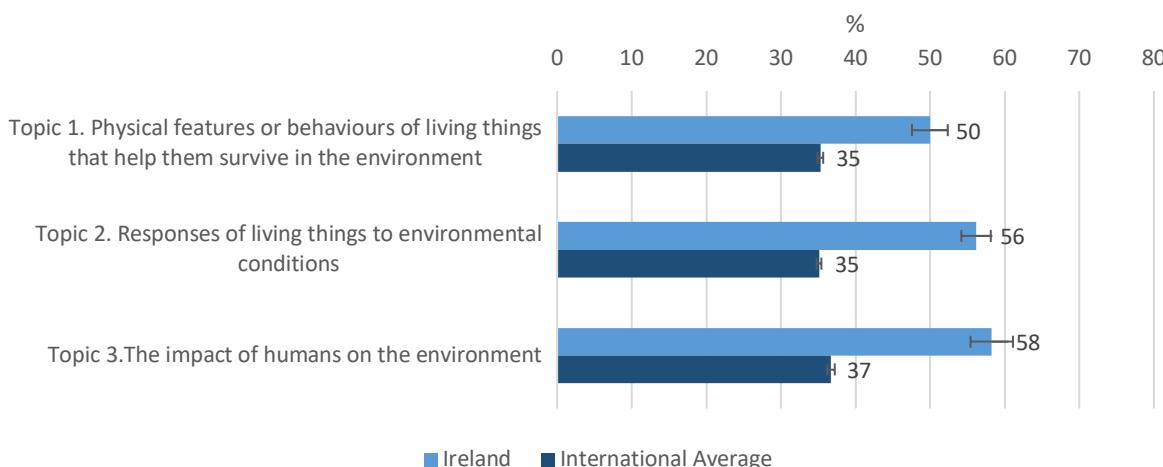
Note. Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

### ***Life Science Subdomain 3: Organisms, Environment, and their Interactions***

The third subdomain within Life Science is *Organisms, environment, and their interactions*. As noted above, this was an area of relative strength for Ireland. This subdomain relates mainly to the strand of Living Things of the Third/Fourth Class science curriculum. However, the third topic (*the impact of humans on the environment*) relates to the 'environmental awareness' strand unit within the strand of Environmental Awareness and Care in the Third/Fourth Class science curriculum.

Figure 3.5 presents the three topics and their respective percent correct scores in Ireland and internationally. The differences between Ireland and the international average were 15, 21, and 22 percentage points for Topics 1-3, which demonstrates that pupils in Ireland performed relatively well across all of the topics within this subdomain and especially in the second and third topics. Small gender differences, in favour of girls, were observed in each of the topics within this subdomain. The largest difference (three percentage points) was for the topic *response of living things to environmental conditions* (Appendix Table A3.4).

**Figure 3.5: Percent correct scores at the topic level for the subdomain *Organisms, environment, and their interactions* in Ireland and on average internationally**



See Appendix Table A3.3.

Note. Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

Table 3.4 presents one released item, which falls under Topic 1 (*physical features or behaviours of living things that help them survive in the environment*). This relates to the 'plant and animal life' strand unit of the Living Things strand of the Third/Fourth Class science curriculum. This item was categorised as being at the *High International Benchmark* (550). Over half of pupils (52%) in Ireland who answered this question did so correctly. This was above the average internationally (45%).

The item explains that ground squirrels often hold their tails over their heads in hot, dry environments and asks pupils to explain how this helps the ground squirrels to survive. It is a constructed response question which requires pupils to give a written response in the space provided. To receive credit for their answer, pupils had to explain that this action shades the squirrel from the heat of the sun.

**Table 3.4: Released Item for *Organisms, environment and their interactions*.**

|                                                |                                                                                                       |                            |
|------------------------------------------------|-------------------------------------------------------------------------------------------------------|----------------------------|
| Organisms, environment, and their interactions | Physical features or behaviours of living things that help them survive in the environment            |                            |
| Item Description                               | Describes how holding its tail over its head helps a ground squirrel survive in hot, dry environments |                            |
| Benchmark                                      | Item at High International Benchmark (550)                                                            |                            |
| Percent Correct Score                          | Ireland: 52%                                                                                          | International Average: 45% |
| Reason for Inclusion                           | Topic which was an area of relative strength for Ireland                                              |                            |



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

How does this behaviour help the cape ground squirrel survive?

**Solution:**

**Explains that holding its tail overhead shades the cape ground squirrel from the heat of the Sun.**

**Examples:**

- ***It keeps it out of the sun.***
- ***It keeps the squirrel from getting too hot.***
- ***The tail makes shade for the squirrel.***

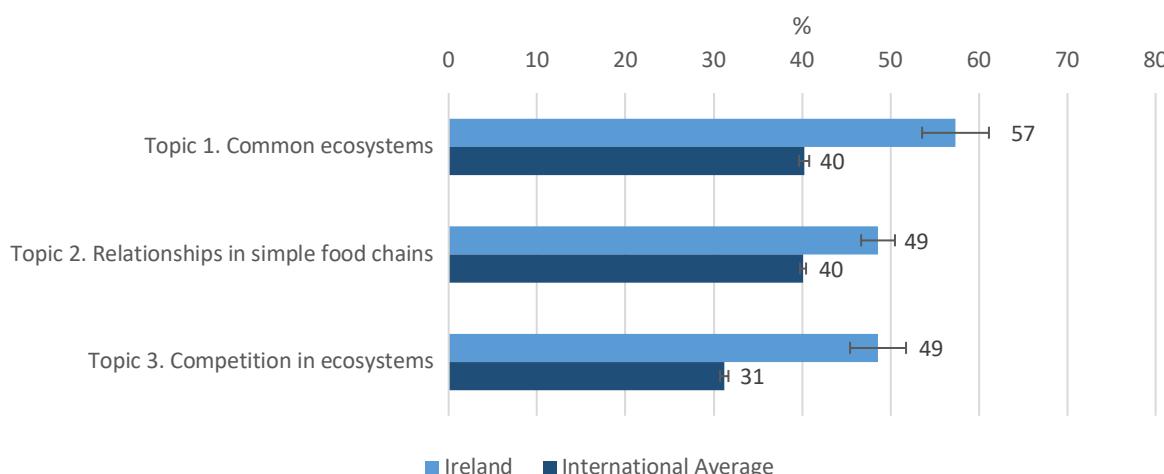
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See Appendix Table A3.5

### **Life Science Subdomain 4: Ecosystems**

The fourth subdomain within Life Science is *Ecosystems*. This includes three topics as presented in Figure 3.6. The second topic relates to the ‘plant and animal life’ strand unit of the Living Things strand. However, neither the first nor third topics are included in the Third/Fourth Class curriculum, not being introduced until Fifth/Sixth Class. Looking at differences between Ireland and the international average, both the first and third topics had a difference of 17 percentage points, while there was a nine percentage point difference for the second topic. Small gender differences in favour of boys were observed for the first and second topic (ranging from three to four percentage points) but almost no difference was seen for the third topic (Appendix Table A3.4).

**Figure 3.6: Percent correct scores at the topic level for the subdomain *Ecosystems* in Ireland and on average internationally**



See Appendix Table A3.3.

Note. Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

Table 3.5 presents a released item on which pupils in Ireland did not perform significantly differently to the international average, which relates to the *relationships in simple food chains* topic. This item relates to the 'plant and animal life' strand unit in the Living Things strand of the Third/Fourth Class curriculum. This item was categorised at the *High International Benchmark (550)* (Table 3.1). Ireland achieved 47% correct on this item, while internationally, the percent correct score was 43%. This item asks pupils to explain how an increase in the number of bats in an area could lead to a decrease in the number of insects. To answer the item correctly, pupils need to understand that bats eat insects and to make the link that an increase in the number of bats means that more insects are eaten, thereby leading to their decline in number.

**Table 3.5: Released Item for *Ecosystems*.**

|                       |                                                                                                             |                            |
|-----------------------|-------------------------------------------------------------------------------------------------------------|----------------------------|
| Ecosystems            | Relationships in simple food chains                                                                         |                            |
| Item Description      | Explains how an increase in the number of bats in an area could lead to a decrease in the number of insects |                            |
| Benchmark             | Item at High International Benchmark (550)                                                                  |                            |
| Percent Correct Score | Ireland: 47%                                                                                                | International Average: 43% |
| Reason for Inclusion  | Only topic within this subdomain which is included in the Third/Fourth Class curriculum.                    |                            |

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

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

**Solution:**

**Explains that the bats are likely eating the insects.**

**Examples:**

- **Bats eat insects.**
- **The bats are eating them.**
- **The bats are the insects' predators.**

See Appendix Table A3.5

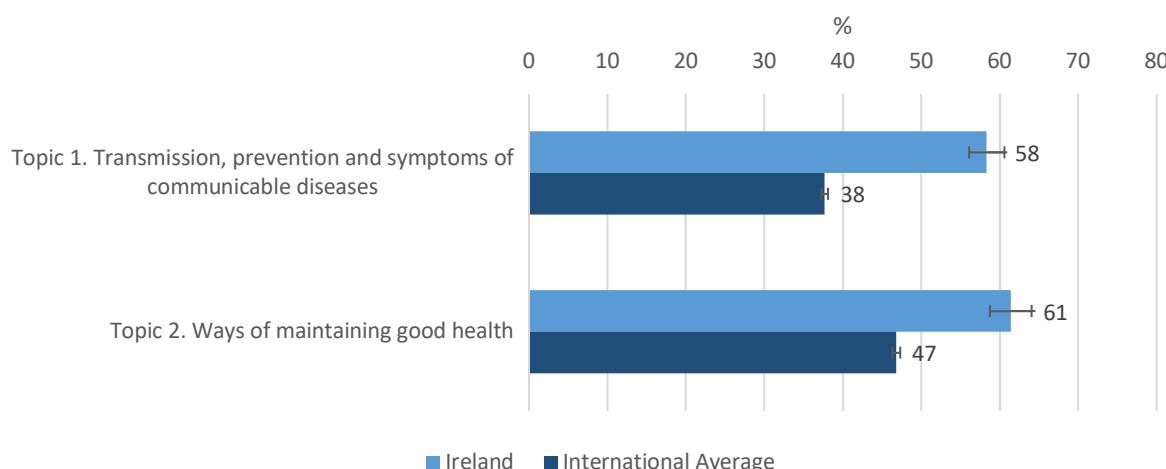
## Life Science Subdomain 5: Human Health

The final subdomain within Life Science is *Human health*. There are two topics within this subdomain. The second topic (*ways of maintaining good health*) links to the ‘human life’ strand unit within the Living Things strand. The first topic (*transmission, prevention, and symptoms of communicable diseases*) is not included in the primary science curriculum (for Third/Fourth Class or elsewhere) but is somewhat related to the Myself strand of the Third/Fourth Class SPHE curriculum.

Figure 3.7 presents the percent correct score for the two topics within *Human health*. At the topic level, the differences between Ireland and the international average were 21 percentage points for the first topic and 15 percentage points for the second topic. The first topic also showed the largest gender difference in Ireland of all the topics within Fourth Class science, with a ten percentage point difference in favour of girls (Appendix Table A3.4).

There were no released items relating to this subdomain.

**Figure 3.7: Percent correct scores at the topic level for the subdomain *Human health* in Ireland and on average internationally**



See Appendix Table A3.3.

*Note.* Ireland’s percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

## 3.3 PHYSICAL SCIENCE

In TIMSS 2019, Physical Science accounted for approximately one-third of the items (35%). Table 3.6 presents the linking of the Third/Fourth Class primary school science curriculum to the Physical Science content domain of the TIMSS framework. Physical Science is made up of three subdomains: *Classification and properties of matter and changes in matter*; *Forms of energy and energy transfer*; and *Forces and motion*. These subdomains do not map directly to the Third/Fourth Class curriculum, but relate mainly to the Energy and Forces and the Materials strands of the Third/Fourth Class primary science curriculum.

Within the subdomain of *Classification and properties of matter and changes in matter*, part of the second topic (*physical properties as a basis for classifying matter*) links with various parts of the science curriculum. Some elements, including the idea that heat can be transferred, link to the ‘heat’ strand unit within the curriculum, while grouping materials as conductors and insulators links with the ‘magnetism and electricity’ strand unit. Another topic within this subdomain is *physical changes*

*observed in everyday life*. This includes identifying observable changes which do not result in new materials with different properties, and identifying ways of increasing how quickly a solid material dissolves in a given amount of water. These concepts are not introduced until Fifth/Sixth Class. The final topic (*chemical changes observed in everyday life*) is not included at any stage in the primary science curriculum.

Within the subdomain *Forms of energy and energy transfer*, the first topic (*common sources and uses of energy*) relates somewhat to the ‘environmental awareness’ strand unit within the Environmental Awareness and Care strand of the Third/Fourth Class science curriculum. Other elements of this topic are not included in the primary science curriculum. All other topics within this subdomain relate to the Energy and Forces strand.

The final subdomain, *Forces and motion*, relates directly to the ‘forces’ strand unit within the Energy and Forces strand of the curriculum.

**Table 3.6: Primary School Curriculum: Science (Department of Education and Science, 1999c) linked to TIMSS 2019 Framework**

|                   | Third/Fourth Class Curriculum: Energy and Forces, Materials                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | TIMSS Framework                                                                                                                                                                                                                        |
|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Energy and Forces | <p><b>Light</b></p> <ul style="list-style-type: none"> <li>• Learn that light is a form of energy</li> <li>• Recognise that light comes from different natural and artificial sources</li> <li>• Investigate that light can be broken up into many different colours</li> <li>• Investigate the relationships between light and materials</li> <li>• Investigate how mirrors and other shiny surfaces are good reflectors of light</li> <li>• Recognise that the sun gives us heat and light, without which people and animals could not survive</li> <li>• Be aware of the dangers of looking directly at the sun</li> </ul> | <p><b>Forms of Energy and Energy Transfer</b></p> <p><b>2. Light and sound in everyday life</b></p>                                                                                                                                    |
|                   | <p><b>Sound</b></p> <ul style="list-style-type: none"> <li>• Learn that sound is a form of energy</li> <li>• Recognise and identify a variety of sounds in the environment</li> <li>• Understand and explore how different sounds may be made by making a variety of materials vibrate</li> <li>• Design and make a range of simple string instruments using an increasing variety of tools and materials</li> <li>• Explore the fact that sound travels through materials</li> </ul>                                                                                                                                         | <p><b>Forms of Energy and Energy Transfer</b></p> <p><b>2. Light and sound in everyday life</b></p>                                                                                                                                    |
|                   | <p><b>Heat</b></p> <ul style="list-style-type: none"> <li>• Learn that heat can be transferred</li> <li>• Recognise that temperature is a measurement of how hot something is</li> <li>• Measure changes in temperature using a thermometer</li> <li>• Measure and compare temperatures in different places in the classroom, school and environment and explore reasons for variations</li> <li>• Understand that the sun is the Earth’s most important heat source</li> <li>• Identify ways in which homes, buildings and materials are heated</li> </ul>                                                                   | <p><b>Classification and Properties of Matter and Changes in Matter</b></p> <p><b>2. Physical properties as a basis for classifying materials</b></p> <p><b>Forms of Energy and Energy Transfer</b></p> <p><b>2. Heat transfer</b></p> |

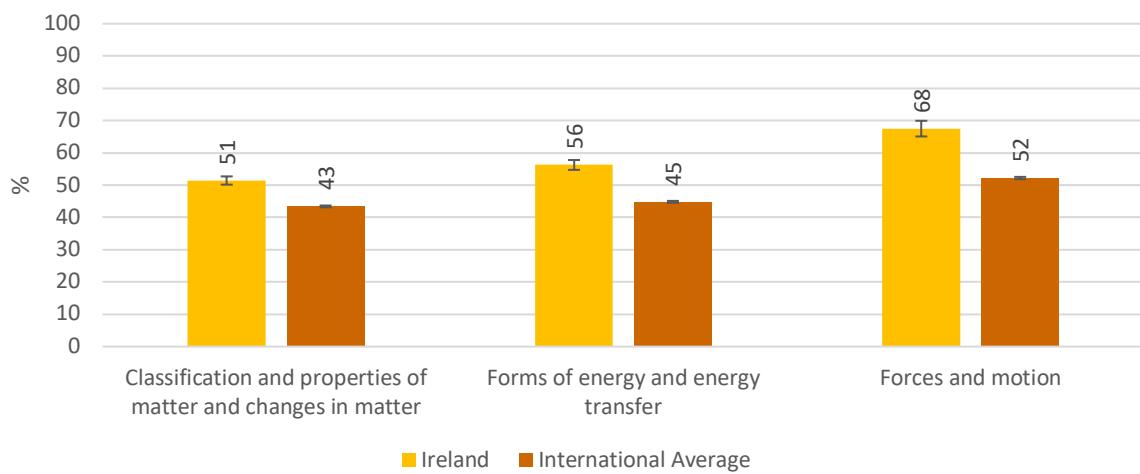
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|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Energy and Forces</b> | <p><b>Magnetism and Electricity</b></p> <ul style="list-style-type: none"> <li>• Learn that magnets can push or pull magnetic materials</li> <li>• Explore how magnets have poles and investigate how these poles attract and repel each other</li> <li>• Explore the relationship between magnets and compasses</li> <li>• Examine and classify objects and materials as magnetic and non-magnetic</li> <li>• Investigate that magnets attract certain materials through other materials</li> <li>• Explore the effects of static electricity</li> <li>• Observe the effects of static electricity on everyday things in the environment</li> <li>• Learn about electrical energy</li> <li>• Investigate current electricity by constructing simple circuits</li> <li>• Examine and group materials as conductors (those that conduct electricity) and insulators (those that do not allow electricity to pass through)</li> <li>• Become aware of the dangers of electricity.</li> </ul> <p><b>Forces</b></p> <ul style="list-style-type: none"> <li>• Explore how objects may be moved</li> <li>• Explore how some moving objects may be slowed down</li> <li>• Explore the effect of friction on movement through experimenting with toys and objects on various surfaces</li> <li>• Investigate falling objects</li> <li>• Explore how levers may be used to help lift different objects</li> <li>• Investigate the pushing force of water</li> </ul> | <p><b>Classification and Properties of Matter and Changes in Matter</b></p> <ol style="list-style-type: none"> <li>2. Physical properties as a basis for classifying materials</li> <li>3. Magnetic attraction and repulsion</li> </ol> <p><b>Forms of Energy and Energy Transfer</b></p> <ol style="list-style-type: none"> <li>4. Electricity and simple electrical systems</li> </ol>                                                                                    |
|                          | <p><b>Length Properties and characteristics of materials</b></p> <ul style="list-style-type: none"> <li>• Identify and investigate a range of common materials in the immediate environment</li> <li>• Recognise that materials can be solid, liquid or gaseous</li> <li>• Describe and compare materials, noting the differences in colour, shape and texture</li> <li>• Distinguish between raw and manufactured materials</li> <li>• Group materials according to their properties</li> <li>• Investigate how materials may be used in construction</li> </ul> <p><b>Materials and change</b></p> <p><i>Heating and cooling</i></p> <ul style="list-style-type: none"> <li>• Explore the effects of heating and cooling on a range of liquids, solids and gases</li> <li>• Investigate the suitability of different kinds of clothes for variations in temperature</li> <li>• Experiment to establish which materials are conductors of heat or insulators</li> </ul> <p><i>Mixing and other changes</i></p> <ul style="list-style-type: none"> <li>• Investigate how materials may be changed by mixing</li> <li>• Investigate the characteristics of different materials when wet and dry</li> <li>• Examine the changes that take place in materials when physical forces are applied</li> <li>• Explore some simple ways in which materials may be separated</li> </ul>                                                                             | <p><b>Classification and Properties of Matter and Changes in Matter</b></p> <ol style="list-style-type: none"> <li>1. Familiar forces and the motion of objects</li> <li>2. Simple machines</li> </ol> <p><b>Classification and Properties of Matter and Changes in Matter</b></p> <ol style="list-style-type: none"> <li>1. States of matter and characteristics differences of each state</li> <li>2. Physical properties as a basis for classifying materials</li> </ol> |
| <b>Materials</b>         | <p><b>Classification and Properties of Matter and Changes in Matter</b></p> <ol style="list-style-type: none"> <li>2. Physical properties as a basis for classifying materials</li> <li>4. Physical changes observed in everyday life</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |

Figure 3.8 presents the percent correct scores for the three subdomains of Physical Science. Comparing Ireland with the international average, there was an 18 percentage point difference for *Forces and motion*, an 11 percentage point difference for *Forms of energy and energy transfer*, and an eight percentage point difference for *Classification and properties of matter and changes in matter*. All of these differences were in favour of Ireland. This could be interpreted as indicating that

the subdomain *Forces and motion* was an area of relative strength for Ireland (i.e., the difference between Ireland and the international average in favour of Ireland was larger than for many other subdomains within Physical Science). Boys outperformed girls by four percentage points on *Forms of energy and energy transfer* and *Forces and motion*, while there was almost no gender difference in the subdomain *Classification and properties of matter and changes in matter* (Appendix Table A3.2).

Fourth Class teachers indicated that the proportions of pupils who had been taught the topics within Physical Science either before or during Fourth Class varied greatly. Topics including “common sources of energy and uses of energy” and “light and sound in everyday life” were already covered by at least four-fifths of pupils. However, other topics including “mixtures” and “chemical change in everyday life” had not yet been covered by the majority of pupils (Appendix Table A3.6).

**Figure 3.8: Percent correct score for the subdomains of Physical Science in Ireland and on average internationally**



See Appendix Table A3.1.

*Note.* The figure is an amended version of Figure 3.1 with only the subdomains of Physical Science represented. Due to rounding, some differences may appear inconsistent with those reported in text.

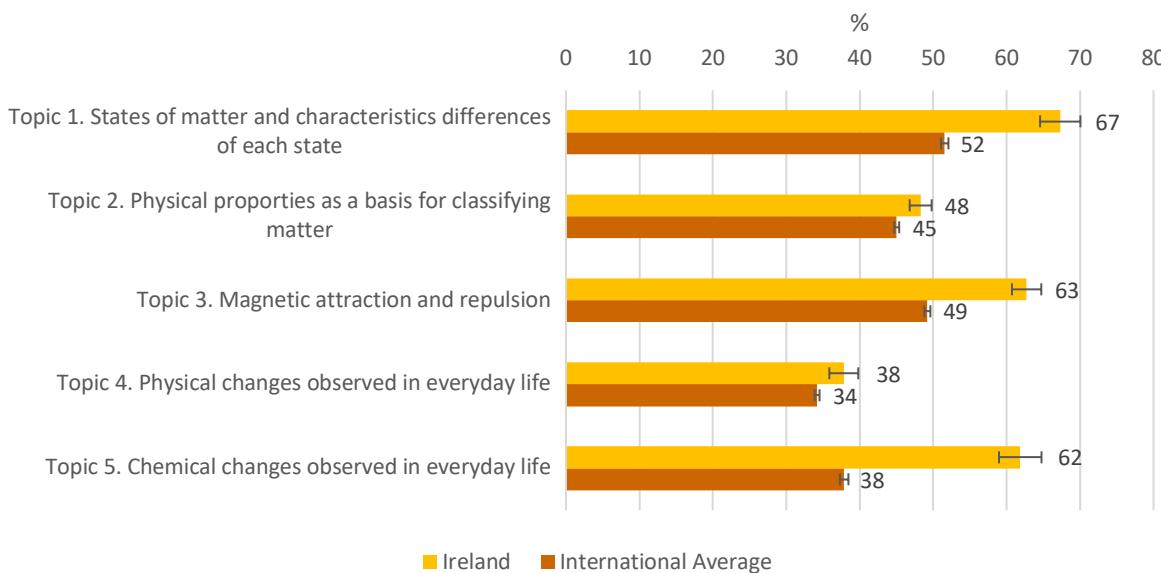
### **Physical Science Subdomain 1: Classification and Properties of Matter and Changes in Matter**

The first subdomain of Physical Science is *Classification and properties of matter and changes in matter* and it includes five topics. As mentioned above, the subdomain *Classification and properties of matter and changes in matter* relates mainly to the Materials strand of the Third/Fourth Class primary science curriculum. However, parts of the second topic (*physical properties as a basis for classifying matter*) relate to the strand units of ‘heat’ and ‘magnetism and electricity’ within the Energy and Forces strand. The fifth topic (*chemical changes observed in everyday life*) is not included in the primary science curriculum.

Figure 3.9 presents the percent correct score at the topic level in Ireland and on average internationally. The largest differences between Ireland and the TIMSS average were observed for the first, third and fifth topics (Figure 3.9). This suggests that these are topics where pupils in Ireland are performing relatively well. It is noteworthy that this includes the topic of *chemical changes observed in everyday life*, which is not part of the curriculum at primary level. Small differences in favour of Ireland (three percentage points and four percentage points, respectively) were observed for the second and fourth topics (Figure 3.9). The gender differences on each of these topics were two percentage points or

less. Some differences were in favour of boys while others were in favour of girls (Appendix Table A3.4).

**Figure 3.9: Percent correct scores at the topic level for the subdomain of *Classification and properties of matter and changes in matter* in Ireland and on average internationally**



See Appendix Table A3.3

Note. Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

Table 3.7 presents a released item which relates to the topic of *physical changes observed in everyday life*. This item was categorised as being at the *Advanced International Benchmark (625)*. Ireland had a percent correct score of 44% for part A and 35% for part B. Ireland's percent correct score was not significantly different from the international average for part A (41%) but was significantly above the international average for part B (26%).

For part A, pupils are asked, for each test, which of the experimental set-ups will dissolve the sugar faster. The three tests include different water temperatures, stirring of the water, and different cube sizes.

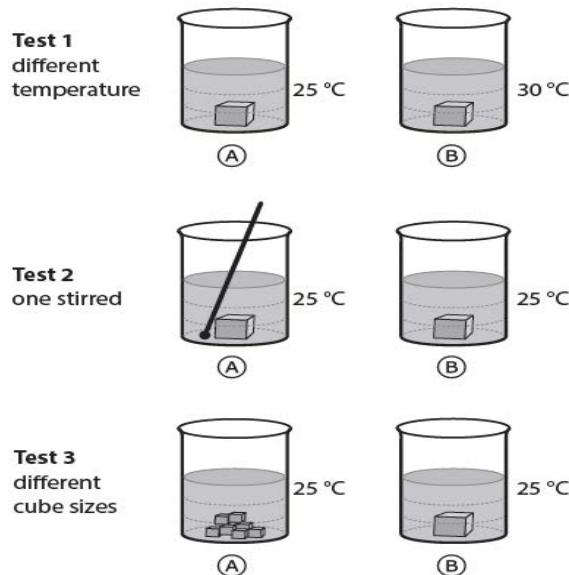
For part B, pupils are asked to explain why it is important that the amount of water is the same in each beaker. To receive credit, pupils must make at least one of these points: that the amount of water influences the rate of dissolution, that the amount of water is the control variable, or that if the amount of water varies between setups it is impossible to tell what effect the other variable has on the rate of dissolution.

**Table 3.7: Released Item for Classification and properties of matter and changes in matter**

|                                                               |                                                                                                                                                |                                                                                                          |
|---------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|
| Classification and properties of matter and changes in matter | Classification and properties of matter and changes in matter                                                                                  |                                                                                                          |
| Item Description                                              | A. Recognises setups that will more quickly dissolve a solid in water<br>B. Explains the importance of controlling a variable in an experiment |                                                                                                          |
| Benchmark                                                     | Item at Advanced International Benchmark (625)                                                                                                 |                                                                                                          |
| Percent Correct Score                                         | A. Ireland: Overall 44%<br>Part (a) 72%; (b) 69%; (c) 61%<br>B. Ireland: 35%                                                                   | A. International Average: Overall 41%<br>Part (a) 63%; (b) 64%; (c) 58%<br>B. International Average: 26% |
| Reason for Inclusion                                          | Item with two parts and topic where Ireland performed similar to the international average                                                     |                                                                                                          |

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

A. For each of the tests, tick the circle under the beaker that will dissolve the sugar faster.



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

**Solution:**

A. **Test 1 – B**  
**Test 2 – A**  
**Test 3 – A**

B. **Indicates one or more of these points:**

- The amount of water has an effect on the rate at which sugar dissolves.
- If the amount of water varies (is different) between setups, it is not possible to tell what effect changing the temperature (or stirring or cube size) has on the rate that the sugar dissolves.
- The amount of water is controlled or is a control variable.

See Appendix Table A3.5

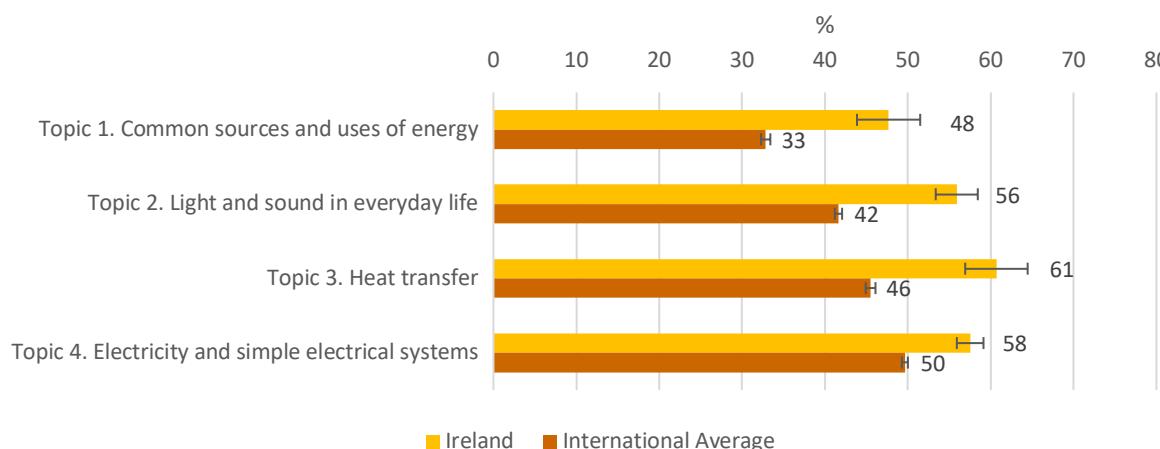
## Physical Science Subdomain 2: Forms of Energy and Energy Transfer

The second subdomain within Physical Science is *Forms of energy and energy transfer* which includes four topics, listed in Figure 3.10. This subdomain aligns mainly with the Energy and Forces strand of the Third/Fourth Class science curriculum. The first topic, *common sources and uses of energy*, is the exception as it somewhat aligns with the 'environmental awareness' strand unit in the Environmental Awareness and Care strand. Some other parts of this topic are not included in the primary science curriculum.

Comparing Ireland and the international average, three of the topics (the first, second and third topics shown in Figure 3.10) display similar differences in favour of Ireland (by 14 to 15 percentage points), highlighting several topics where pupils in Ireland performed relatively well. The remaining topic (Topic 4) had an eight percentage point difference between Ireland and the international average. For each of these topics, the gender difference in Ireland was in favour of boys, with differences ranging from two percentage points for the topic *light and sound in everyday life* to seven percentage points for *common sources and uses of energy* (Appendix Table A3.4).

According to the Teacher Questionnaire, most pupils (over four-fifths) had been taught the concepts of "common sources of energy and uses of energy" and "light and sound in everyday life" before or during Fourth Class. However, over two-fifths (44%) had not yet covered heat transfer or electricity and simple electrical circuits by the time that the TIMSS testing took place (March/April 2019) (Appendix Table A3.6).

**Figure 3.10: Percent correct scores at the topic level for the subdomain of *Forms of energy and energy transfer* in Ireland and on average internationally**



See Appendix Table A3.3.

*Note.* Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

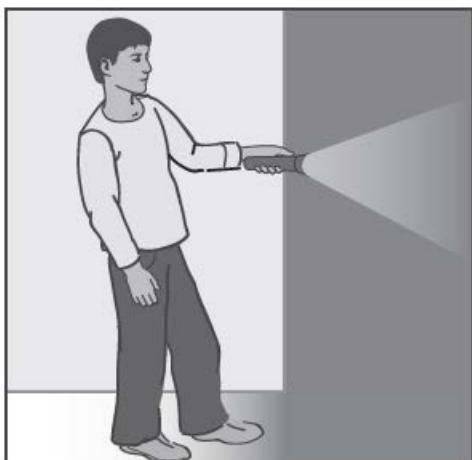
A released item relating to the subdomain *Forms of energy and energy transfer* is presented in Table 3.8. This relates to the topic *electricity and simple electrical systems*. The item was categorised as being at the *High International Benchmark (550)*. In Ireland, over three in five pupils (62%) who answered this item did so correctly, while internationally the percent correct score was 64%. There was no significant difference between Ireland and the international average.

Pupils are asked to choose which statement describes the change in energy caused by Jake switching on a torch; i.e., that electrical energy changes into light energy. Almost one-fifth of pupils (18%) in Ireland chose option (c) indicating that light energy changes into electrical energy, while over one-tenth (12%) chose option (b) suggesting that motion energy changes into light energy.

**Table 3.8: Released Item for *Forms of Energy and Energy Transfer***

|                                     |                                                                                                                            |                            |
|-------------------------------------|----------------------------------------------------------------------------------------------------------------------------|----------------------------|
| Forms of energy and energy transfer | Electricity and simple electrical systems                                                                                  |                            |
| Item Description                    | Recognises the energy change that occurs when a torch is turned on                                                         |                            |
| Benchmark                           | Item at High International Benchmark (550)                                                                                 |                            |
| Percent Correct Score               | Ireland: 62%                                                                                                               | International Average: 64% |
| Reason for Inclusion                | Item where there is no significant difference between the percent correct score in Ireland and on average internationally. |                            |

Jake switches on a torch.



One kind of energy changes into another kind of energy in the torch. Which statement describes this change?

- (a) Electrical energy changes into light energy
- (b) Motion energy changes into light energy
- (c) Light energy changes into electrical energy
- (d) Light energy changes into motion energy

**Solution: (a) Electrical energy changes into light energy**

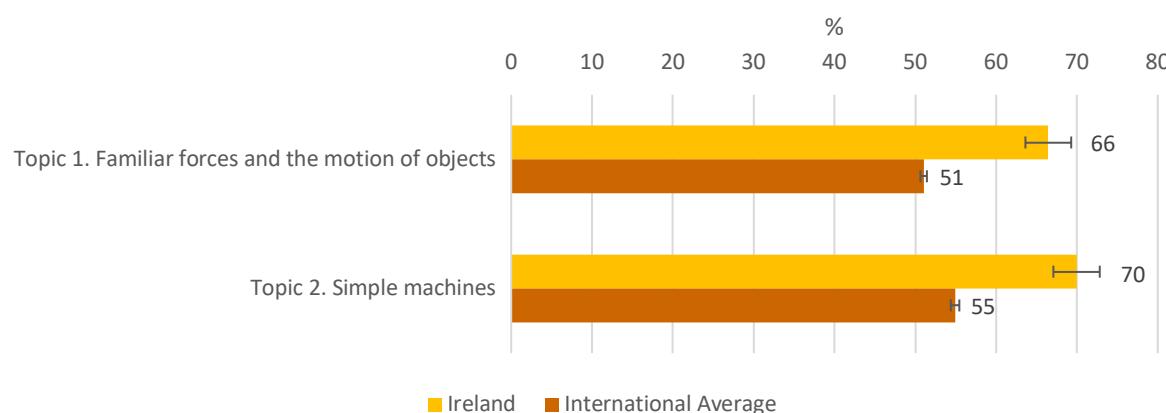
See Appendix Table A3.5

### **Physical Science Subdomain 3: Forces and Motion**

The final subdomain within Physical Science is *Forces and motion*. The difference between Ireland and the international average on this subdomain was larger than at the overall domain level, and also compared to the other subdomains within Physical Science. This could be interpreted as indicating that *Forces and motion* was an area of relative strength for Ireland. This subdomain relates to the 'forces' strand unit within the Energy and Forces strand of the Third/Fourth Class science curriculum.

Figure 3.11 presents the percent correct scores at the topic level for this subdomain, which includes two topics. There were differences of 15 percentage points between Ireland and the international average on each of these topics. Gender differences in favour of boys were observed for each of these topics, with a two percentage point difference for the first topic and an eight percentage point difference for the second topic (Appendix Table A3.4).

**Figure 3.11: Percent correct scores at the topic level for the subdomain of *Forces and motion* in Ireland and on average internationally**



See Appendix Table A3.3.

*Note.* Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

Table 3.9 presents a released item which relates to the first topic within *Forces and motion: familiar forces and the motion of objects*. This item relates to the ‘forces’ strand unit within the Energy and Forces strand of the Third/Fourth Class primary science curriculum. The item was classified at the *High International Benchmark (550)*. Three-quarters of pupils in Ireland who answered this question did so correctly, which was significantly above the international average (60%).

In this question, pupils are asked to recognise the force that causes a skydiver to fall to Earth. Looking at the proportions of pupils who responded to distractor (that is, incorrect) options, close to one-tenth of pupils in Ireland chose option (a) (Earth’s air; 12%) or option (b) (Earth’s magnetic force; 9%). Less than 5% of pupils responded with option (d) (Earth’s rotation).

**Table 3.9: Released Item for *Forces and motion*.**

|                       |                                                                                                                                    |                            |
|-----------------------|------------------------------------------------------------------------------------------------------------------------------------|----------------------------|
| Forces and motion     | Familiar forces and the motion of objects                                                                                          |                            |
| Item Description      | Recognises the force that causes a skydiver to fall to Earth                                                                       |                            |
| Benchmark             | Item at High International Benchmark (550)                                                                                         |                            |
| Percent Correct Score | Ireland: 75%                                                                                                                       | International Average: 60% |
| Reason for Inclusion  | Item where Ireland was significantly above the international average in a topic and subdomain where Ireland was relatively strong. |                            |

A skydiver jumps out of a plane and parachutes to Earth.



What causes the skydiver to fall towards the Earth?

- (a) Earth's air
- (b) Earth's magnetic force
- (c) Earth's gravity
- (d) Earth's rotation

**Solution: (c) Earth's gravity**

See Appendix Table A3.5.

## 3.4 EARTH SCIENCE

The final content domain for Grade 4 science is Earth Science. This accounted for one-fifth of the items on the TIMSS assessment. Table 3.10 and Table 3.11 present the linking of the Third/Fourth Class primary school science curriculum to Earth Science in the TIMSS framework. In contrast to the other domains, this content domain relates mainly to the primary geography curriculum (Table 3.10). It aligns somewhat with the Third/Fourth Class, but mainly with the Fifth/Sixth Class, geography curriculum, relating to the Natural Environments strand.

Table 3.10 presents the linking of the TIMSS framework to the geography curriculum to provide an understanding of where the subdomains fit in within the Irish context.<sup>13</sup> It should be noted that despite many of the topics being part of the Fifth/Sixth Class curriculum, Ireland performed equally as well as, if not slightly better than, their peers internationally in this domain).

<sup>13</sup> Please note that Table 3.10 includes only the parts of the geography curriculum which relate to the TIMSS framework. For the full curriculum, please see: [PSEC03b\\_Geography\\_Curriculum.pdf \(curriculumonline.ie\)](https://curriculumonline.ie/PSEC03b_Geography_Curriculum.pdf).

**Table 3.10: Primary School Curriculum (Third/Fourth Class and Fifth/Sixth Class): Geography (Department of Education and Science, 1999a) linked to the TIMSS 2019 Framework**

|                                                    | <b>Primary Geography Curriculum</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>TIMSS Framework</b>                                                                                                                |
|----------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| <b>Third/Fourth Class<br/>Natural Environments</b> | <p><b>Planet Earth in Space</b></p> <ul style="list-style-type: none"> <li>Observe, describe, and record the positions of the sun when rising and setting and the changing lengths of day and night during the seasons</li> <li>Investigate shadows, directions, and sunlight</li> <li>Understand the importance of sunlight for plants and animals</li> <li>Begin to understand the influence of the sun on weather and atmospheric conditions</li> <li>Become aware of the dangers of sunlight for skin and eyesight</li> </ul> <p><b>Weather, Climate and Atmosphere</b></p> <p><i>Weather observations</i></p> <ul style="list-style-type: none"> <li>Use simple equipment to observe and record weather phenomena</li> <li>Record and display simple weather observations in a systematic way using graphs, charts and common meteorological symbols</li> <li>Use analysis of weather recordings to associate simple descriptions of clouds, amount of cloud cover, wind direction and other conditions with particular types of weather; make and test weather predictions</li> <li>Compare temperatures indoors and outdoors, in shade and sunlight, on different sides of the same building, and explore reasons for differences</li> </ul> <p><i>Weather and climate</i></p> <ul style="list-style-type: none"> <li>Study weather variations during the year and their influence on plants, animals and humans</li> <li>Begin to appreciate the importance of solar energy for the Earth</li> <li>Develop some awareness of weather and climate patterns and their relationships with plant, animal and human life in some environments in other parts of the world</li> <li>Collect and record weather lore from the locality</li> </ul> | <p><b>Earth in the Solar System</b></p> <p><b>2. Earth's motion and related patterns observed on Earth</b></p>                        |
|                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | <p><b>Earth's Weather and Climates</b></p> <p><b>1. Weather and climates on Earth</b></p>                                             |
| <b>Fifth/Sixth Class<br/>Natural Environments</b>  | <p><b>The Local Natural Environment</b></p> <ul style="list-style-type: none"> <li>Investigate and learn about the main natural features in the locality and county</li> <li>Observe and develop simple understanding of the links between these features</li> <li>Investigate the influence of these features on plants and on the lives of animals and people</li> <li>Become aware of the ways in which people, animals and plants have exploited and/or altered these features</li> </ul> <p><b>Land, Rivers and Seas in Ireland</b></p> <ul style="list-style-type: none"> <li>Become familiar with the names and locations of some major natural features in Ireland</li> <li>Become familiar with the relationship of these features with each other, with elements of the built environment and with significant natural features of Ireland</li> <li>Understand some of the interrelationships between these natural features and the lives of plants, animals and humans</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <p><b>Earth's Physical Characteristics, Resources and History</b></p> <p><b>3. Earth's history</b></p>                                |
|                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | <p><b>Earth's Physical Characteristics, Resources and History</b></p> <p><b>1. Physical characteristics of the Earth's system</b></p> |

|                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                    |
|---------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Fifth/Sixth Class<br/>Natural Environments</b> | <p><b>Rocks and Soils</b></p> <p><i>Rocks</i></p> <ul style="list-style-type: none"> <li>• Collect and identify some common rocks in the locality</li> <li>• Identify and explore the use of stone in building and other human activities, especially in the locality</li> <li>• Develop simple understanding of the structure of the Earth, using terms such as core, mantle, crust, plates of the crust, lava flow, volcano, earthquake</li> <li>• Learn about the characteristics of some common rock types and where they may be found in Ireland and in other parts of the world</li> </ul> <p><i>Soils</i></p> <ul style="list-style-type: none"> <li>• Collect and examine soil samples and their constituents</li> <li>• Compare soil samples from different parts of the locality</li> <li>• Learn of the relationship of plants and farming to soil types</li> <li>• Be familiar with some ways of changing and/or improving soil structure.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <p><b>Earth's Physical Characteristics, Resources and History</b></p> <p><b>3. Earth's history</b></p>                                                                             |
|                                                   | <p><b>Weather, Climate and Atmosphere</b></p> <p><i>Weather observations</i></p> <ul style="list-style-type: none"> <li>• Use simple equipment to make detailed weather observations and recordings of phenomena</li> <li>• Record and display simple weather observations in a systematic way using graphs, charts and common meteorological symbols</li> <li>• Use analysis of weather recordings to associate simple descriptions of clouds, amount of cloud cover, wind direction and other conditions with particular types of weather; make and test weather predictions</li> <li>• Collect weather lore, especially local traditions and knowledge</li> </ul> <p><i>Weather and climate</i></p> <ul style="list-style-type: none"> <li>• Explore weather patterns over the year in the locality using a variety of graphical and analytical skills</li> <li>• Begin to appreciate the difference between climate and weather</li> <li>• Develop some awareness of weather patterns in other parts of Ireland and factors influencing climate in the locality and in Ireland</li> <li>• Explore the relationships between climatic factors and aspects of building construction</li> <li>• Become aware of the characteristics of some major climatic regions in different parts of the world</li> <li>• Explore the relationship of climate to plant, animal and human life</li> </ul> <p><i>The atmosphere</i></p> <ul style="list-style-type: none"> <li>• Develop simple understanding of some atmospheric features</li> </ul> | <p><b>Earth's Weather and Climates</b></p> <p><b>1. Weather and climates on Earth</b></p>                                                                                          |
|                                                   | <p><b>Planet Earth in Space</b></p> <p><i>The Earth and the sun</i></p> <ul style="list-style-type: none"> <li>• Observe and record the positions of the sun when rising and setting and at different times of the day</li> <li>• Investigate the relative lengths and directions of shadows and the intensity of sunlight at different times of the year</li> <li>• Observe the changing lengths of day and night during the seasons</li> <li>• Understand the importance of sunlight as a source of energy for plants and animals</li> <li>• Become aware of the influence of the sun on atmospheric conditions</li> <li>• Become aware of the dangers of sunlight for eyesight and skin</li> </ul> <p><i>The Earth, moon and Solar System</i></p> <ul style="list-style-type: none"> <li>• Recognise that the Earth, its moon, the sun, other planets and their satellites are separate bodies and are parts of the Solar System</li> <li>• Develop a simple understanding of the interrelationship of these bodies, including day and night and seasonal movements</li> <li>• Recognise a few of the major star constellations</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                            | <p><b>Earth in the Solar System</b></p> <p><b>1. Objects in the Solar System and their environments</b></p> <p><b>2. Earth's motion and related patterns observed on Earth</b></p> |

Table 3.11 presents the linking between the Third/Fourth Class science curriculum and the TIMSS Framework. These topics relate to the Environmental Awareness and Care strand (Table 3.10). As mentioned in the previous sections, one topic from both Life Science and Physical Science also relate to the Environmental Awareness and Care strand (Table 3.11).

**Table 3.11: Primary School Curriculum: Science (Department of Education and Science, 1999c) linked to TIMSS 2019 Framework**

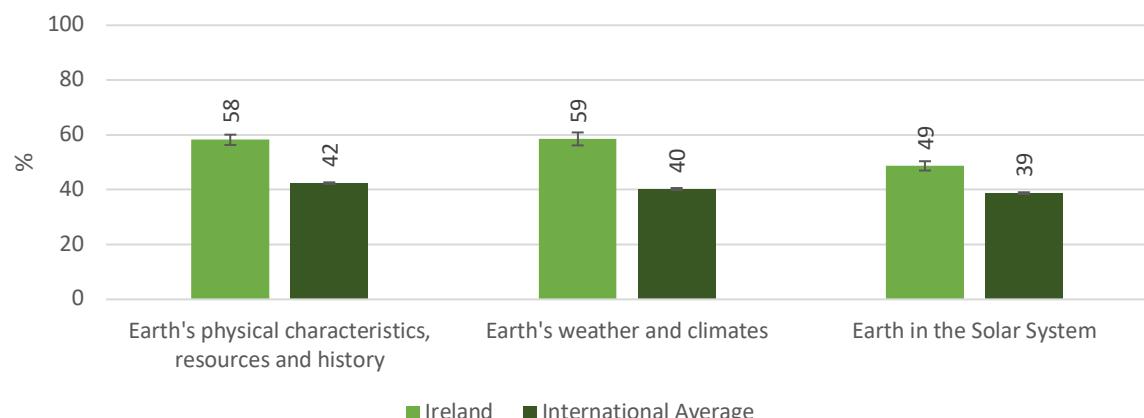
|                                  | Third/Fourth Class Curriculum: Environmental Awareness and Care                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | TIMSS Framework                                                                                                                                                                                                            |
|----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Environmental Awareness and Care | <p><b>Environmental Awareness</b></p> <ul style="list-style-type: none"> <li>Identify positive aspects of natural and built environments through observation, discussion and recording</li> <li>Identify the interrelationship of the living and non-living elements of local and other environments</li> <li>Become aware of the importance of the Earth's renewable and non-renewable resources</li> <li>Recognise how the actions of people may impact upon environments</li> <li>Come to appreciate the need to conserve resources</li> </ul> | <p><b>Organisms, Environment, and Their Interactions</b></p> <p><b>3. The impact of humans on the environment</b></p> <p><b>Forms of Energy and Energy Transfer</b></p> <p><b>1. Common sources and uses of energy</b></p> |
|                                  | <p><b>Science and the Environment</b></p> <ul style="list-style-type: none"> <li>Begin to explore and appreciate the application of science and technology in familiar contexts</li> <li>Identify some ways in which science and technology contributes positively to society</li> <li>Recognise and investigate human activities which have positive or adverse effects on local and wider environments</li> </ul>                                                                                                                               | <p><b>Earth's Physical Characteristics, Resources and History</b></p> <p><b>2. Earth's resources</b></p>                                                                                                                   |
|                                  | <p><b>Caring for the Environment</b></p> <ul style="list-style-type: none"> <li>Examine a number of ways in which the local environment could be improved or enhanced</li> <li>Identify and discuss a local, national or global environmental issue</li> <li>Realise that there is a personal and community responsibility for taking care of the environment.</li> </ul>                                                                                                                                                                         |                                                                                                                                                                                                                            |

Figure 3.12 presents the percent correct score for the subdomains of Earth Science in Ireland and on average internationally. Pupils in Ireland had a percent correct score which was 16 percentage points above the international average for *Earth's physical characteristics, resources and history*, and 18 percentage points above the international average for *Earth's weather and climates*. The third subdomain (*Earth in the Solar System*) had the smallest difference between Ireland and the international average (10 percentage points). This suggests that *Earth in the Solar System* is an area where pupils in Ireland are performing less well relative to the other subdomains within this domain.

Boys and girls performed very similarly on the second subdomain (*Earth's weather and climates*). Boys' score for *Earth's physical characteristics, resources and history* was three percentage points higher than girls', and four percentage points higher for *Earth in the Solar System* (Appendix Table A3.2).

Teachers of over three-quarters of pupils reported that most of the concepts relating to Earth Science were taught either before or during Fourth Class. Exceptions to this include "changes in the Earth's surface over time", and "fossils and what they can tell us about past conditions on Earth". Teachers reported that more than half of pupils had not yet covered these concepts (Appendix Table A3.6).

**Figure 3.12: Percent correct score for the subdomains of Earth Science in Ireland and on average internationally**



See Appendix Table A3.1.

Note. The figure is an amended version of Figure 3.1 with only the subdomains of Earth Science represented. Due to rounding, some differences may appear inconsistent with those reported in text.

### ***Earth Science Subdomain 1: Earth's Physical Characteristics, Resources and History***

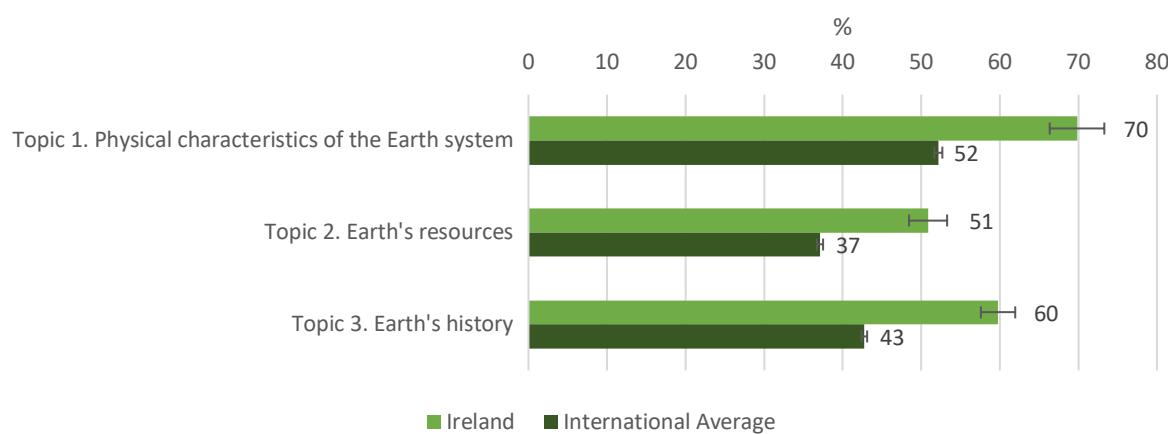
The first subdomain of Earth Science is *Earth's physical characteristics, resources and history* which has three topics. This subdomain links to the Environmental Awareness and Care strand of the Third/Fourth Class science curriculum (topic: *physical characteristics of the Earth system*) and the Natural Environments strand of the Fifth/Sixth Class geography curriculum (topics: *Earth's resources* and *Earth's history*).

Figure 3.13 presents the percent correct scores at the topic level. The difference between Ireland and the international average for the first and third topics were similar (17 percentage points). The second topic had a 14 percentage point difference in favour of Ireland. Boys in Fourth Class had a higher percent correct score than girls for both the first topic (by nine percentage points) and the third topic (by four percentage points). For the second topic, boys and girls had broadly similar percent correct scores (Appendix Table A3.4).

The first and third topics were reported by teachers to have been well-covered, with more than 90% of pupils reported to have covered the topics before or during Fourth Class (Appendix Table A2.6).

There were no released items relating to this subdomain.

**Figure 3.13: Percent correct scores at the topic level for the subdomain *Earth's physical characteristics, resources and history* in Ireland and on average internationally**



See Appendix Table A3.3.

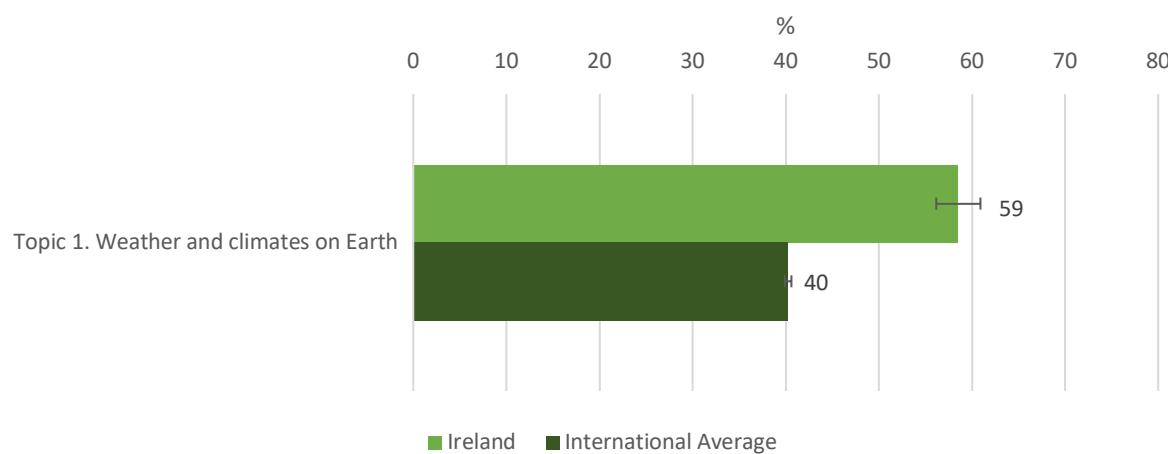
Note. Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

### **Earth Science Subdomain 2: Earth's Weather and Climates**

The second subdomain within Earth Science is *Earth's weather and climates*. This topic aligns with the 'weather, climate and atmosphere' strand unit of the Natural Environments strand of the primary geography curriculum. Some parts of this topic align with the Third/Fourth Class geography curriculum while other parts, including knowledge of weather events, align with the Fifth/Sixth Class geography curriculum.

Figure 3.14 presents the percent correct score at the topic level. There is only one topic in this subdomain: *weather and climates on Earth*. Ireland's percent correct score was 18 percentage points higher than on average internationally. Boys and girls in Fourth Class had a similar percent correct score for this topic (Appendix Table A3.4).

**Figure 3.14: Percent correct scores at the topic level for the subdomain *Earth's weather and climates* in Ireland and on average internationally**



See Appendix Table A3.3.

Note. Ireland's percent correct score was significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

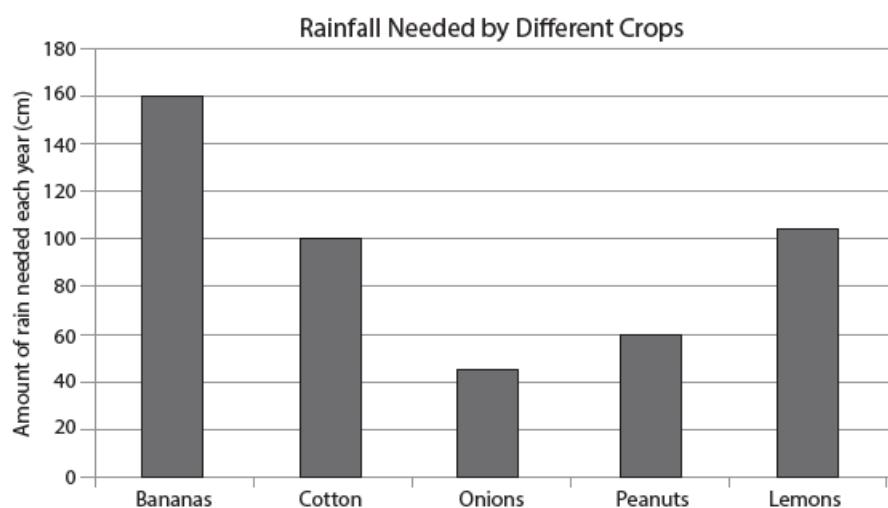
A released item relating to this subdomain is presented in Table 3.12. It includes two parts, the first of which is presented below. It was classified at the *High International Benchmark (550)*.

In this item, pupils are asked to interpret information from a graph to recognise which crops will grow best in an area with given precipitation. Three-fifth of pupils in Ireland who answered this question did so correctly, which was significantly above the international average (52%). Almost one-fifth of pupils (19%) chose option (d) and over one-tenth (12%) chose option (a).

**Table 3.12: Released Item for *Earth's Weather and Climates***

|                             |                                                                                                                 |                            |
|-----------------------------|-----------------------------------------------------------------------------------------------------------------|----------------------------|
| Earth's weather and climate | Weather and climates on Earth                                                                                   |                            |
| Item Description            | Interprets information from a graph to recognise which crops will grow best in an area with given precipitation |                            |
| Benchmark                   | Item at High International Benchmark (550)                                                                      |                            |
| Percent Correct Score       | Ireland: 62%                                                                                                    | International Average: 52% |
| Reason for Inclusion        | Item where Ireland performed significantly above the international average                                      |                            |

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



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

- Onions only
- Onions and peanuts
- Cotton and lemons
- Bananas, lemons and cotton

**Solution: (b) Onions and peanuts**

See Appendix Table A3.5

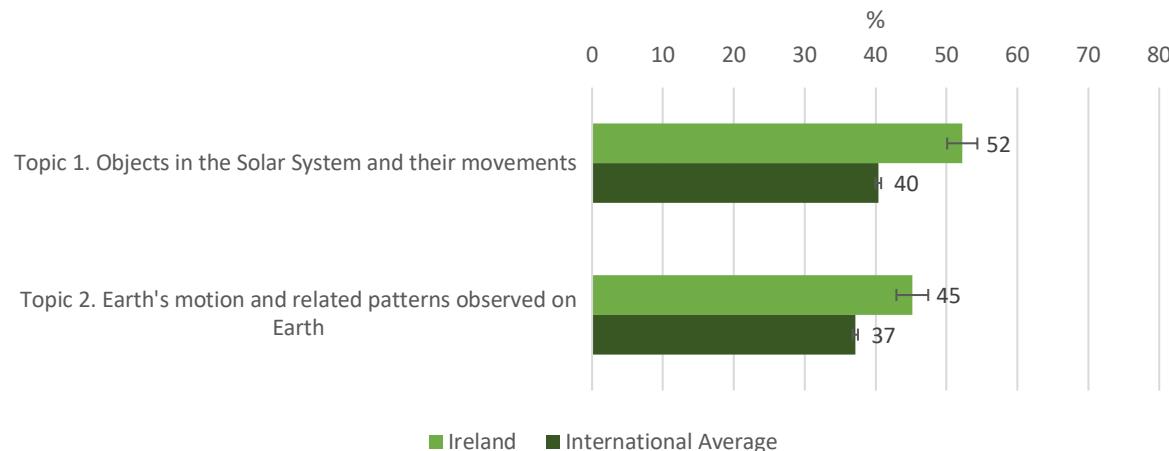
### ***Earth Science Subdomain 3: Earth in the Solar System***

The final subdomain within Earth Science is *Earth in the Solar System*. This subdomain relates to the ‘planet earth in space’ strand unit of the Natural Environments strand of the primary geography curriculum. Similar to the last subdomain, some topics and parts of topics are included in the Third/Fourth Class geography curriculum, while others are included in the Fifth/Sixth Class curriculum.

Figure 3.15 presents the percent correct scores at the topic level. Pupils in Ireland had a 12 percentage point advantage over the international average for Topic 1, and an eight percentage point advantage for Topic 2. Boys had a higher percent correct score than girls for the second topic (by six percentage points) while for the first topic, boys and girls achieved very similar scores (Appendix Table A3.4).

Both topics were reported by teachers to have been well-covered by the end of Fourth Class, with more than 80% of pupils reported to have covered the topics before or during Fourth Class (Appendix Table A3.6).

**Figure 3.15: Percent correct scores at the topic level for the subdomain *Earth in the Solar System* in Ireland and on average internationally**



See Appendix Table A3.3.

*Note.* Ireland's percent correct score at each of these optics levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

A released item relating to this subdomain is presented in Table 3.13. It was classified at the *Advanced International Benchmark (625)*. As noted in Chapter 1, TIMSS 2019 included a TCMA exercise which asked subject experts to identify any items that would be considered outside the curriculum. This is one example of an item which subject experts deemed to be not part of the prescribed curriculum for Third/Fourth Class. Despite this, pupils in Ireland achieved 44% correct on this item – choosing option (c) – which was significantly above the international average (34%).

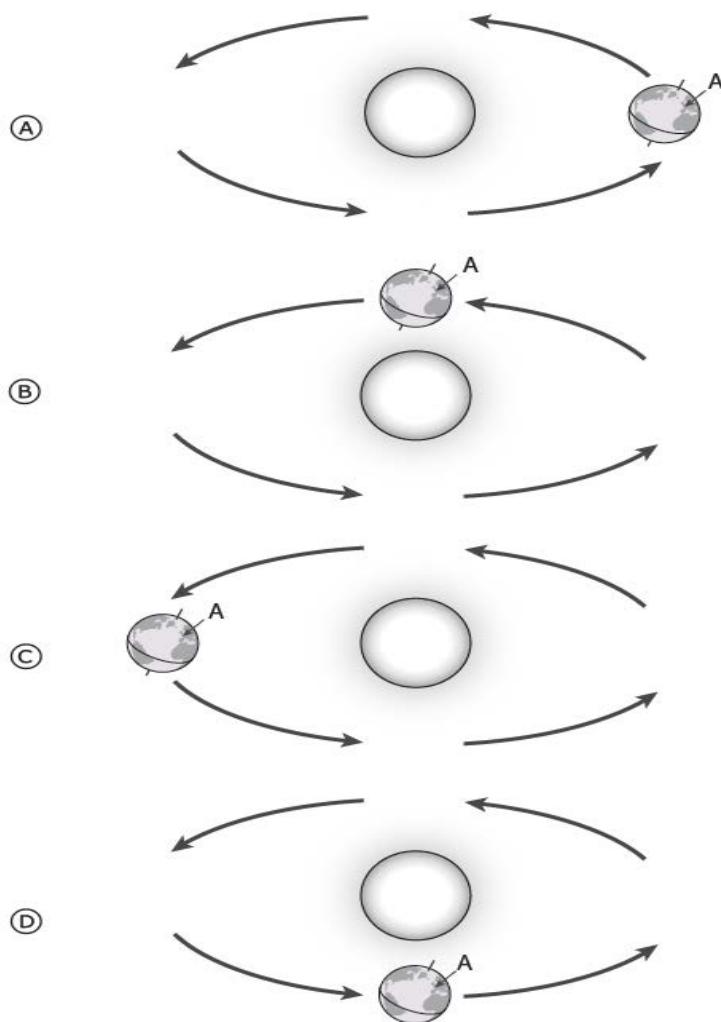
Table 3.13 presents the item. In this question, pupils are asked to indicate which option shows the position of the Earth relative to the sun when City A is experiencing summer. Two-fifths of pupils chose option (b) and (d), while a further one-tenth chose option (a).

**Table 3.13: Released Item for *Earth in the Solar System***

|                           |                                                                                                                                                       |                            |
|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|
| Earth in the Solar System | Earth's motion and related patterns observed on Earth                                                                                                 |                            |
| Item Description          | Places the Earth in a model to show its position relative to the Sun when a labelled city is experiencing summer                                      |                            |
| Benchmark                 | Item at Advanced International Benchmark (625)                                                                                                        |                            |
| Percent Correct Score     | Ireland: 44%                                                                                                                                          | International Average: 34% |
| Reason for Inclusion      | Pupils in Ireland were significantly above the international average on this item despite it not being included as part of the prescribed curriculum. |                            |

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

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



**Solution: (c)**

See Appendix Table A3.5

# Chapter 4 – Second Year Mathematics

## 4.1 INTRODUCTION

The TIMSS mathematics assessment at Grade 8 (in Ireland, Second Year) has four content domains: Number, Algebra, Geometry, and Data & Probability. Each of the content domains contributes a different proportion of the assessment. The TIMSS 2019 Framework outlines the proportion of the assessment allocated to each of the content domains. Number and Algebra were each planned to account for 30%, and Geometry and Data & Probability were each planned to account for 20%, of the mathematics assessment (Mullis & Martin, 2017). Perkins and Clerkin (2020) reported that the final distributions of items across the four content domains (Number, Algebra, Geometry and Data & Probability) were similar to the planned distributions at 30%, 29%, 21% and 20% respectively.

The content domains differ somewhat between Grade 4 and Grade 8 to reflect the mathematics widely taught at each level across the range of TIMSS countries. At Grade 4, Algebra content is included as part of Number while at Grade 8 it is a separate content domain. Measurement & Geometry is a content domain for Grade 4, but the corresponding domain at Grade 8 is Geometry. However, it is important to note that the Grade 8 domain of Geometry also includes measurements, such as area and volume. Finally, the Data domain at Grade 4 does not include any probability, while the content domain is framed as Data & Probability for Grade 8.

Each content domain is made up of a number of subdomains and topics, as outlined in Chapter 1. This chapter presents the percent correct scores at the mathematics content domain, subdomain and topic levels for Ireland and on average internationally for Grade 8. Comparisons to the international average are used as a basis for identifying areas where students in Ireland perform particularly strongly or do relatively less well, as percent correct scores do not take relative item difficulty across subdomains or topics into consideration.

As part of the Teacher Questionnaire, teachers were asked to indicate whether various concepts were *mostly taught before this year*, *mostly taught this year*, or *not yet taught or just introduced*. This contextual information collected from teachers is used for further interpretation of the findings, which is particularly helpful in this context given that the mathematics curriculum at Junior Cycle covers First Year to Third Year whereas students participating in TIMSS are assessed near the end of Second Year. It should be noted that the wording of the concepts in the Teacher Questionnaire are not identical to those of the subdomains or topics in the Assessment Framework but are generally broadly similar. For example, one set of concepts in the Teacher Questionnaire is “translation, reflection and rotation” while the corresponding topic is framed as *recognise and draw images of geometric transformations (translations, reflections, and rotations) in the plane; identify congruent and similar triangles and rectangles and solve related problems*. It should also be noted that new specifications for Junior Cycle mathematics were introduced in September 2018.

Released items are also presented for each subdomain (one per subdomain). This is to provide examples of the types of items used in TIMSS. Items are classified by benchmark as being indicative of the *Low International Benchmark (400)*, *Intermediate International Benchmark (475)*, *High International Benchmark (550)*, *Advanced International Benchmark (625)*, or *Above the Advanced International Benchmark (625+)*. Table 4.1 is adapted from Exhibit 3.8 in the TIMSS 2019 International Report and summarises what Grade 8 students who reached each of the International Benchmarks can do in mathematics (Mullis et al., 2020).

**Table 4.1: Summary of the TIMSS 2019 International Benchmarks of Grade 8 Mathematics Achievement (adapted from Exhibit 3.8 in Mullis et al., 2020)**

| International Benchmarks                    | Scale Score | Summary                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|---------------------------------------------|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Advanced International Benchmark</b>     | <b>625</b>  | Students can apply and reason in a variety of problem situations, solve linear equations, and make generalisations. They can solve a variety of fraction, proportion, and percent problems and justify their conclusions. They can understand linear functions and algebraic expressions. Students can use their knowledge of geometric figures to solve a wide range of problems involving angles, area, and surface area. They can calculate means and medians and understand how changing data points can impact the mean. Students can interpret a wide variety of data displays to draw and justify conclusions and solve multistep problems. They can solve problems involving expected values. |
| <b>High International Benchmark</b>         | <b>550</b>  | Students can apply their understanding and knowledge in a variety of relatively complex situations. They can solve problems with fractions, decimals, ratios, and proportions. Students at this level show basic procedural knowledge related to algebraic expressions and equations. They can solve a variety of problems with angles, including problems involving triangles, parallel lines, rectangles, and congruent and similar figures. Students can interpret data in a variety of graphs and solve simple problems involving outcomes and probabilities.                                                                                                                                     |
| <b>Intermediate International Benchmark</b> | <b>475</b>  | Students can apply basic mathematical knowledge in a variety of situations. They can solve problems involving whole numbers, negative numbers, fractions, decimals, and ratios. Students have some basic knowledge about properties of two-dimensional shapes. They can read and interpret data in graphs and have some rudimentary knowledge of probability.                                                                                                                                                                                                                                                                                                                                         |
| <b>Low International Benchmark</b>          | <b>400</b>  | Students have some knowledge of whole numbers and basic graphs.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

At the content domain level, students in Ireland had percent correct scores which were above the international average for the 17 countries that participated in *paperTIMSS* at Grade 8 in 2019.<sup>14</sup> There was a difference of approximately 20 percentage points between Ireland and the international average for Number and for Data & Probability, which can be viewed as areas of relative strength for Ireland, and differences of eight and seven percentage points for Geometry and Algebra respectively, indicating that the advantage of students in Ireland on these domains is smaller. This pattern of results across content areas reflects those described in Perkins and Clerkin (2020), where student performance across content areas was described in terms of scale scores which take the difficulty level of items into account.

Figure 4.1 presents the percent correct score on each of the Grade 8 mathematics subdomains in Ireland (lighter bars) and internationally (darker bars). As was found at the domain level, in each of the subdomains Ireland's percent correct score was significantly above the international average (Appendix Table A4.1).

<sup>14</sup> Australia, Bahrain, Cyprus, Egypt, Iran, Ireland, Japan, Jordan, Kazakhstan, Kuwait, Lebanon, Morocco, New Zealand, Oman Romania, Saudi Arabia and South Africa.

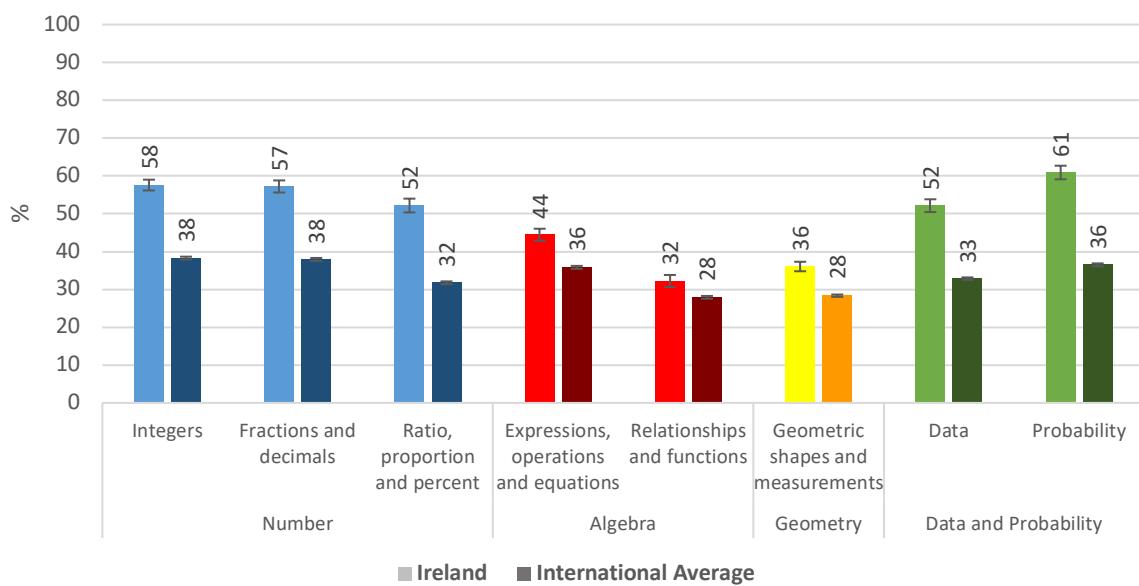
In brief, the content domain of Number has three subdomains: *Integers*; *Fractions and decimals*; and *Ratio, proportion and percent*. The differences between Ireland and the international average in each of these subdomains were broadly similar (20, 19, and 19 percentage points respectively). This shows that within Number, Ireland performed similarly well across each of the subdomains.

Algebra has two subdomains: *Expressions, operations and equations* and *Relationships and functions*. These subdomains link with the subdomain of *Expressions, simple equations and relationships*, a subdomain within Number, in Fourth Class (Grade 4) mathematics. *Relationships and functions* was an area that students in Ireland performed relatively less well in within Algebra, with a difference of only four percentage points between Ireland and the international average. The difference between Ireland and the international average for the other subdomain (*Expressions, operations and equations*) was nine percentage points.

Data & Probability has two subdomains: *Data* and *Probability*. The differences between Ireland and the international average for these subdomains were 19 and 24 percentage points respectively. This suggests that *Probability*, in particular, is an area where Second Year students performed relatively well.

Geometry has one subdomain only: *Geometric shapes and measurements*. As mentioned above, while Ireland's performance on this domain was above the international average, the difference was somewhat narrower than across many of the other content domains and subdomains, indicating that Geometry was an area of relative weakness relative to Ireland's overall performance.

**Figure 4.1: Percent correct scores by subdomain in Ireland and the average internationally**



See Appendix Table A4.1

Note. Due to rounding, some differences may appear inconsistent with those reported in text.

The following sections describe the patterns of performance within each content domain for Ireland in more detail, and how the TIMSS subdomains relate to the Junior Cycle Curriculum.

## 4.2 NUMBER

As noted above, Number accounts for 30% of the mathematics assessment at Grade 8. While Number accounts for half of the assessment at Grade 4, this is inclusive of pre-algebra topics.

Therefore, the proportion of the Grade 8 assessment made up by Number and Algebra combined (50%) is comparable to the proportion given to Number (50%) at Grade 4.

Table 4.2 presents the linking between the Junior Cycle mathematics learning outcomes and the TIMSS Framework for the Number content domain. All topics within the TIMSS framework link with a learning outcome in the Junior Cycle mathematics specification. Conversely, not all of the content in Junior Cycle mathematics is featured in the TIMSS framework. For example, as Table 4.2 shows, set theory (N.5) is not represented in the TIMSS framework.

**Table 4.2: Junior Cycle mathematics specification linked to TIMSS 2019 Framework for the Number content domain**

| Number Strand | Junior Cycle mathematics: Number Strand                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | TIMSS Framework                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|               | <p><b>N.1</b><br/><b>investigate the representation of numbers and arithmetic operations so that they can:</b></p> <p>a. represent the operations of addition, subtraction, multiplication, and division in <math>\mathbb{N}</math>, <math>\mathbb{Z}</math>, and <math>\mathbb{Q}</math> using models including the number line, decomposition, and accumulating groups of equal size</p> <p>b. perform the operations of addition, subtraction, multiplication, and division and understand the relationship between these operations and the properties: commutative, associative and distributive in <math>\mathbb{N}</math>, <math>\mathbb{Z}</math>, and <math>\mathbb{Q}</math> <b>and in <math>\mathbb{R} \setminus \mathbb{Q}</math>, including operating on surds</b></p> <p>c. explore numbers written as <math>a^b</math> (in index form) so that they can:</p> <p>I. flexibly translate between whole numbers and index representation of numbers</p> <p>II. use and apply generalisations such as <math>a^q = a^{p+q}</math>; <math>(a^p)/(a^q) = a^{p-q}</math>; <math>(a^p)^q = a^{pq}</math>; and <math>n^{1/2} = \sqrt{n}</math>, for <math>a \in \mathbb{Z}</math>, and <math>p, q, p-q, \sqrt{n} \in \mathbb{N}</math> <b>and for <math>a, b, \sqrt{n} \in \mathbb{R}</math>, and <math>p, q \in \mathbb{Q}</math></b></p> <p>III. use and apply generalisations such as <math>a^0 = 1</math> ; <math>a^{p/q} = \sqrt[q]{a^p} = (\sqrt[q]{a})^p</math> ; <math>a^{-r} = 1/(a^r)</math>; <math>(ab)^r = (a^r)(b^r)</math> ; and <math>(a/b)^r = (a^r)/(b^r)</math>, for <math>a, b \in \mathbb{R}</math> ; <math>p, q \in \mathbb{Z}</math>; and <math>r \in \mathbb{Q}</math></p> <p>IV. generalise numerical relationships involving operations involving numbers written in index form</p> <p>V. correctly use the order of arithmetic and index operations including the use of brackets</p> <p>d. calculate and interpret factors (including the highest common factor), multiples (including the lowest common multiple), and prime numbers</p> | <p><b>Integers</b></p> <p>2. Compute and solve problems with positive and negative numbers, including through movement on the number line or various models (e.g., losses and gains, thermometers)</p> <p><b>Integers</b></p> <p>2. Compute and solve problems with positive and negative numbers, including through movement on the number line or various models (e.g., losses and gains, thermometers)</p> <p><b>Integers</b></p> <p>1. Demonstrate understanding of properties of numbers and operations; find and use multiples and factors, identify prime numbers, evaluate positive integer powers of numbers, evaluate square roots of perfect squares up to 144, and solve problems involving square roots of whole numbers</p> <p><b>Integers</b></p> <p>1. Demonstrate understanding of properties of numbers and operations; find and use multiples and factors, identify prime numbers, evaluate positive integer powers of numbers, evaluate square roots of perfect squares up to 144, and solve problems involving square roots of whole numbers</p> |

|                      |                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                               |
|----------------------|--------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Number Strand</b> | <b>N.1 investigate the representation of numbers and arithmetic operations so that they can:</b> | <p>e. present numerical answers to the degree of accuracy specified, for example, correct to the nearest hundred, to two decimal places, or to three significant figures</p> <p>f. convert the number <math>p</math> in decimal form to the form <math>a \times 10^n</math>, where <math>1 \leq a &lt; 10</math>, <math>n \in \mathbb{Z}</math>, <math>p \in \mathbb{Q}</math>, and <math>p \geq 1</math> <b>and</b> <math>0 &lt; p &lt; 1</math></p>                                                                                         | <b>Fractions and Decimals</b><br><b>1.</b> Using various models and representations, compare and order fractions and decimals, and identify equivalent fractions and decimals<br><b>2.</b> Compute with fractions and decimals, including those set in problem situations                                     |
|                      | <b>N.2 investigate equivalent representations of rational numbers so that they can:</b>          | <p>a. flexibly convert between fractions, decimals, and percentages</p> <p>b. use and understand ratio and proportion</p>                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>Fractions and Decimals</b><br><b>1.</b> Using various models and representations, compare and order fractions and decimals, and identify equivalent fractions and decimals<br><b>2.</b> Compute with fractions and decimals, including those set in problem situations                                     |
|                      |                                                                                                  | <p>c. solve money-related problems including those involving bills, VAT, profit or loss, % profit or loss (on the cost price), cost price, selling price, compound interest for not more than 3 years, income tax (standard rate only), net pay (including other deductions of specified amounts), value for money calculations and judgements, <b>mark up (profit as a % of cost price)</b>, <b>margin (profit as a % of selling price)</b>, <b>compound interest</b>, <b>income tax</b> and <b>net pay (including other deductions)</b></p> | <b>Ratio, Proportion, and Percent</b><br><b>1.</b> Identify and find equivalent ratios; model a given situation by using a ratio; divide a quantity according to a given ratio<br><b>2.</b> Solve problems involving proportions or percents, including converting between percents and fractions or decimals |
|                      | <b>N.3 investigate situations involving proportionality so that they can:</b>                    | <p>a. use absolute and relative comparison where appropriate</p> <p>b. solve problems involving proportionality including those involving currency conversion and those involving average speed, distance, and time</p>                                                                                                                                                                                                                                                                                                                       | <b>Fractions and Decimals</b><br><b>2.</b> Compute with fractions and decimals, including those set in problem situations<br><b>Ratio, Proportion, and Percent</b><br><b>2.</b> Solve problems involving proportions or percents, including converting between percents and fractions or decimals             |

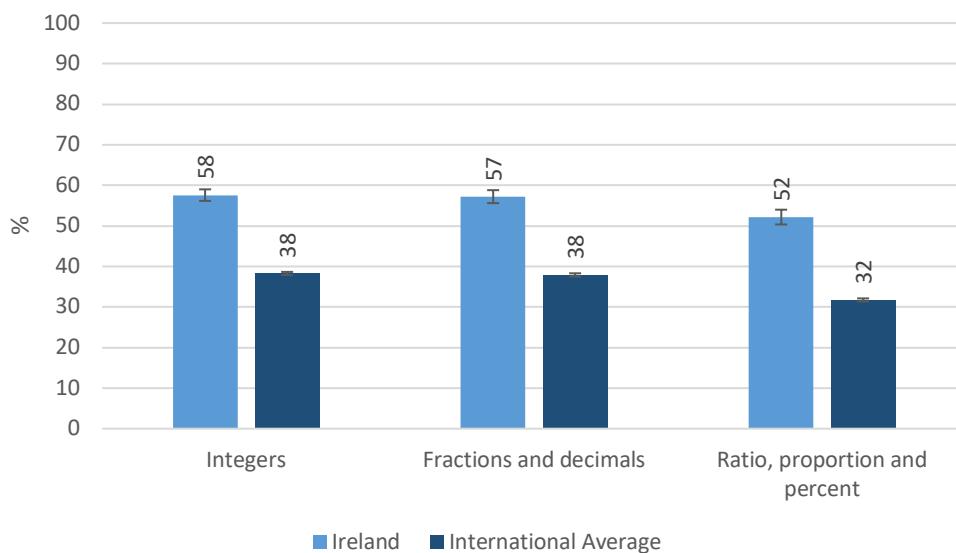
|               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Number Strand | <p><b>N.4</b> analyse numerical patterns in different ways, including making out tables and graphs, and continue such patterns</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | <p><b>Relationships and Functions</b></p> <p><b>1.</b> Interpret, relate and generate representations of linear functions in tables, graphs, or words; identify properties of linear functions including slope and intercepts</p> <p><b>2.</b> Interpret, relate and generate representations of simple non-linear functions (e.g., quadratic) in tables, graphs, or words; generalize pattern relationships in a sequence using numbers, words, or algebraic expressions</p> |
|               | <p><b>N.5 explore the concept of a set so that they can:</b></p> <ul style="list-style-type: none"> <li>a. understand the concept of a set as a well-defined collection of elements, and that set equality is a relationship where two sets have the same elements</li> <li>b. define sets by listing their elements, if finite (including in a 2-set or <b>3-set</b> Venn diagram), or by generating rules that define them</li> <li>c. use and understand suitable set notation and terminology, including null set, <math>\emptyset</math>, subset, <math>\subset</math>, complement, element, <math>\in</math>, universal set, cardinal number, <math>\#</math>, intersection, <math>\cap</math>, union, <math>\cup</math>, set difference, <math>\setminus</math>, <math>\mathbb{N}</math>, <math>\mathbb{Z}</math>, <math>\mathbb{Q}</math>, <math>\mathbb{R}</math>, and <math>\mathbb{R} \setminus \mathbb{Q}</math></li> <li>d. perform the operations of intersection and union on 2 sets <b>and on 3 sets</b>, set difference, and complement, including the use of brackets to define the order of operations</li> <li><b>e. investigate whether the set operations of intersection, union, and difference are commutative and/or associative</b></li> </ul> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

*Note.* **Bold** font indicates learning outcomes in the Junior Cycle mathematics specification that are only for students studying Higher Level mathematics.

Figure 4.2 presents the percent correct scores for the subdomains within Number in Ireland and on average internationally. Ireland's percent correct scores were significantly above the international average with an advantage of approximately 20 percentage points in each of the subdomains, highlighting that Second Year students performed equally well in each of the subdomains in Number. Boys in Ireland had slightly higher percent correct scores in each of the subdomains, with the largest difference (three percentage points) observed for *Ratio, proportion and percent* (Appendix Table A4.2).

Teachers' responses indicated that almost all students were taught the concepts relating to Number either before or during Second Year, which may contribute to Ireland's relatively strong performance in this area (Appendix Table A4.6).

**Figure 4.2: Percent correct score for the subdomains of Number in Ireland and on average internationally**



See Appendix Table A4.1.

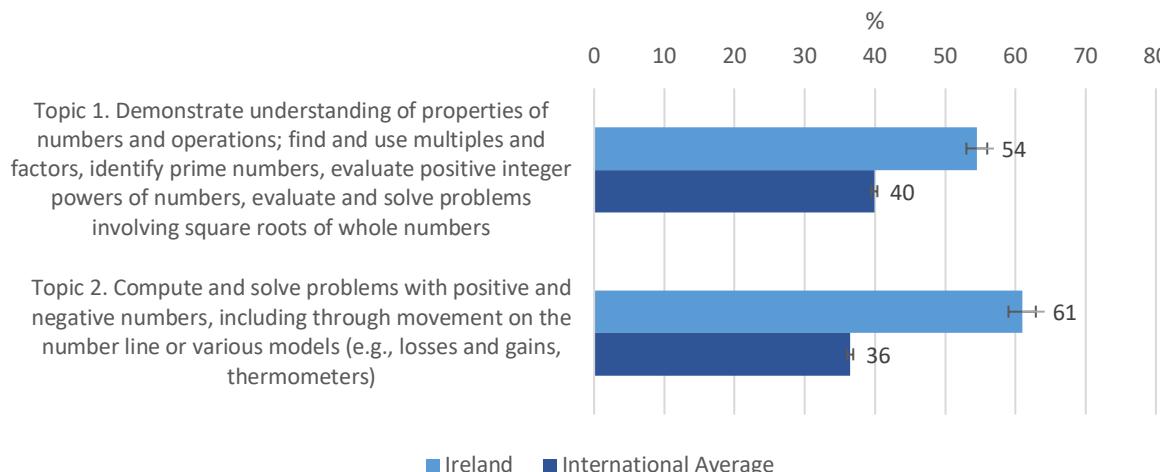
Note. The figure is an amended version of Figure 4.1 with only the subdomains of Number represented. Due to rounding, some differences may appear inconsistent with those reported in text.

### Number Subdomain 1: Integers

The first subdomain of Number is *Integers* and includes two topics. These topics link to points (a-d) in the first learning outcome (N.1) for Junior Cycle mathematics (see Table 4.2). Figure 4.3 presents the percent correct scores for these topics in Ireland and internationally.

Students in Ireland achieved 54% correct on Topic 1 in Figure 4.3, with a difference of 14 percentage points between Ireland and the international average (40%). On Topic 2, Ireland's percent correct score (61%) was considerably higher than the corresponding international average (36%). Whereas Second Year students performed better on Topic 2, Grade 8 students internationally performed better on Topic 1. In Ireland, boys had a higher percent correct score than girls (by three percentage points) for Topic 2 while girls had a higher percent correct score for Topic 1 (by two percentage points) (Appendix Table A4.4).

**Figure 4.3: Percent correct scores at the topic level for the subdomain *Integers* in Ireland and on average internationally**



See Appendix Table A4.3.

Note. Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

Table 4.3 presents a released item relating to *Integers*. Ireland was significantly below the international average on this item. The item relates to Topic 1 (*demonstrate understanding of properties of numbers and operations; find and use multiples and factors, identify prime numbers, evaluate positive integer powers of numbers, evaluate square roots of perfect squares up to 144 and solve problems involving square roots of whole numbers*). This is one of the more difficult TIMSS items and was placed *Above the Advanced International Benchmark (625+)*. Only six percent of Second Year students answered the item correctly, compared to 15% of students internationally. To receive full credit, students had to answer all parts of the item correctly.

To answer this question, students must understand the concept of an integer and be able to use this understanding to deduce whether the statements are true. Looking at each of the individual parts of this item, part (d) is the only part where Ireland (54%) was significantly above the international average (48%). For parts (a), (b) and (c), Ireland's score was not significantly different from the international average (Ireland: 53%, 47% and 64%; international average: 50%, 49% and 61%). Part (e) was the only part where Ireland's score (46%) was significantly below the international average (59%). This is worth noting as both parts (d) and (e) include integers as fractions. However, part (e) concerns the properties of multiplication with fractions, whereas part (d) features addition with fractions. It is possible that some students might be more familiar with the latter.

**Table 4.3: Released item for *Integers***

|                       |                                                                                                                                                                                                                                                                                             |                                                                                           |
|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
| Integers              | Demonstrate understanding of properties of numbers and operations; find and use multiples and factors, identify prime numbers, evaluate positive integer powers of numbers, evaluate square roots of perfect squares up to 144, and solve problems involving square roots of whole numbers. |                                                                                           |
| Item Description      | Recognises true or false statements based on properties of operations                                                                                                                                                                                                                       |                                                                                           |
| Benchmark             | Item Above Advanced International Benchmark (625+)                                                                                                                                                                                                                                          |                                                                                           |
| Percent Correct Score | Ireland: Overall 6%<br>Part (a): 53%; (b): 47%; (c) 64%; (d) 54%; (e) 46%.                                                                                                                                                                                                                  | International Average: Overall 15%<br>Part (a): 50%; (b): 49%; (c) 61%; (d) 48%; (e) 59%. |
| Reason for Inclusion  | Ireland significantly below the international average                                                                                                                                                                                                                                       |                                                                                           |

If  $a$  is an integer, are these statements true for **all** values of  $a$ ?

Tick one circle for each statement.

|                                                   | <b>True</b>               | <b>False</b>              |
|---------------------------------------------------|---------------------------|---------------------------|
| (a) $a^2 = 2a$                                    | <input type="radio"/> (A) | <input type="radio"/> (B) |
| (b) $a + 2 = 2 - (-a)$                            | <input type="radio"/> (A) | <input type="radio"/> (B) |
| (c) $a - 2 = -2 + a$                              | <input type="radio"/> (A) | <input type="radio"/> (B) |
| (d) $\frac{a+3}{2} = a + \frac{3}{2}$             | <input type="radio"/> (A) | <input type="radio"/> (B) |
| (e) $\frac{a \times 3}{2} = a \times \frac{3}{2}$ | <input type="radio"/> (A) | <input type="radio"/> (B) |

**Solution:**

- (a) **False**
- (b) **True**
- (c) **True**
- (d) **False**
- (e) **True**

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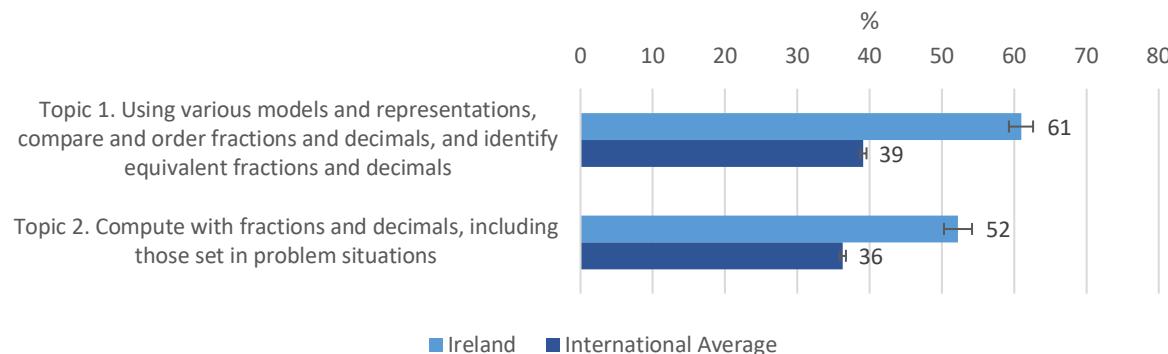
See Appendix Table A4.5

### **Number Subdomain 2: Fractions and Decimals**

The second subdomain in Number is *Fractions and decimals*, which includes two topics as listed in Figure 4.4 below. The two topics relate to both “N.1: investigate the representation of numbers and arithmetic operations so that they can: (e) present numerical answers to the degree of accuracy specified, for example, correct to the nearest hundred, to two decimal places, or to three significant figures”, and “N.2: investigate equivalent representations of rational numbers so that they can: (a) flexibly convert between fractions, decimals, and percentages” of Junior Cycle mathematics. Topic 2 also relates to “N.2: (c) solve money problems”.

Similar to the pattern seen at Fourth Class, the subdomain of *Fractions and decimals* was an area of relative strength for Ireland. Students in Ireland had a 22 percentage point advantage over the international average for Topic 1 and a 16 percentage point advantage for Topic 2. The score of boys in Ireland was two percentage points higher than girls' score on Topic 1, while the scores of girls and boys on Topic 2 were almost identical (Appendix Table A4.4).

**Figure 4.4: Percent correct scores by topic for the subdomain *Fractions and decimals* in Ireland and on average internationally**



See Appendix Table A4.3.

*Note.* Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

Table 4.4 presents a released item relating to *Fractions and decimals*. This item was classified at the *Advanced International Benchmark* (625). Almost one-quarter (24%) of students in Ireland answered the item correctly, compared to 16% internationally. In this item, students are presented with a  $3 \times 3$  square with three fractions and one unknown (marked X). Students are provided with three constraints or rules and asked to find the value of X. To find the value, students first need to find the value of the bottom left square. Using this information, they can find the value of X.

**Table 4.4: Released Item for *Fractions and decimals***

|                        |                                                                                 |                            |
|------------------------|---------------------------------------------------------------------------------|----------------------------|
| Fractions and decimals | Compute with fractions and decimals, including those set in problem situations. |                            |
| Item Description       | Solves a multi-step problem involving addition and subtraction of fractions     |                            |
| Benchmark              | Item at Advanced International Benchmark (625)                                  |                            |
| Percent Correct Score  | Ireland: 24%                                                                    | International Average: 16% |
| Reason for Inclusion   | Example of word problem in TIMSS                                                |                            |

In the square below:

- The numbers in each row add to 1.
- The numbers in each column add to 1, and
- The numbers in both diagonals add to 1.

|                |     |               |
|----------------|-----|---------------|
| $\frac{8}{15}$ |     | $\frac{2}{5}$ |
| $\frac{1}{5}$  | $X$ |               |
|                |     |               |

What is the value of  $X$ ?

$X = \underline{\hspace{2cm}}$

**Solution:**  $\frac{5}{15}$  or equivalent

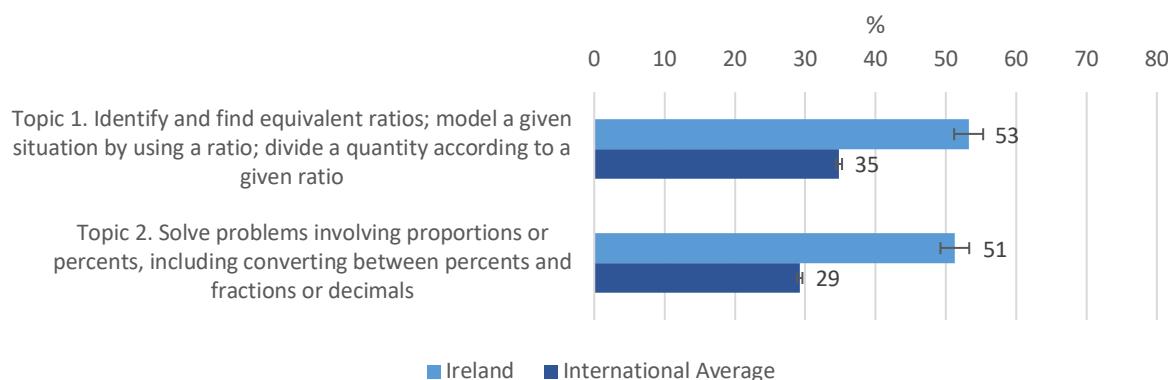
See Appendix Table A4.5

### Number Subdomain 3: *Ratio, Proportion and Percent*

The third and final subdomain within Number is *Ratio, proportion and percent*. This relates to two learning outcomes in Junior Cycle mathematics: “N.2: investigate equivalent representations of rational numbers so that they can b) use and understand ratio and proportion and c) solve money problems” and “N.3: investigate situations involving proportionality so that they can b) solve problems involving proportionality” (see Table 4.2).

Figure 4.5 presents the two topics which relate to *Ratio, proportion and percent* and their respective percent correct scores. For Topic 1, Ireland’s percent correct score (53%) was 19 percentage points above the average internationally. The second topic, which relates to proportion and percent, had a marginally lower percent correct score in Ireland (51%), which was 22 percentage points above the international average. This indicates that students in Ireland performed similarly well across the topics within *Ratio, proportion and percent*. Boys in Ireland had a four percentage point advantage over girls for the second topic, while the scores were very similar on the first topic (Appendix Table A4.4).

**Figure 4.5: Percent correct scores by topic for the subdomain *Ratio, proportion and percent* in Ireland and on average internationally**



See Appendix Table A4.3.

*Note.* Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

Table 4.5 presents a released item that was categorised at the *Advanced International Benchmark* (625). Almost two-fifths (39%) of students in Ireland answered this item correctly. This was not significantly different from the international average (35%). In this item, students are presented with a word problem, aided by a visual representation. They are asked to determine the dimensions of a rectangle that is similar to the rectangle shown in the question. They are presented with four possible answers and asked to select the correct answer.

Almost half of students in Ireland (48%) chose option (d) (35 cm). Students may have arrived at this incorrect answer by adding the same absolute increase to both the height and width (i.e., 15cm) to the original height (20cm) as well as to the width, rather than realising that the absolute increase was not the same for the height and width.

**Table 4.5: Released Item for *Ratio, proportion and percent***

|                               |                                                                                                                   |                            |
|-------------------------------|-------------------------------------------------------------------------------------------------------------------|----------------------------|
| Ratio, proportion and percent | Solve problems involving proportions or percents, including converting between percents and fractions or decimals |                            |
| Item Description              | Determines the dimensions of a rectangle that is similar to a given rectangle                                     |                            |
| Benchmark                     | Item at Advanced International Benchmark (625)                                                                    |                            |
| Percent Correct Score         | Ireland: 39%                                                                                                      | International Average: 35% |
| Reason for Inclusion          | Item where Ireland's percent correct was not significantly different from the international average               |                            |

Katy wants to enlarge this photo keeping the same proportion between height and width.



height = 20 cm

width = 10 cm

She wants her new photo to have a width of 25 cm. What will be the height of her new photo?

- (a) 50 cm
- (b) 45 cm
- (c) 40 cm
- (d) 35 cm

**Solution: (a) 50 cm**

See Appendix Table A4.5

## 4.2 ALGEBRA

The second content domain for Grade 8 mathematics is Algebra. This accounts for 30% of the TIMSS assessment. Table 4.6 presents the linking of the Junior Cycle mathematics learning outcomes to the TIMSS framework for this domain. The content domain of Algebra relates to the Algebra & Functions strand of Junior Cycle mathematics. All topics in the TIMSS Algebra framework are covered in the Junior Cycle mathematics learning outcomes. However, some topics within Junior Cycle mathematics are not part of the TIMSS framework, including “AF.1 (c): categorising patterns as linear, non-linear, quadratic and exponential (doubling and tripling) using their defining characteristics as they appear in different representations”.

**Table 4.6: Junior Cycle mathematics specification linked to TIMSS 2019 Framework for the Algebra content domain**

| Junior Cycle mathematics: Algebra and Function Strand |                                                                                                                                                                                | TIMSS Framework                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|-------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Algebra and Functions Strand                          | AF.1 investigate patterns and relationships (linear, quadratic, doubling and tripling) in number, spatial patterns and real-world phenomena involving change so that they can: | <p>a. represent these patterns and relationships in tables and graphs</p> <p><b>Expressions, Operations, and Equations</b><br/>3. Write expressions, equations, or inequalities to represent problem situations</p> <p><b>Relationships and Functions</b><br/>1. Interpret, relate and generate representations of linear functions in tables, graphs, or words; identify properties of linear functions including slope and intercepts</p>          |
|                                                       |                                                                                                                                                                                | <p>b. generate a generalised expression for linear <b>and quadratic</b> patterns in words and algebraic expressions and fluently convert between each representation</p> <p><b>Relationships and Functions</b><br/>2. Interpret, relate and generate representations of simple non-linear functions (e.g., quadratic) in tables, graphs, or words; generalize pattern relationships in a sequence using numbers, words, or algebraic expressions</p> |
|                                                       |                                                                                                                                                                                | <p>c. categorise patterns as linear, non-linear, <b>quadratic, and exponential (doubling and tripling)</b> using their defining characteristics as they appear in the different representations</p>                                                                                                                                                                                                                                                  |
|                                                       | AF.2 investigate situations in which letters stand for quantities that are variable so that they can:                                                                          | <p>a. generate and interpret expressions in which letters stand for numbers</p> <p><b>Expressions, Operations, and Equations</b><br/>3. Write expressions, equations, or inequalities to represent problem situations</p>                                                                                                                                                                                                                            |
|                                                       |                                                                                                                                                                                | <p>b. find the value of expressions given the value of the variables</p> <p><b>Expressions, Operations, and Equations</b><br/>1. Find the value of an expression or a formula given values of the variables</p>                                                                                                                                                                                                                                      |
|                                                       |                                                                                                                                                                                | <p>c. use the concept of equality to generate and interpret equations</p> <p><b>Expressions, Operations, and Equations</b><br/>4. Solve linear equations, linear inequalities, and simultaneous linear equations in two variables, including those that model real life situations</p>                                                                                                                                                               |

|                                     |                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|-------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Algebra and Functions Strand</b> | <b>AF.3 apply the properties of arithmetic operations and factorisation to generate equivalent expressions so that they can develop and use appropriate strategies to:</b> | <p>a. add, subtract and simplify</p> <p>I. linear expressions in one or more variables with coefficients in <math>\mathbb{Q}</math></p> <p>II. quadratic expressions in one variable with coefficients in <math>\mathbb{Z}</math></p> <p><b>III. expressions of the form <math>a/(bx+c)</math>, where <math>a, b, c \in \mathbb{Z}</math></b></p> <p>b. multiply expressions of the form</p> <p>I. <math>a(bx+cy+d)</math>; <math>a(bx^2+cx+d)</math>; and <math>ax(bx^2+cx+d)</math>, where <math>a, b, c, d \in \mathbb{Z}</math></p> <p>II. <math>(ax+b)(cx+d)</math> and <b><math>(ax+b)(cx^2+dx+e)</math></b>, where <math>a, b, c, d, e \in \mathbb{Z}</math></p> <p>c. divide quadratic <b>and cubic expressions</b> by linear expressions, where all coefficients are integers and there is no remainder</p> <p>d. flexibly convert between the factorised and expanded forms of algebraic expressions of the form:</p> <p>I. <math>axy</math>, where <math>a \in \mathbb{Z}</math></p> <p>II. <math>axy + byz</math>, where <math>a, b \in \mathbb{Z}</math></p> <p>III. <math>sx - ty + tx - sy</math>, where <math>s, t \in \mathbb{Z}</math></p> <p>IV. <math>dx^2 + bx</math>; <math>x^2 + bx + c</math>; and <b><math>ax^2 + bx + c</math></b>, where <math>b, c, d \in \mathbb{Z}</math> <b>and <math>a \in \mathbb{N}</math></b></p> <p>V. <math>x^2 - a^2</math> and <b><math>a^2 x^2 - b^2 y^2</math></b>, where <math>a, b \in \mathbb{Z}</math></p> | <p><b>Expressions, Operations, and Equations</b></p> <p><b>2. Simplify algebraic expressions involving sums, products, and powers; compare expressions to determine if they are equivalent</b></p> <p><b>Expressions, Operations, and Equations</b></p> <p><b>2. Simplify algebraic expressions involving sums, products, and powers; compare expressions to determine if they are equivalent</b></p> <p><b>Expressions, Operations, and Equations</b></p> <p><b>2. Simplify algebraic expressions involving sums, products, and powers; compare expressions to determine if they are equivalent</b></p> |
|                                     | <b>AF.4 select and use suitable strategies (graphic, numeric, algebraic, trial and improvement, working backwards) for finding solutions to:</b>                           | <p>a. linear equations in one variable with coefficients in <math>\mathbb{Q}</math> and solutions in <math>\mathbb{Z}</math> <b>or in <math>\mathbb{Q}</math></b></p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | <p><b>Expressions, Operations, and Equations</b></p> <p><b>4. Solve linear equations, linear inequalities, and simultaneous linear equations in two variables, including those that model real life situations</b></p>                                                                                                                                                                                                                                                                                                                                                                                   |
|                                     |                                                                                                                                                                            | <p>b. quadratic equations in one variable with coefficients and solutions in <math>\mathbb{Z}</math> <b>or coefficients in <math>\mathbb{Q}</math> and solutions in <math>\mathbb{R}</math></b></p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <p><b>Expressions, Operations, and Equations</b></p> <p><b>4. Solve linear equations, linear inequalities, and simultaneous linear equations in two variables, including those that model real life situations</b></p>                                                                                                                                                                                                                                                                                                                                                                                   |
|                                     |                                                                                                                                                                            | <p>c. simultaneous linear equations in two variables with coefficients and solutions in <math>\mathbb{Z}</math> <b>or in <math>\mathbb{Q}</math></b></p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <p><b>Expressions, Operations, and Equations</b></p> <p><b>4. Solve linear equations, linear inequalities, and simultaneous linear equations in two variables, including those that model real life situations</b></p>                                                                                                                                                                                                                                                                                                                                                                                   |
|                                     |                                                                                                                                                                            | <p>d. linear inequalities in one variable of the form <math>g(x) &lt; k</math>, and graph the solution sets on the number line for <math>x \in \mathbb{N}</math>, <math>\mathbb{Z}</math>, and <math>\mathbb{R}</math></p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <p><b>Expressions, Operations, and Equations</b></p> <p><b>4. Solve linear equations, linear inequalities, and simultaneous linear equations in two variables, including those that model real life situations</b></p>                                                                                                                                                                                                                                                                                                                                                                                   |

|                                     |                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                     |
|-------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Algebra and Functions Strand</b> | <b>AF.5 generate quadratic equations given integer roots</b>                                                                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <b>Relationships and Functions</b><br>2. Interpret, relate and generate representations of simple non-linear functions (e.g., quadratic) in tables, graphs, or words; generalize pattern relationships in a sequence using numbers, words, or algebraic expressions |
|                                     | <b>AF.6 apply the relationship between operations and an understanding of the order of operations including brackets and exponents to change the subject of a formula</b> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                     |
|                                     | <b>AF.7 investigate functions so that they can:</b>                                                                                                                       | a. demonstrate understanding of the concept of a function                                                                                                                                                                                                                                                                                                                                                                                                       | <b>Relationships and Functions</b><br>1. Interpret, relate and generate representations of linear functions in tables, graphs, or words; identify properties of linear functions including slope and intercepts                                                     |
|                                     |                                                                                                                                                                           | b. represent and interpret functions in different ways—graphically (for $x \in \mathbb{N}$ , $\mathbb{Z}$ , and $\mathbb{R}$ , [continuous functions only], as appropriate), diagrammatically, in words, and algebraically—using the language and notation of functions (domain, range, co-domain, $f(x) =$ , $f : x \mapsto$ , and $y =$ ) (drawing the graph of a function given its algebraic expression is limited to linear and quadratic functions at OL) | <b>Relationships and Functions</b><br>1. Interpret, relate and generate representations of linear functions in tables, graphs, or words; identify properties of linear functions including slope and intercepts                                                     |
|                                     |                                                                                                                                                                           | c. use graphical methods to find and interpret approximate solutions of equations such as $f(x) = g(x)$ and <b>approximate solution sets of inequalities such as <math>f(x) &lt; g(x)</math></b>                                                                                                                                                                                                                                                                | <b>Expressions, Operations, and Equations</b><br>4. Solve linear equations, linear inequalities, and simultaneous linear equations in two variables, including those that model real life situations                                                                |
|                                     |                                                                                                                                                                           | d. make connections between the shape of a graph and the story of a phenomenon, including identifying and interpreting maximum and minimum points                                                                                                                                                                                                                                                                                                               | <b>Relationships and Functions</b><br>1. Interpret, relate and generate representations of linear functions in tables, graphs, or words; identify properties of linear functions including slope and intercepts                                                     |

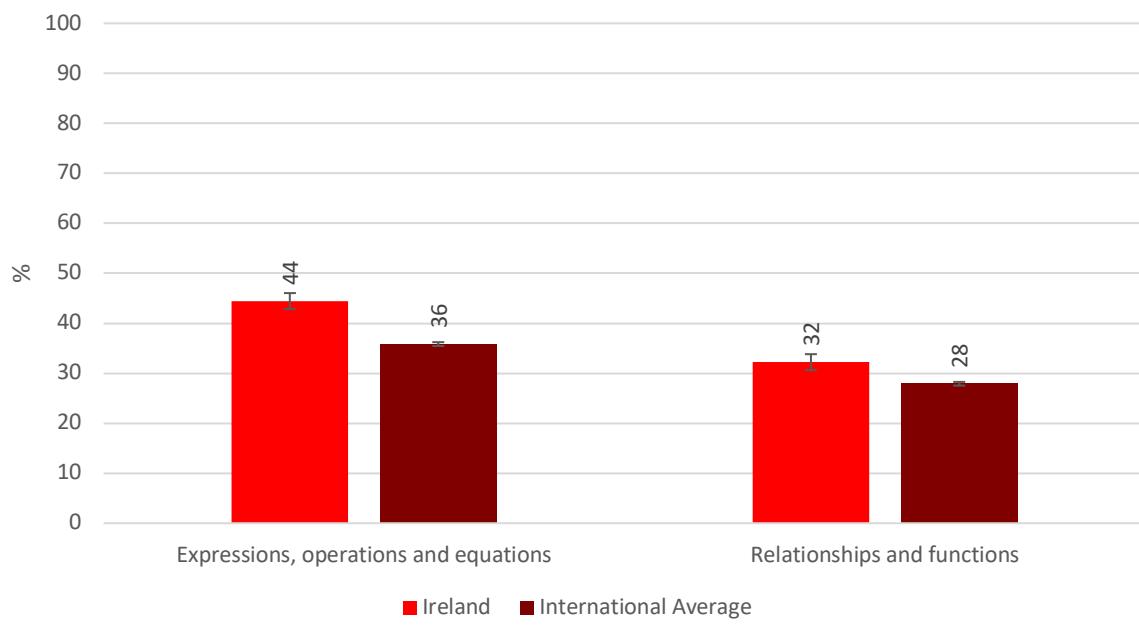
*Note.* **Bold** font indicates learning outcomes in the Junior Cycle mathematics specification that are only for students studying Higher Level mathematics.

Figure 4.6 presents the percent correct scores for the subdomains within Algebra. There are two subdomains: *Expressions, operations and equations* and *Relationships and functions*. Ireland's percent correct scores for these subdomains were significantly above the international averages, with the magnitude of the difference being larger on the *Expressions, operations and equations* subdomain. Girls in Ireland scored four percentage points higher than boys in *Expressions, operations*

and equations, with almost no difference between boys and girls for *Relationships and functions* (Appendix Table A4.4).

Teachers' reports indicated that concepts relating to simplifying and evaluating algebraic expressions, and simple linear equations, were mainly taught before or during Second Year (Appendix Table A4.6). Approximately three-quarters of students in Ireland had been taught about simple linear inequalities and simultaneous equations. On the other hand, approximately half of students in Ireland had not yet been taught about properties of functions, numeric, algebraic and geometric patterns or sequences, or about representation of linear and quadratic functions in tables, graphs, words, or equations.

**Figure 4.6: Percent correct score for the subdomains of Algebra in Ireland and on average internationally**



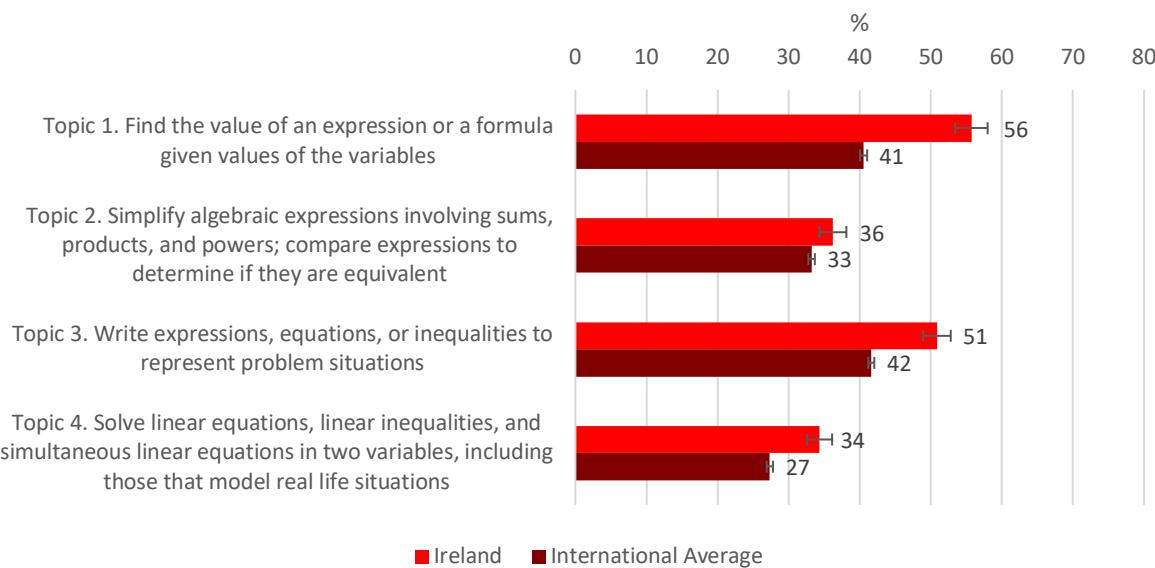
See Appendix Table A4.1.

*Note.* The figure is an amended version of Figure 4.1 with only the subdomains of Algebra represented. Due to rounding, some differences may appear inconsistent with those reported in text.

### **Algebra Subdomain 1: Expressions, Operations and Equations**

The first subdomain of Algebra is *Expressions, operations and equations*. It includes four topics (presented in Figure 4.7). The differences between Ireland and the international average ranged from three percentage points for Topic 2 to 15 percentage points for Topic 1, indicating that simplifying and comparing algebraic expressions is an area where Ireland's advantage is less pronounced. Topic 1 also saw the largest gender difference, with girls in Ireland outperforming boys by eight percentage points. The gender difference for the other topics ranged from two to three percentage points, again in favour of girls (Appendix Table A4.4). It is noteworthy that Second Year students' performance on simplifying algebraic expressions was close to the international average despite almost all students having covered this topic, as reported by their teachers (Appendix Table A4.6).

**Figure 4.7: Percent correct scores by topic for the subdomain *Expressions, operations and equations* in Ireland and on average internationally**



See Appendix Table A4.3

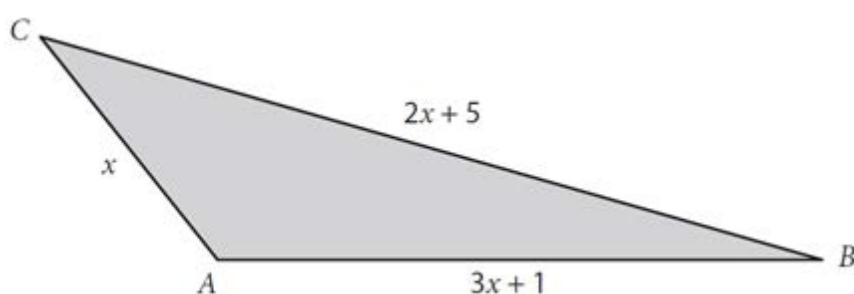
Note. Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

Table 4.7 presents a released item relating to *Expressions, operations and equations*. It was categorised at the *Advanced International Benchmark* (625). This item relates to Topic 4 (*solve linear equations, linear inequalities, and simultaneous linear equations in two variables, including those that model real life situations*). In this item, students are shown a triangle with the lengths of the sides given in terms of  $x$ . They are provided with the value of the perimeter and asked to solve to find the value of  $x$ . Students must first form an equation given the information provided ( $x + 2x + 5 + 3x + 1 = 21\text{cm}$ ) and solve this to find the value of  $x$ .

**Table 4.7: Released Item for *Expressions, operations and equations***

|                                       |                                                                                                                                                  |                            |
|---------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|
| Expressions, operations and equations | Solve linear equations, linear inequalities, and simultaneous linear equations in two variables, including those that model real life situations |                            |
| Item Description                      | Constructs a linear equation for the perimeter of a triangle and solves for the length of one side                                               |                            |
| Benchmark                             | Item at Advanced International Benchmark (625)                                                                                                   |                            |
| Percent Correct Score                 | Ireland: 23%                                                                                                                                     | International Average: 20% |
| Reason for Inclusion                  | Item which includes the use of a linear equation and the understanding of the concept of perimeter                                               |                            |

The perimeter of triangle  $ABC$  is 21 cm.



What is the value of  $x$ ?

$$x = \underline{\hspace{2cm}} \text{ cm}$$

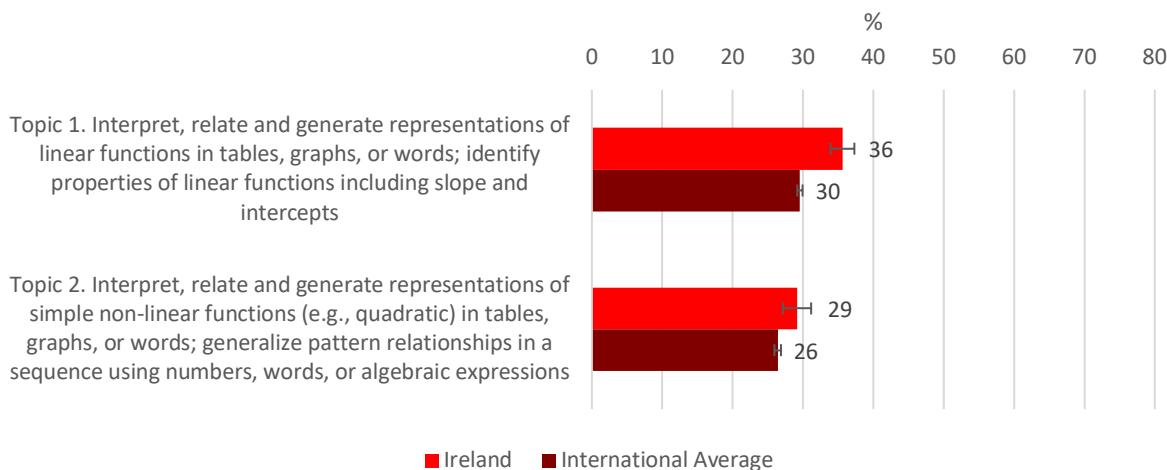
**Solution:**  $x = 2.5$  or equivalent

See Appendix Table A4.5

### Algebra Subdomain 2: Relationships and Functions

The second of the two subdomains within Algebra is *Relationships and functions*. This subdomain includes two topics, as listed in Figure 4.8. Students in Ireland had a six percentage point advantage over the international average in Topic 1, with a difference of three percentage points for Topic 2. Girls in Ireland had a higher percent correct score than boys (by two percentage points) for the first topic, while the same difference in the opposite direction was observed for the second topic (Appendix Table A4.4).

**Figure 4.8: Percent correct scores by topic for the subdomain *Relationships and functions* in Ireland and on average internationally**



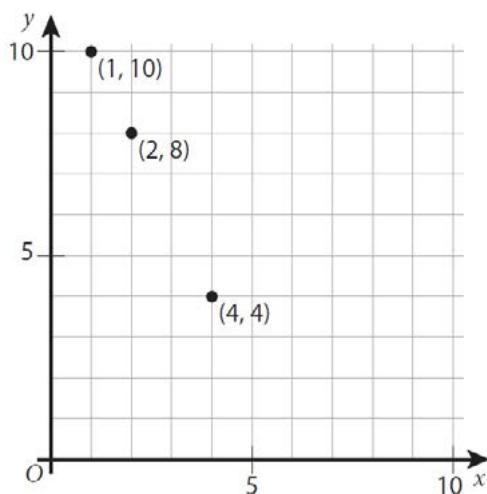
See Appendix Table A4.3.

*Note.* Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

Table 4.8 presents a released item relating to Topic 2. It was classified at the *Advanced International Benchmark (625)*. Two-fifths of students in Ireland (42%) answered this question correctly, compared to 35% internationally. The question asks students to identify a point that is collinear given three other collinear points. Students are provided with a graphical representation of the problem which they can use to answer the question, and are asked to select the correct answer from four possible options. It may be noted that this item is classified as Algebra within the TIMSS 2019 framework, while it would generally be classified as Coordinate Geometry in Ireland.

**Table 4.8: Released Item for *Relationships and functions***

|                             |                                                                                                                                                                         |                            |
|-----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|
| Relationships and Functions | Interpret, relate and generate representations of linear functions in tables, graphs, or words; identify properties of linear functions including slope and intercepts. |                            |
| Item Description            | Identify a point that is collinear with three given collinear points                                                                                                    |                            |
| Benchmark                   | Item at Advanced International Benchmark (625)                                                                                                                          |                            |
| Percent Correct Score       | Ireland: 42%                                                                                                                                                            | International Average: 35% |
| Reason for Inclusion        | Item which is classified as Algebra but is generally regarded as Coordinate Geometry in Ireland                                                                         |                            |



A straight line can be drawn through the points on the graph.

Which point is on the same straight line?

- (a) (2, 5)
- (b) (3, 5)
- (c) (5, 0)
- (d) (5, 2)

**Solution: (d) (5,2)**

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See Appendix Table A4.5.

### 4.3 GEOMETRY

The third content domain for Grade 8 mathematics is Geometry. This accounts for one-fifth of the TIMSS assessment. Table 4.9 presents the linking of the Junior Cycle mathematics learning outcomes to the TIMSS Framework. The TIMSS content domain of Geometry links with the Geometry and Trigonometry strand of Junior Cycle mathematics, and all items within the TIMSS framework can be linked to the Junior Cycle learning outcomes. Some learning outcomes, including GT.1 and GT.4, are not included as part of the TIMSS framework.

**Table 4.9: Junior Cycle mathematics specification linked to TIMSS 2019 Framework for Geometry content domain**

| Junior Cycle mathematics: Geometry and Trigonometry Strand                                            | TIMSS Framework                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>GT.1</b> calculate, interpret, and apply units of measure and time                                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>GT.2 investigate 2-D shapes and 3-D solids so that they can:</b>                                   | <p>a. draw and interpret scaled diagrams</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|                                                                                                       | <p><b>Geometry</b></p> <p>1. Identify and draw types of angles and pairs of lines and use the relationships between angles on lines and in geometric figures to solve problems, including those involving the measures of angles and line segments; solve problems involving points in the Cartesian plane</p> <p><b>Geometry</b></p> <p>2. Identify two-dimensional shapes and use their geometric properties to solve problems, including those involving perimeter, circumference, area, and the Pythagorean Theorem</p> <p>4. Identify three-dimensional shapes and use their geometric properties to solve problems, including those involving surface area and volume; relate three-dimensional shapes with their two-dimensional representations</p> |
|                                                                                                       | <p><b>Geometry</b></p> <p>2. Identify two-dimensional shapes and use their geometric properties to solve problems, including those involving perimeter, circumference, area, and the Pythagorean Theorem</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|                                                                                                       | <p><b>Geometry</b></p> <p>4. Identify three-dimensional shapes and use their geometric properties to solve problems, including those involving surface area and volume; relate three-dimensional shapes with their two-dimensional representations</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|                                                                                                       | <p><b>Geometry</b></p> <p>4. Identify three-dimensional shapes and use their geometric properties to solve problems, including those involving surface area and volume; relate three-dimensional shapes with their two-dimensional representations</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>GT.3 investigate the concept of proof through their engagement with geometry so that they can:</b> | <p>a. perform constructions 1 to 15 in <i>Geometry for Post-Primary School Mathematics</i> (<b>constructions 3 and 7 at HL only</b>)</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

|                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|---------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p style="text-align: center;"><b>Geometry and Trigonometry</b></p> | <p>b. recall and use the concepts, axioms, theorems, corollaries and converses, specified in <i>Geometry for Post-Primary School Mathematics</i> (section 9 for OL <b>and</b> section 10 for HL)</p> <p>    i. axioms 1, 2, 3, 4 and 5</p> <p>    ii. theorems 1, 2, 3, 4, 5, 6, 9, 10, 13, 14, 15 <b>and</b> 11, 12, 19, and appropriate converses, including relevant operations involving square roots</p> <p>    iii. corollaries 3, 4 <b>and</b> 1, 2, 5 and appropriate converses</p> <p>c. use <b>and explain</b> the terms: theorem, proof, axiom, corollary, converse, and implies</p> <p>d. create and evaluate proofs of geometrical propositions</p> <p>e. display understanding of the proofs of theorems 1, 2, 3, 4, 5, 6, 9, 10, 14, 15, <b>and</b> 13, 19; and of corollaries 3, 4, <b>and</b> 1, 2, 5 (full formal proofs are not examinable)</p> | <p><b>Geometry</b></p> <p>1. Identify and draw types of angles and pairs of lines and use the relationships between angles on lines and in geometric figures to solve problems, including those involving the measures of angles and line segments; solve problems involving points in the Cartesian plane</p> <p>2. Identify two-dimensional shapes and use their geometric properties to solve problems, including those involving perimeter, circumference, area, and the Pythagorean Theorem</p>                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|                                                                     | <p><b>GT.4</b> evaluate and use trigonometric ratios (sin, cos, and tan, defined in terms of right-angled triangles) and their inverses, involving angles between 0° and 90° at integer values <b>and in decimal form</b></p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <p style="text-align: center;"><b>Geometry and Trigonometry</b></p> | <p><b>GT.5 investigate properties of points, lines and line segments in the co-ordinate plane so that they can:</b></p> <p>a. find and interpret: distance, midpoint, slope, point of intersection, and slopes of parallel <b>and perpendicular</b> lines</p> <p>b. draw graphs of line segments and interpret such graphs in context, including discussing the rate of change (slope) and the y intercept</p> <p>c. find and interpret the equation of a line in the form <math>y = mx + c</math>; <math>y - y_1 = m(x - x_1)</math>; <b>and</b> <math>ax + by + c = 0</math> (for <math>a, b, c, m, x_1, y_1 \in \mathbb{Q}</math>); including finding the slope, the y intercept, and other points on the line</p>                                                                                                                                              | <p><b>Geometry</b></p> <p>1. Identify and draw types of angles and pairs of lines and use the relationships between angles on lines and in geometric figures to solve problems, including those involving the measures of angles and line segments; solve problems involving points in the Cartesian plane</p> <p><b>Geometry</b></p> <p>1. Identify and draw types of angles and pairs of lines and use the relationships between angles on lines and in geometric figures to solve problems, including those involving the measures of angles and line segments; solve problems involving points in the Cartesian plane</p> <p><b>Geometry</b></p> <p>1. Identify and draw types of angles and pairs of lines and use the relationships between angles on lines and in geometric figures to solve problems, including those involving the measures of angles and line segments; solve problems involving points in the Cartesian plane</p> |

|                                  |                                                                             |                                                                                                                         |                                                                                                                                                                                                                                 |
|----------------------------------|-----------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Geometry and Trigonometry</b> | <b>GT.6 investigate transformations of simple objects so that they can:</b> | a. recognise and draw the image of points and objects under translation, central symmetry, axial symmetry, and rotation | <b>Geometry</b><br><b>3.</b> Recognise and draw images of geometric transformations (translations, reflections, and rotations) in the plane; identify congruent and similar triangles and rectangles and solve related problems |
|                                  |                                                                             | b. draw the axes of symmetry in shapes                                                                                  | <b>Geometry</b><br><b>3.</b> Recognise and draw images of geometric transformations (translations, reflections, and rotations) in the plane; identify congruent and similar triangles and rectangles and solve related problems |

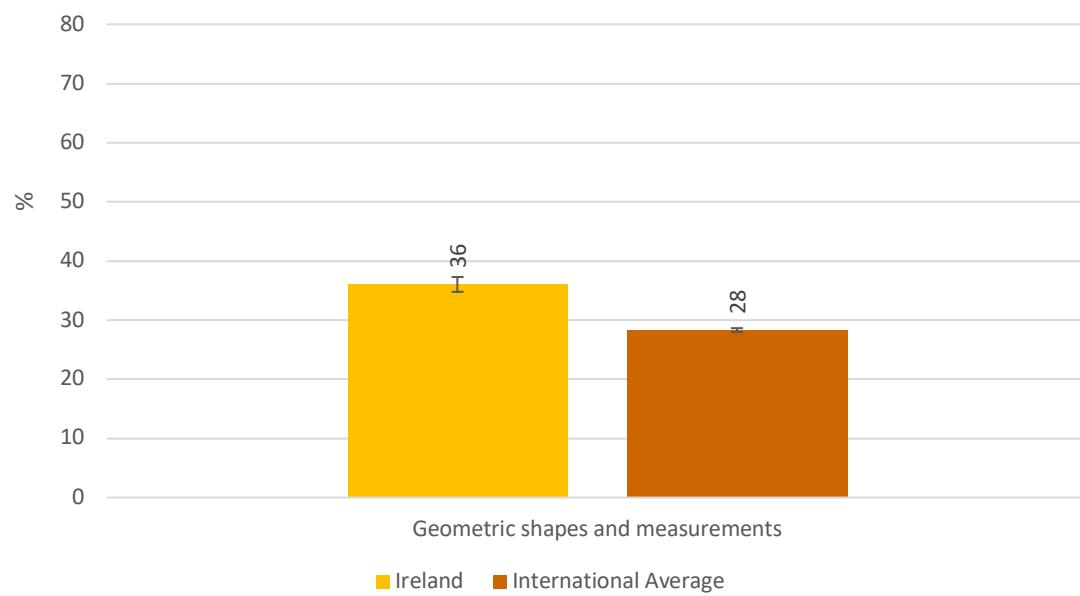
*Note.* **Bold** font indicates learning outcomes in the Junior Cycle mathematics specification that are only for students studying Higher Level mathematics.

Figure 4.9 presents the percent correct score for the single subdomain of Geometry – *Geometric shapes and measurements* – in Ireland and internationally. Ireland’s percent correct score (36%) was significantly above the international average (28%). In Ireland, boys’ score was one percentage point higher than girls for this subdomain (Appendix Table A4.2).

Teachers’ reports indicated that most students in Ireland (at least 70%) had been taught concepts such as “geometric properties of angles, pairs of lines and geometric shapes”, and “solving problems involving perimeters, circumferences, and areas” by the end of Second Year (Appendix Table A4.6). On the other hand, almost half of students had not yet been taught to solve problems involving the Pythagorean Theorem. Similarly, large proportions of students (65-70%) had not yet been taught about geometric transformations (e.g., translations, reflections and rotations), congruent and similar triangles, or to solve problems with three-dimensional shapes.

In general, the percentages of students whose teacher reported covering the various geometry topics by the time of TIMSS testing tended to be much lower in Ireland than on average among all the countries participating in TIMSS (Perkins & Clerkin, 2020). This may be one of the contributing factors to Geometry being an area of relative weakness for Ireland.

**Figure 4.9: Percent correct score for the subdomain of Geometry in Ireland and on average internationally**



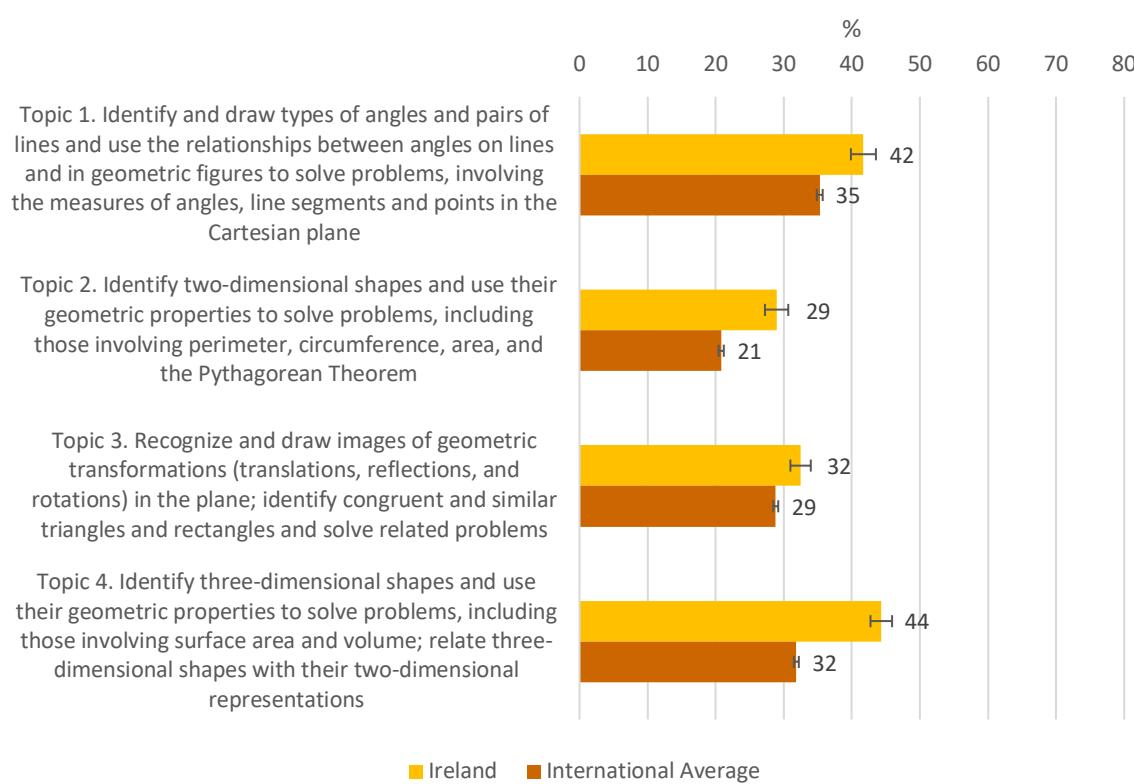
See Appendix Table A4.1

*Note.* The figure is an amended version of Figure 4.1 with only the single subdomain of Geometry represented. Due to rounding, some differences may appear inconsistent with those reported in text.

### **Geometry Subdomain 1: Geometric Shapes and Measurements**

The only subdomain of Geometry is *Geometric shapes and measurements*. The percent correct scores in Ireland were above the corresponding international averages for all topics (Figure 4.10). The difference between Ireland and the TIMSS average ranged from three percentage points on Topic 3 to 12 percentage points on Topic 4. This indicates that Second Year students found it relatively more difficult to recognise and draw images of geometric transformations in the plane, and to identify and solve problems related to congruent and similar triangles and rectangles. The difference for Topic 4 is particularly noteworthy given teachers' reports that almost two-thirds of students had not yet been taught about solving problems with three-dimensional shapes (Appendix Table A4.6). The differences in the percent correct scores for girls and boys in Ireland were less than or equal to three percentage points in each of the topics, and in favour of boys in all topics except for Topic 2 (Appendix Table A4.4).

**Figure 4.10: Percent correct scores at the topic level for the subdomain of *Geometric shapes and measurements* in Ireland and on average internationally**



See Appendix Table 4.3.

*Note.* Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

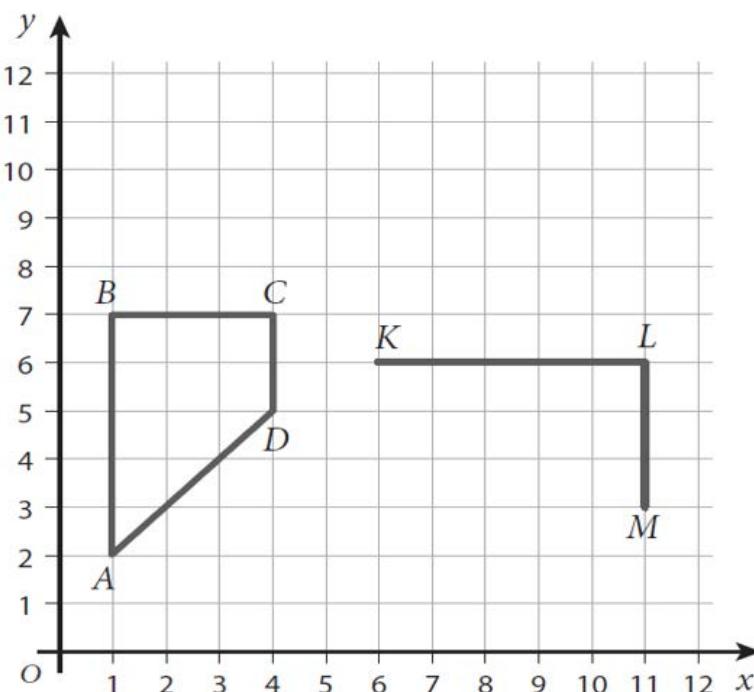
Table 4.10 presents a released item where Ireland had a percent correct score (20%) which was significantly below the international average (24%). This item was categorised at the *High International Benchmark (550)*. It relates to Topic 3 (*recognise and draw images of geometric transformations (translations, reflections, and rotations) in the plane; identify congruent and similar triangles and rectangles and solve related problems*).

In this item, students are presented with a Cartesian plane with a drawn trapezium. An incomplete second congruent trapezium is also on the same Cartesian plane. Students are asked to find the coordinates of the point *N* and need to complete the second trapezium to find the coordinates of the point. The item is made more complex by the fact that the second trapezium is rotated.

**Table 4.10: Released Item for *Geometric shapes and measurements***

|                                          |                                                                                                                                                                                                    |
|------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Geometric shapes and measurements</b> | Recognise and draw images of geometric transformations (translations, reflections, and rotations) in the plane; identify congruent and similar triangles and rectangles and solve related problems |
| <b>Item Description</b>                  | Determines the coordinates of a trapezium's missing vertex given a congruent trapezium in the Cartesian plane                                                                                      |
| <b>Benchmark</b>                         | Item at High International Benchmark (550)                                                                                                                                                         |
| <b>Percent Correct Score</b>             | Ireland: 20%      International Average: 24%                                                                                                                                                       |
| <b>Reason for Inclusion</b>              | Topic which was an area of relative weakness for Ireland                                                                                                                                           |

Will drew trapezium  $ABCD$ . He then started drawing a congruent trapezium  $KLMN$ .



What will the coordinates of point N be when Will completes the figure?

Answer: (\_\_\_\_\_, \_\_\_\_\_)

**Solution: (9, 3)**

See Appendix Table A4.5

#### 4.4 DATA & PROBABILITY

The fourth and final content domain in Grade 8 mathematics is Data & Probability. This accounts for one-fifth of the items in the assessment. Table 4.11 presents the linking of the Junior Cycle mathematics learning outcomes to the TIMSS framework. The TIMSS content area of Data & Probability links with the Probability & Statistics strand in Junior Cycle mathematics. All of the topics within the TIMSS framework for Data & Probability can be linked to Junior Cycle mathematics learning outcomes. However, not all learning outcomes in Junior Cycle mathematics (e.g., SP.1) are represented in the TIMSS framework.

**Table 4.11: Junior Cycle mathematics specification linked to TIMSS 2019 Framework for the Data & Probability content domain**

|                                   | Junior Cycle mathematics: Statistics and Probability Strand                                                                                                                                                                                          | TIMSS Framework                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|-----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Probability and Statistics Strand | <b>SP.1 investigate the outcomes of experiments so that they can:</b>                                                                                                                                                                                | <p>a. generate a sample space for an experiment in a systematic way, including tree diagrams for successive events and two-way tables for independent events</p> <p>b. use the fundamental principle of counting to solve authentic problems</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|                                   | <b>SP.2 investigate random events so that they can:</b>                                                                                                                                                                                              | <p>a. demonstrate understanding that probability is a measure on a scale of 0-1 of how likely an event (including an everyday event) is to occur</p> <p>b. use the principle that, in the case of equally likely outcomes, the probability of an event is given by the number of outcomes of interest divided by the total number of outcomes</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|                                   |                                                                                                                                                                                                                                                      | <p>c. use relative frequency as an estimate of the probability of an event, given experimental data, and recognise that increasing the number of times an experiment is repeated generally leads to progressively better estimates of its theoretical probability</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|                                   | <b>SP.3 carry out a statistical investigation which includes the ability to:</b>                                                                                                                                                                     | <p>a. generate a statistical question</p> <p>b. plan and implement a method to generate and/or source unbiased, representative data, and present this data in a frequency table</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|                                   |                                                                                                                                                                                                                                                      | <p>c. classify data (categorical, numerical)</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|                                   | <p>d. select, draw and interpret appropriate graphical displays of univariate data, including pie charts, bar charts, line plots, histograms (equal intervals), ordered stem and leaf plots, <b>and ordered back-to-back stem and leaf plots</b></p> | <p><b>Probability</b></p> <p>1. For simple and compound events: a) determine theoretical probability (based on equally likely outcomes, e.g., rolling a fair die) or b) estimate the empirical probability (based on experimental outcomes)</p> <p><b>Probability</b></p> <p>1. For simple and compound events: a) determine theoretical probability (based on equally likely outcomes, e.g., rolling a fair die) or b) estimate the empirical probability (based on experimental outcomes)</p> <p><b>Probability</b></p> <p>1. For simple and compound events: a) determine theoretical probability (based on equally likely outcomes, e.g., rolling a fair die) or b) estimate the empirical probability (based on experimental outcomes)</p> <p><b>Data</b></p> <p>2. Identify appropriate procedures for collecting data; organise and represent data to help answer question</p> <p><b>Data</b></p> <p>2. Identify appropriate procedures for collecting data; organise and represent data to help answer questions</p> <p><b>Data</b></p> <p>1. Read and interpret data from one or more sources to solve problems (e.g., interpolate and extrapolate, make comparisons, draw conclusions)</p> <p>2. Identify appropriate procedures for collecting data; organise and represent data to help answer questions</p> |

|                                          |                                                                                                                                                                                                                             |
|------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Probability and Statistics Strand</b> | e. select, calculate and interpret appropriate summary statistics to describe aspects of univariate data. Central tendency: mean ( <b>including of a grouped frequency distribution</b> ), median, mode. Variability: range |
|                                          | f. evaluate the effectiveness of different graphical displays in representing data                                                                                                                                          |
|                                          | g. discuss misconceptions and misuses of statistics                                                                                                                                                                         |
|                                          | h. discuss the assumptions and limitations of conclusions drawn from sample data or graphical/numerical summaries of data                                                                                                   |

**Data**

**3.** Calculate, use, or interpret statistics (i.e., mean, median, mode, range) summarizing data distributions; recognise the effect of spread and outliers

**Data**

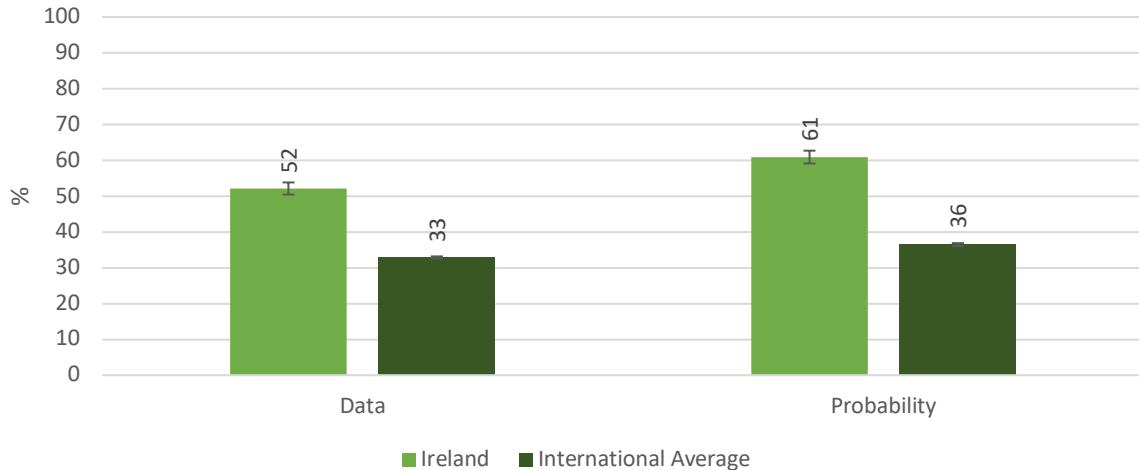
**2.** Identify appropriate procedures for collecting data; organise and represent data to help answer questions

*Note.* **Bold** font indicates learning outcomes in the Junior Cycle mathematics specification that are only for students studying Higher Level mathematics.

Figure 4.11 presents the percent correct scores for the subdomains of Data & Probability. Students in Ireland achieved 61% correct for *Probability*, which was 24 percentage points above the international average, and 52% correct for *Data*, which was 19 percentage points above the international average. This suggests that *Probability* in particular was an area of relative strength for Ireland. Boys in Ireland had a three percentage point advantage over girls for *Probability*, while girls' score was two percentage points higher than boys' for *Data* (Appendix Table A4.2).

Teachers' reports indicated that most students (over 80%) had covered the concepts "identify appropriate procedures for collecting data" and "organising and representing data" (Appendix Table A4.6). Approximately two-thirds of students had covered the concepts "reading and interpreting data from various sources to solve problems" and "calculating and interpreting statistics". A somewhat smaller proportion (58%) had covered "theoretical and empirical probability of simple events", while less than 40% had covered theoretical and empirical probability of compound events.

**Figure 4.11: Percent correct score for the subdomains of Data & Probability in Ireland and on average internationally**



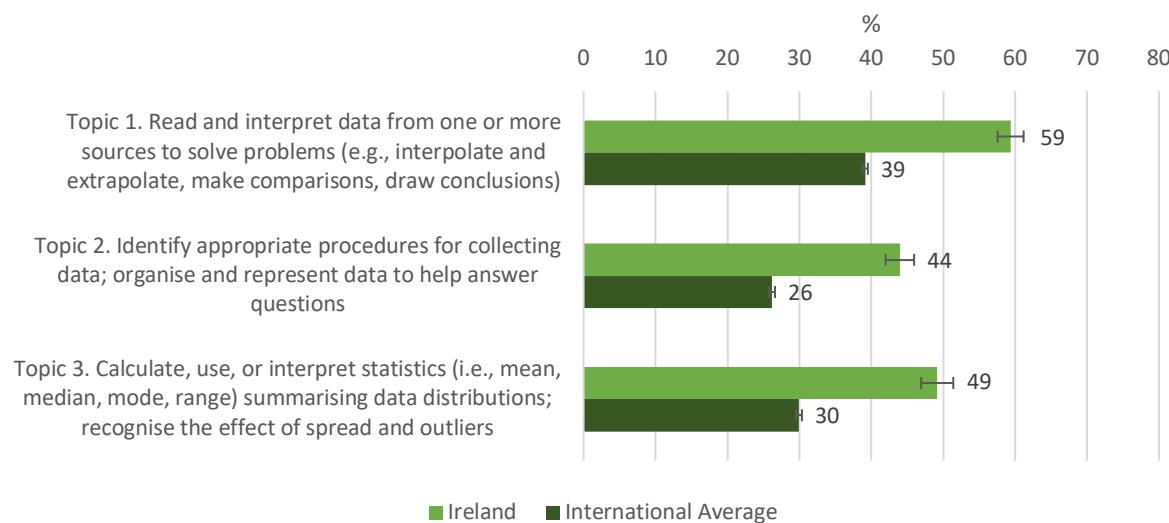
See Appendix Table A4.1

*Note.* The figure is an amended version of Figure 4.1 with only the subdomains of Data & Probability represented. Due to rounding, some differences may appear inconsistent with those reported in text.

## Data and Probability Subdomain 1: Data

The first subdomain of Data & Probability is *Data*, which has three topics (Figure 4.12). The percent correct scores achieved by Second Year students were significantly above the international averages, with differences of 20, 19, and 18 percentage points, respectively, for Topics 1-3. In Ireland, girls' score was two percentage points higher than boys' for the second and third topics listed in Figure 4.12, and one percentage point higher for the first topic (Appendix Table A4.4)

**Figure 4.12: Percent correct scores at the topic level for the subdomain *Data* in Ireland and on average internationally**



See Appendix Table A4.3.

*Note.* Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

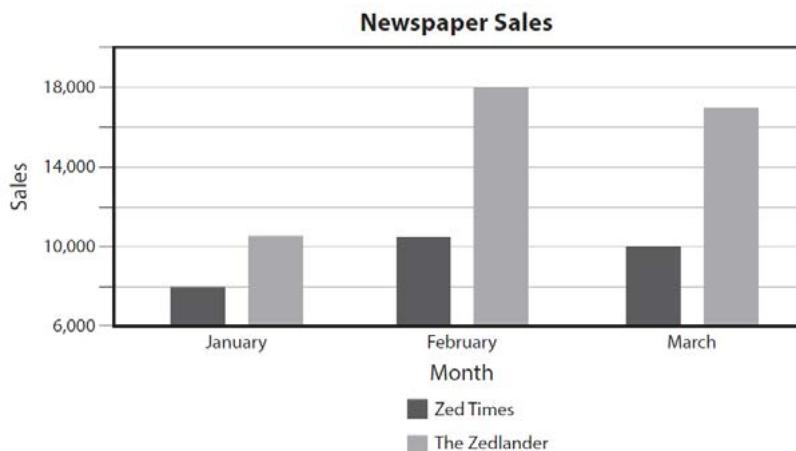
Table 4.12 presents a released item which was categorised as being *Above the Advanced International Benchmark (625+)*. One-fifth of students in Ireland (20%) answered this question correctly, compared to 12% of students on average internationally.

In this item, students are presented with a graph of sales of two newspapers over three months. A statement is provided and students are asked to explain why the statement is incorrect. This item requires a constructed response from students (i.e., no multiple-choice response options are provided) and students need to explain that the statement is not based on the actual number of sales. Responses were also considered correct if the student highlighted the fact that the y-axis scale started at 6,000 rather than zero, identifying that Nancy's claim relies on making an inference based on visual differences rather than the actual number of sales.

**Table 4.12: Released Item for Data**

|                              |                                                                                                              |                            |
|------------------------------|--------------------------------------------------------------------------------------------------------------|----------------------------|
| <b>Data</b>                  | Identify appropriate procedures for collecting data; organise and represent data to help answer questions    |                            |
| <b>Item Description</b>      | Explains why a statement about data in a bar graph with a y-axis scale that does not start at 0 is incorrect |                            |
| <b>Benchmark</b>             | Item Above Advanced International Benchmark (625+)                                                           |                            |
| <b>Percent Correct Score</b> | Ireland: 20%                                                                                                 | International Average: 12% |
| <b>Reason for Inclusion</b>  | Example of constructed response item relating to Data                                                        |                            |

The graph shows the sales of two Zedland newspapers over three months.



Nancy claimed that sales for the Zedlander were more than double the sales for the Zed Times each month.

Explain why Nancy's claim is incorrect.

**Solution:** Students need to explain that Nancy's claim is not based on the actual number of sales and/or that the y-axis scale does not start at zero.

See Appendix Table A4.5.

### **Data and Probability Subdomain 2: Probability**

The second subdomain within Data and Probability is *Probability*. As mentioned in Chapter 2, this subdomain is not included in the TIMSS assessment for Grade 4. There is only one topic in this subdomain (Figure 4.13). Ireland's percent correct score (61%) was 24 percentage points higher than the international average, suggesting that this topic (and therefore also the subdomain of *Probability*) was an area of relative strength. This is noteworthy in light of the finding that teachers reported that large proportions of Second Year students had not yet been taught about the probability of simple or compound events (Appendix Table A4.6). In Ireland, boys' score was three percentage points higher than girls' for this topic (Appendix Table A4.4).

**Figure 4.13: Percent correct scores at the topic level for the subdomain *Probability* in Ireland and on average internationally**



See Appendix Table A4.3.

*Note.* Ireland's percent correct score on this topic was significantly above the international average.

Due to rounding, some differences may appear inconsistent with those reported in text.

A released item relating to this topic is presented in Table 4.13. The item was categorised at the *High International Benchmark* (550). Almost three-fifths of students in Ireland (57%) answered this question correctly, which was significantly above the international average (39%). In this item, students are presented with a situation and asked to estimate the number of objects in a given probability sample. Students are presented with four options and are asked to select the correct response. Of the incorrect response options, 20% of students in Ireland chose option (c) while approximately 10% chose each of options (a) and (b).

**Table 4.13: Released Item for *Probability***

|                              |                                                                                                                                                                                                             |                            |
|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|
| <b>Probability</b>           | For simple and compound events: a) determine theoretical probability (based on equally likely outcomes, e.g., rolling a fair die) or b) estimate the empirical probability (based on experimental outcomes) |                            |
| <b>Item Description</b>      | Estimates the number of objects in a given probability sample                                                                                                                                               |                            |
| <b>Benchmark</b>             | Item at High International Benchmark (550)                                                                                                                                                                  |                            |
| <b>Percent Correct Score</b> | Ireland: 57%                                                                                                                                                                                                | International Average: 39% |
| <b>Reason for Inclusion</b>  | Example item relating to Probability; Ireland's percent correct above international average                                                                                                                 |                            |

A bag contains 24 marbles, some white and some black.

A marble is chosen at random, its colour is noted, and the marble is placed back into the bag. This is done 120 times, and a white marble appears 70 times.

How many white marbles are likely to be in the bag?

- (a) 7
- (b) 10
- (c) 12
- (d) 14

**Solution: (d) 14**

See Appendix Table A4.5.

# Chapter 5 – Second Year Science

## 5.1 INTRODUCTION

The TIMSS science assessment has four content domains at Grade 8 (in Ireland, Second Year): Biology, Chemistry, Physics, and Earth Science. Each of the content domains contributes a different proportion of the assessment, as outlined in detail in the TIMSS 2019 Assessment Framework (Mullis & Martin, 2017). Biology was planned to account for 35%, Physics for 25%, Chemistry for 20% and Earth Science for the remaining 20% of the assessment. Perkins and Clerkin (2020) reported that the final distributions of items across the four content domains were in line with the planned distributions.

The content domains differ somewhat between Grade 4 and Grade 8 to reflect the science widely taught at each level across the range of TIMSS countries. At Grade 4, Physics and Chemistry content is included as part of Physical Science while at Grade 8 they are separate content domains. Life Science is a content domain for Grade 4, but the corresponding domain at Grade 8 is Biology.

Each content domain is made up of a number of subdomains and topics, as outlined in Chapter 1. This chapter presents the percent correct scores at the content domain, subdomain and topic levels for Ireland, and on average internationally, for Grade 8. Comparisons to the international average are used as a basis for identifying areas where students in Ireland perform particularly strongly or do relatively less well, as percent correct scores do not take relative item difficulty across subdomains or topics into consideration.

As part of the Teacher Questionnaire, teachers were asked to indicate whether various concepts were *mostly taught before this year, mostly taught this year, or not yet taught or just introduced*. The contextual information collected from teachers is used for further interpretation of the findings, which is particularly helpful in this context given that the science curriculum at Junior Cycle covers the span from First Year to Third Year, whereas students participating in TIMSS are assessed at one point partway through that cycle near the end of Second Year. It should be noted that the wording of the concepts in the Teacher Questionnaire and the subdomains or topics in the Assessment Framework are not identical to the subdomains or topics but are broadly similar. For example, one set of concepts listed in the Teacher Questionnaire is “cells, their structure and functions, including respiration and photosynthesis as cellular processes”. This relates to two TIMSS topics – *the structure and functions of cells* and *the processes of photosynthesis and cellular respiration* – within the subdomain *Cells and their functions* in the Biology content domain.

Where available, released items are also presented for each subdomain to provide examples of the types of items used in TIMSS. Items are classified as being indicative of the *Low International Benchmark (400)*, the *Intermediate International Benchmark (475)*, the *High International Benchmark (550)*, the *Advanced International Benchmark (625)*, or as being *Above the Advanced International Benchmark (625+)*. Table 5.1 below is adapted from Exhibit 4.7 in the TIMSS 2019 International Report (Mullis et al., 2020) and summarises what Grade 8 students who reached each of the International Benchmarks can do in science.

**Table 5.1: Summary of the TIMSS 2019 International Benchmarks of Grade 8 Science Achievement (adapted from Mullis et al., 2020)**

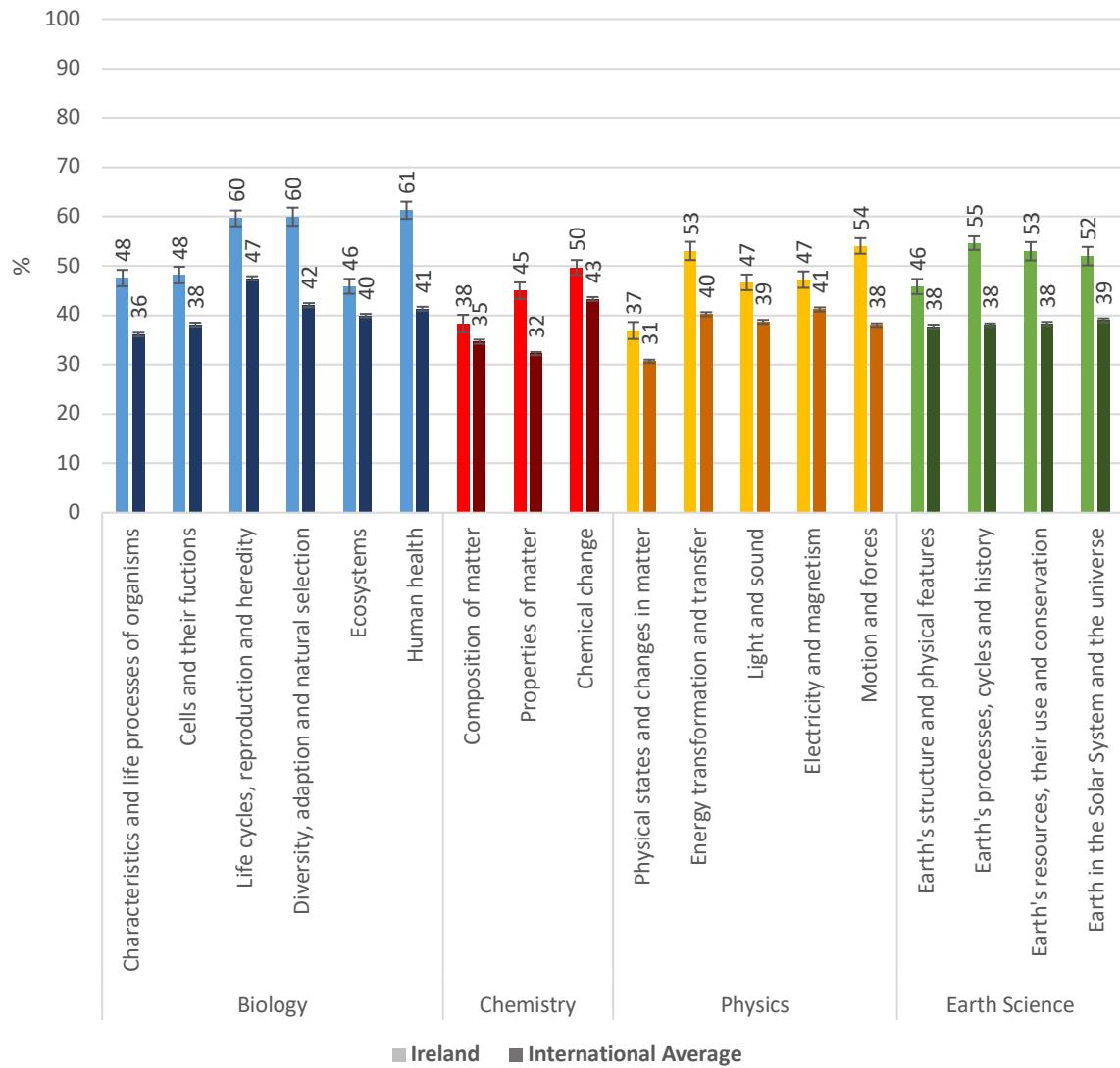
| International Benchmarks                    | Scale Score | Summary                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|---------------------------------------------|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Advanced International Benchmark</b>     | <b>625</b>  | Students communicate understanding of concepts related to biology, chemistry, physics, and Earth science in a variety of contexts. Students can classify animals into taxonomic groups. They can apply knowledge of cell structures and their functions. Students show some understanding of diversity, adaptation, and natural selection. They also recognise the interdependence of populations of organisms in an ecosystem. Students demonstrate knowledge of the composition of matter and the periodic table of the elements. Students use physical properties of matter to sort, classify, and compare substances and materials. They also recognise evidence that a chemical reaction has occurred. Students communicate understanding of particle spacing and motion in different physical states. Students apply knowledge of energy transfer and electrical circuits, can relate the properties of light and sound to common phenomena, and demonstrate understanding of forces in everyday contexts. Students communicate understanding of Earth's structure, physical features, and processes. They demonstrate knowledge of the Earth's resources and their conservation. |
| <b>High International Benchmark</b>         | <b>550</b>  | Students apply understanding of concepts from biology, chemistry, physics, and Earth science. Students can apply knowledge of the characteristics of groups of animals, life processes in humans, cells and their functions, genetic inheritance, ecosystems, and nutrition. Students show some knowledge and understanding of the composition and properties of matter and chemical reactions. They can apply basic knowledge of energy transformation and transfer, electrical circuits, properties of magnets, light, sound, and forces. They can apply knowledge of Earth's physical features, processes, cycles, and history, and show some understanding of Earth's resources and their use.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Intermediate International Benchmark</b> | <b>475</b>  | Students show and apply some knowledge of biology and the physical sciences. Students demonstrate some knowledge of characteristics of animals and apply knowledge of ecosystems. They show some knowledge of the properties of matter, chemical changes, and a few physics concepts.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Low International Benchmark</b>          | <b>400</b>  | Students show limited understanding of scientific principles and concepts and limited knowledge of science facts.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

Perkins and Clerkin (2020) reported that Second Year students in Ireland displayed a relative strength in the Earth Science content domain and relative weaknesses on the Chemistry and Physics content domains, when student performance was described in terms of scale scores which take the difficulty of items into account. Looking at the percent correct scores at the content domain level, similar patterns can be seen. Ireland was above the international average for each of the content domains among the 17 countries that participated in *paperTIMSS* at Grade 8<sup>15</sup> (Appendix Table F.4, Mullis et al., 2020). Ireland was 14 percentage points above the international average for Earth Science (which could be viewed as an area where students in Ireland performed relatively well), 11 percentage points higher for Biology, and ten and nine percentage points higher for Physics and Chemistry respectively.

<sup>15</sup> Australia, Bahrain, Cyprus, Egypt, Iran, Ireland, Japan, Jordan, Kazakhstan, Kuwait, Lebanon, Morocco, New Zealand, Oman, Romania, Saudi Arabia and South Africa.

Figure 5.1 presents the percent correct score for each of the subdomains in Ireland (lighter bars) and internationally (darker bars). In each of these subdomains, Ireland's percent correct score was significantly above the international average (Appendix Table A5.1).

**Figure 5.1: Percent correct scores by subdomain in Ireland and on average internationally**



See Appendix Table A5.1.

Note. Due to rounding, some differences may appear inconsistent with those reported in text.

Biology includes six subdomains: *Characteristics and life processes of organisms*; *Cells and their functions*; *Life cycles, reproduction and heredity*; *Diversity, adaptation and natural selection*; *Ecosystems*; and *Human health*. As noted above, comparisons between Ireland and the international average are used as a benchmark for identifying areas of relative strength and weakness at the subdomain level. Applying this here, within Biology, *Diversity, adaptation and natural selection* and *Human health* can be considered areas of relative strength in Ireland as the difference between Ireland and the international average was larger than at the domain level (these differences, and those for the other content domains, are discussed further below). Conversely, *Ecosystems* can be considered an area of relative weakness within Biology for Second Year students.

Chemistry has three subdomains including *Composition of matter*; *Properties of matter*; and *Chemical change*. *Properties of matter* was a subdomain where students in Ireland showed a relatively stronger performance than in the other subdomains.

Physics has five subdomains: *Physical states and changes in matter*; *Energy transformation and transfer*; *Light and sound*; *Electricity and magnetism*; and *Motion and forces*. *Motion and forces* is a subdomain where students in Ireland showed relatively stronger performance, while *Physical states and changes in matter* and *Electricity and magnetism* are subdomains where students in Ireland showed relatively weaker performance.

The final content domain, Earth Science, has four subdomains: *Earth's structure and physical features*; *Earth's processes, cycles and history*; *Earth's resources, their use and conservation*; and *Earth in the Solar System and the universe*. There was a smaller difference between Ireland and the international average for *Earth's structures and physical features*, indicating that this was an area of relative weakness for Ireland. In comparison, Second Year students showed relatively stronger performance on *Earth's processes, cycles and history*.

The following sections describe the patterns of performance within each content domain for Ireland in more detail, and how the TIMSS subdomains relate to the Junior Cycle Curriculum.

## 5.2 BIOLOGY

In TIMSS 2019, Biology accounted for over one-third (35%) of the items. Table 5.2 presents the connections between the Junior Cycle science curriculum (Department of Education and Skills, 2015) and the Biology content domain within the TIMSS Framework. The content domain of Biology generally relates to the Biological World strand of Junior Cycle science.

Junior Cycle science does not map directly onto the TIMSS Framework and there are some topics which are not covered at this level. For example, within the TIMSS subdomain *Characteristics and life processes of organisms*, one topic which is not covered in the curriculum is *physiological processes in animals*, and there is no explicit mention in Junior Cycle science of comparing and contrasting major organs and organ systems in humans and other vertebrates. Within the subdomain *Life cycles, reproduction and heredity*, the topic *life cycles and patterns of development* (which includes comparing and contrasting the life cycles and patterns of growth and development of different types of organisms) is not part of Junior Cycle science.

Within the subdomain *Diversity, adaptation and natural selection*, one topic (*evidence for changes in life on Earth over time*) relates more strongly to the Exploring the Physical World strand of Junior Cycle geography. Similarly, within the subdomain Ecosystems, one topic (*factors affecting population size in an ecosystem*) is more strongly associated with the strand of Exploring People, Place and Change in Junior Cycle geography. For the final subdomain, *Human health*, the topic of *causes, transmission, and prevention of, and resistance to diseases* is not part of Junior Cycle science.<sup>16</sup>

<sup>16</sup> Following the COVID-19 pandemic, students would now have an increased awareness of this topic. However, the data reported here were collected in 2019 prior to the pandemic.

**Table 5.2: Junior Cycle science linked to TIMSS 2019 Framework for the Biology content domain**

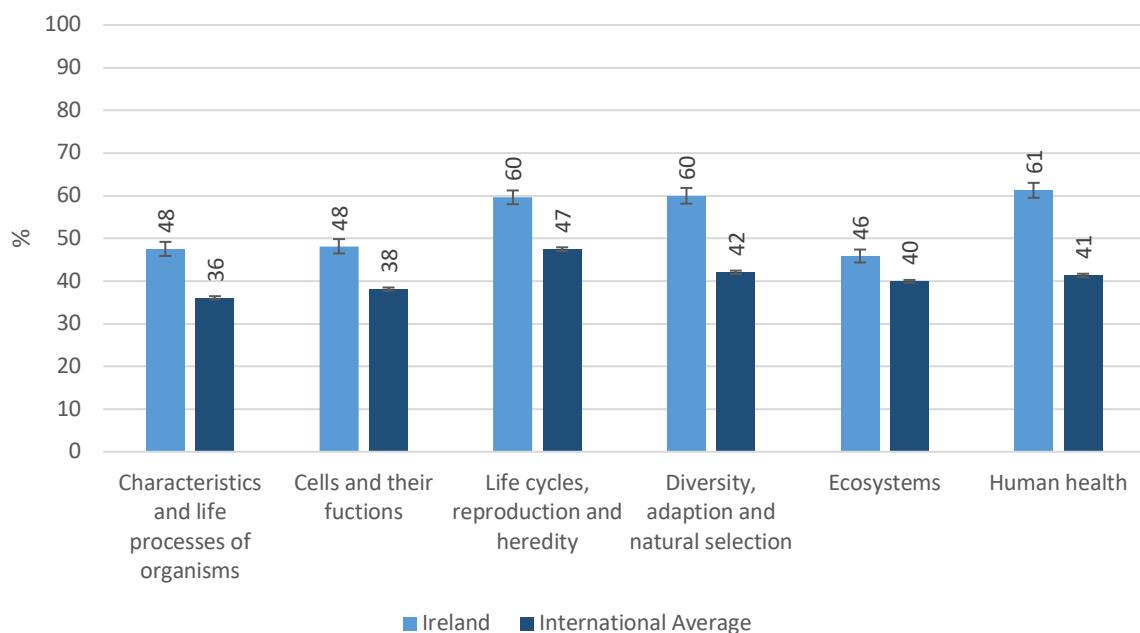
| Junior Cycle science: Biological World Strand |                                 | TIMSS Framework                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|-----------------------------------------------|---------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Biological World                              | <b>Building Blocks</b>          | <p>1. Students should be able to investigate the structures of animal and plant cells and relate them to their functions</p> <p>2. Students should be able to describe asexual and sexual reproduction; explore patterns in the inheritance and variation of genetically controlled characteristics</p> <p>3. Students should be able to outline evolution by natural selection and how it explains the diversity of living things</p>                                                                                                                                              |
|                                               | <b>Systems and Interactions</b> | <p>4. Students should be able to describe the structure, function, and interactions of the organs of the human digestive, circulatory and respiratory systems</p> <p>5. Students should be able to conduct a habitat study; research and investigate the adaption, competition and interdependence of organisms within specific habitats and communities</p> <p>6. Students should be able to evaluate how human health is affected by: inherited factors and environmental factors including nutrition; lifestyle choices; examine the role of micro-organisms in human health</p> |
|                                               | <b>Energy</b>                   | <p>7. Students should be able to describe respiration and photosynthesis as both chemical and biological processes; investigate factors that affect respiration and photosynthesis</p> <p>8. Students should be able to explain how matter and energy flow through ecosystems</p>                                                                                                                                                                                                                                                                                                   |
|                                               | <b>Sustainability</b>           | <p>9. Students should be able to explain human sexual reproduction; discuss medical, ethical, and societal issues</p> <p>10. Students should be able to evaluate how humans can successfully conserve ecological biodiversity and contribute to global food production; appreciate the benefits that people obtain from ecosystems</p>                                                                                                                                                                                                                                              |
|                                               |                                 | <b>Characteristics and Life Processes of Organisms</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|                                               |                                 | <p>1. Differences among major taxonomic groups of organisms</p> <p><b>Cells and their Functions</b></p> <p>1. The structures and functions of cells</p>                                                                                                                                                                                                                                                                                                                                                                                                                             |
|                                               |                                 | <p><b>Life Cycles, Reproduction and Heredity</b></p> <p>2. Sexual reproduction and inheritance in plants and animals</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|                                               |                                 | <b>Diversity, Adaptation and Natural Selection</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|                                               |                                 | <p>1. Variation as the basis for natural selection</p> <p><b>Characteristics and Life Processes of Organisms</b></p> <p>2. Structures and functions of major organ systems</p>                                                                                                                                                                                                                                                                                                                                                                                                      |
|                                               |                                 | <p><b>Ecosystems</b></p> <p>1. The flow of energy in ecosystem</p> <p>3. Interdependence of populations of organisms in an ecosystem</p>                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|                                               |                                 | <b>Cells and their Functions</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|                                               |                                 | <p>2. The processes of photosynthesis and cellular respiration</p> <p><b>Ecosystems</b></p> <p>1. The flow of energy in ecosystem</p> <p>2. The cycling of water, oxygen, and carbon in ecosystems</p>                                                                                                                                                                                                                                                                                                                                                                              |
|                                               |                                 | <b>Ecosystems</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|                                               |                                 | <p>5. Human impact on the environment</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

While Figure 5.1 presents the percent correct scores for each of the subdomains, Figure 5.2 presents a closer focus on the subdomains of Biology only. Ireland performed significantly above the international average in each of the subdomains, with differences ranging from six percentage points

for *Ecosystems* to 20 percentage points for *Human health* (Appendix Table A5.1). As previously mentioned, the differences between Ireland and the international average indicate that *Diversity, adaptation and natural selection* and *Human health* were areas of relative strength, while *Ecosystems* was an area where the advantage displayed by students in Ireland was relatively smaller. In Ireland, girls had a higher percent correct score than boys for *Human health* (by six percentage points) and *Life cycles, reproduction and heredity* (by five percentage points) while gender differences for the other subdomains were two percentage points or less (Appendix Table A5.2).

Looking at the concepts relating to Biology in the Teacher Questionnaire, the proportions of students who were reported to have covered the topics varied greatly (Appendix Table A5.6). Some concepts such as “major organs and organ systems in humans and other organisms” and “cells, their structure and functions, including respiration and photosynthesis”, were more commonly taught before or during Second Year. Over half of students had not covered the concepts “life cycles, sexual reproduction and heredity” or the “role of variation and adaptation in survival/extinction of species”.

**Figure 5.2: Percent correct score for the subdomains of Biology in Ireland and on average internationally**



See Appendix Table A5.1.

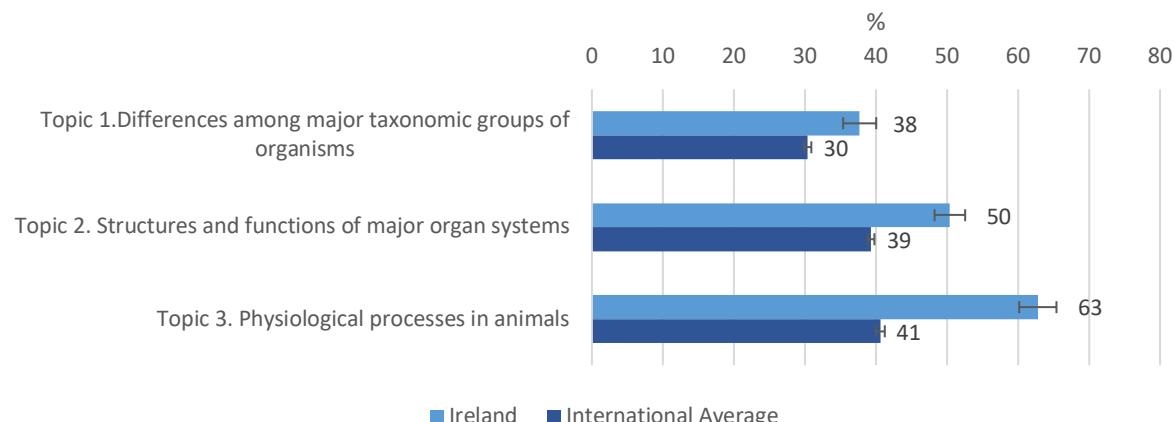
*Note.* The figure is an amended version of Figure 5.1 with only the subdomains of Biology represented. Due to rounding, some differences may appear inconsistent with those reported in text.

### ***Biology Subdomain 1: Characteristics and Life Processes of Organisms***

The first subdomain, *Characteristics and life processes of organisms*, includes three topics. Mapped on to Junior Cycle science in Ireland, two of the TIMSS topics relate to the building blocks and systems and interactions elements of the Biological World strand. The third topic, *physiological processes in animals*, is not part of Junior Cycle science.

Figure 5.3 presents percent correct scores at the topic level. Comparing Ireland with the international average, the largest difference in favour of students in Ireland (22 percentage points) was observed for Topic 3 (which is not included in the Junior Cycle specifications) and the smallest difference (seven percentage points) for Topic 1. Gender differences were small, ranging from one to four percentage points (Appendix Table A5.4).

**Figure 5.3: Percent correct scores at the topic level for the subdomain *Characteristics and life processes of organisms* in Ireland and on average internationally**



See Appendix Table A5.3.

*Note.* Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

As described in Chapter 1, selected items are released after each cycle of TIMSS. Following TIMSS 2019, there was one released item from the subdomain *Characteristics and life processes of organisms*. Table 5.3 presents this item, which has two parts. The item relates to the topic of *differences among major taxonomic groups of organisms*, for which students both in Ireland and internationally had the lowest percent correct score. As noted in Chapter 1, TIMSS 2019 included a TCMA exercise which asked subject experts to identify any items that would be considered outside the Junior Cycle curriculum. This item is one that was classified as being outside the scope of Junior Cycle science, meaning that Second Year students would not have been expected to have covered this in class.

Part (A) of this item asks students to classify seven animals as mammals or non-mammals (Table 5.3). To receive full credit, students had to classify each of the animals correctly. In Part (B), students are presented with a table where the same animals are sorted into two groups. The students are asked to identify which characteristic was used to classify the animals into these two groups.

Part (A) of the item was categorised as at the *Advanced International Benchmark (625)*; students in Ireland performed significantly below the international average on this part. Part (B) was categorised as *Above the Advanced International Benchmark (625+)*, and there was no significant difference between the percent correct scores in Ireland and internationally.

**Table 5.3: Released item for *Characteristics and life processes of organisms*.**

|                                                 |                                                                                                                                                      |                                                                |
|-------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------|
| Characteristics and life processes of organisms | Differences among major taxonomic groups of organisms                                                                                                |                                                                |
| Item Description                                | A. Classifies 7 of 7 animals as mammals or non-mammals<br>B. States the biological characteristic used to distinguish vertebrates from invertebrates |                                                                |
| Benchmark                                       | A. Item at Advanced International Benchmark (625)<br>B. Item Above Advanced International Benchmark (625+)                                           |                                                                |
| Percent Correct Score                           | A. Ireland: 20%<br>B. Ireland: 14%                                                                                                                   | A. International Average: 25%<br>B. International Average: 16% |
| Reason for Inclusion                            | Only released item relating to this subdomain                                                                                                        |                                                                |

Here is a list of animals.

**Ant      Cat      Dolphin      Earthworm      Fish      Frog      Jellyfish**

A. Classify the animals into two groups based on whether or not the animal is a mammal. List the animals in each group in the table.

|        |              |
|--------|--------------|
| Mammal | Not a mammal |
|        |              |

B. The same animals have been classified into these two groups.

| Group 1 | Group 2   |
|---------|-----------|
| Cat     | Ant       |
| Dolphin | Earthworm |
| Fish    | Jellyfish |
| Frog    |           |

What characteristic was used to classify the animals into these two groups?

**Solutions:**

**A.**

|         |              |
|---------|--------------|
| Mammal  | Not a mammal |
| Cat     | Ant          |
| Dolphin | Earthworm    |
|         | Fish         |
|         | Frog         |
|         | Jellyfish    |

**B. Identifies the characteristic used to classify the animals into Group 1 and Group 2 as *Vertebrates/Has a backbone* and *Invertebrates/Does not have a backbone*.**

**Examples:**

- **Whether or not the animal is a vertebrate**
- **Answers the question of whether or not the animal has a backbone.**
- **Group 1 animals have backbones and Group 2 animals do not.**
- **All the animals in the first group have a spine.**
- **The animals in the second group are invertebrates**
- **Backbone**

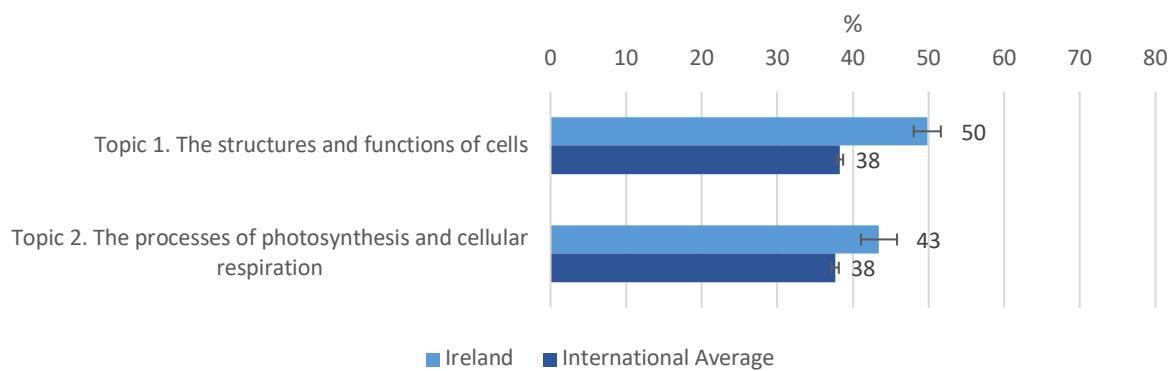
See Appendix Table A5.5.

## Biology Subdomain 2: Cells and their Functions

The second subdomain within Biology is *Cells and their functions*. This includes two topics, as listed in Figure 5.4. Each of the topics relate to the Biological World strand of the curriculum and, in particular, the building blocks and energy elements.

Second Year students in Ireland had a 12 percentage point advantage over the international average for Topic 1 and a smaller advantage (six percentage points) for Topic 2. Boys in Ireland had a three percentage point advantage over girls for the second topic, with almost no difference between boys and girls for the first topic (Appendix Table A5.4).

**Figure 5.4: Percent correct scores by topic for the subdomain *Cells and their functions* in Ireland and on average internationally**



See Appendix Table A5.3

*Note.* Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

Table 5.4 presents a released item relating to *Cells and their functions*. This item has two parts. In the first part, students are asked to identify two ways that plant and animal cells are similar. This part was classified at the *Intermediate International Benchmark* (475). Almost two-fifths (39%) of students in Ireland who answered this item did so correctly, which was above the international average (26%).

In the second part of the item, students are asked to identify two differences between plant and animal cells. This was classified as *Above the Advanced International Benchmark* (625+) and less than one-tenth of students in Ireland (8%) who answered this question did so correctly. This was not significantly different to the international average (9%).

**Table 5.4: Released item for *Cells and their functions*.**

| Cells and their functions | The structures and functions of cells                                                                                                                                                                           |                                                               |
|---------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|
| Item Description          | A. Identifies two ways that plant and animal cells are similar<br>B. Identifies two ways that plant and animal cells are different                                                                              |                                                               |
| Benchmark                 | A. Item at Intermediate International Benchmark (475)<br>B. Item Above Advanced International Benchmark (625+)                                                                                                  |                                                               |
| Percent Correct Score     | A. Ireland: 39%<br>B. Ireland: 8%                                                                                                                                                                               | A. International Average: 26%<br>B. International Average: 9% |
| Reason for Inclusion      | Constructed response question with two parts where Ireland was significantly above the international average in the first part and not significantly different to the international average in the second part. |                                                               |

Plant cells and animal cells have some similarities and some differences.

A. List two ways that plant cells and animal cells are **similar**.

- 1.
- 2.

B. List two ways that plant cells and animal cells are **different**.

- 1.
- 2.

**Solution:**

**A. List two similarities from the list of acceptable responses below.**

**Both plant and animal cells:**

- **Have a nucleus (or chromosomes or DNA).**
- **Have cell membranes.**
- **Have cytoplasm.**
- **Have mitochondria.**
- **Are alive (or both can die).**
- **Undergo cell division (or reproduce or grow).**
- **Carry out respiration (or use oxygen or air).**
- **Require energy (or food or nutrients or water) to survive.**
- **Make proteins.**
- **Are usually very small in size.**
- **Have vacuoles.**

**B. List two differences from this list of acceptable responses below.**

- **Plant cells have cell walls and animal cells do not.**
- **Plant cells have chloroplasts and animal cells do not.**
- **Plant cells carry out photosynthesis (or make their own food or have chlorophyll) and animal cells do not.**
- **Plant cells have a large (central) vacuole and animal cells do not have a large vacuole (or animal cells have many small vacuoles); OR plant cells have cell sap and animal cells do not.**
- **Animal cells have centrioles and plant cells do not.**
- **Animal cells have lysosomes and plant cells do not.**

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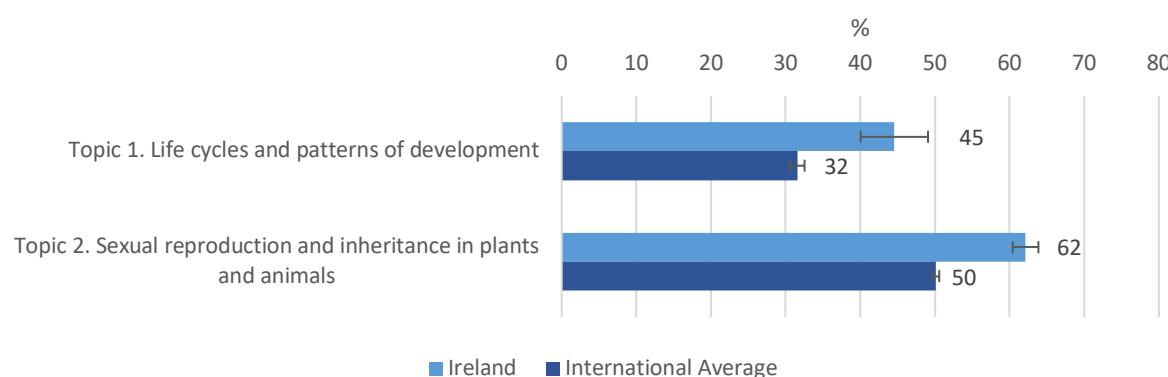
See Appendix Table A5.5

### Biology Subdomain 3: Life Cycles, Reproduction and Heredity

The third subdomain within Biology is *Life Cycles, reproduction and heredity*. This includes two topics. The first topic is not part of Junior Cycle science, while the second relates to the Biological World strand in Junior Cycle science. Figure 5.5 presents percent correct scores, at the topic level, for this subdomain.

The differences between Ireland and the international average were broadly similar for both items (13 and 12 percentage points, respectively). In terms of gender differences, for both topics, girls in Ireland showed a two percentage point advantage for the first topic and a six percentage point advantage for the second topic (Appendix Table A5.4).

**Figure 5.5: Percent correct scores by topic for the subdomain *Life Cycles, reproduction and heredity* in Ireland and on average internationally**



See Appendix Table A5.3

*Note.* Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

There was one released item relating to *Life cycles, reproduction and heredity* (Table 5.5). The item was classified at the *High International Benchmark* (550). In this item, students are presented with a question about inheritance of traits among rabbits when parents do not have the same traits. To answer the item correctly, students need to understand that the male and female rabbits can pass the trait of white hair onto their offspring even though they do not display the trait themselves.

Three-fifths of students in Ireland (62%) who answered this question did so correctly, compared to less than half of students internationally (47%). One-fifth of Second Year students (20%) incorrectly chose option (d), which suggests that rabbits' offspring will blend in with the colour of their surroundings, thereby implying that environment has an impact on hair colour at birth.

**Table 5.5: Released Item for *Life cycles, reproduction and heredity*.**

|                                        |                                                                        |                            |
|----------------------------------------|------------------------------------------------------------------------|----------------------------|
| Life cycles, reproduction and heredity | Sexual reproduction and inheritance in plants and animal               |                            |
| Item Description                       | Recognises why rabbits inherit traits that their parents do not have   |                            |
| Benchmark                              | Item at High International Benchmark (550)                             |                            |
| Percent Correct Score                  | Ireland: 62%                                                           | International Average: 47% |
| Reason for Inclusion                   | Item where Ireland was significantly above the average internationally |                            |

Francisco had a male rabbit and a female rabbit. He kept them in a pen painted white on the inside. Both rabbits had black hair. When these rabbits bred, some of their offspring had white hair.

Which of the following explains how this pair of black-haired rabbits could produce offspring with white hair?

- (a) When any black-haired male and female rabbits breed, they will eventually produce some white-haired offspring.
- (b) The male and female black-haired rabbits can pass some traits on to their offspring, even though they do not express the trait themselves.
- (c) If the male and female black-haired rabbits are old, they will only produce offspring with white hair.
- (d) Male and female rabbits will produce offspring that blend in with the colour of their surroundings.

**Solution: (b)**

See Appendix Table A5.5.

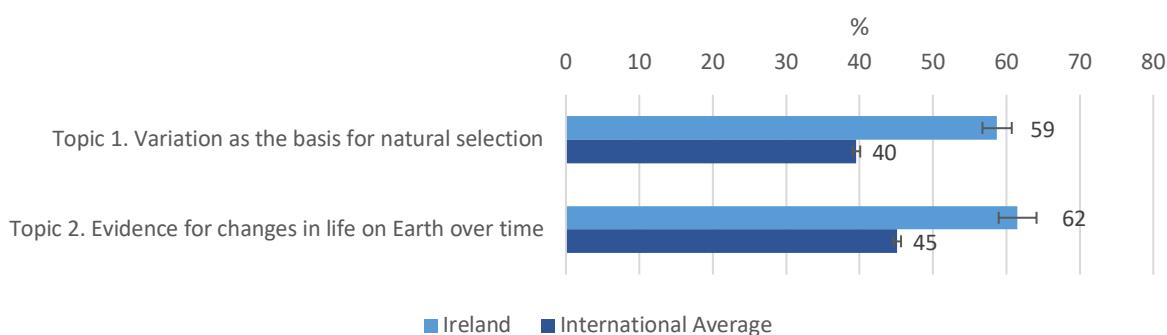
**Biology Subdomain 4: Diversity, Adaptation, and Natural Selection**

The fourth subdomain within Biology is *Diversity, adaptation and natural selection*. As noted above, this was an area of relative strength for students in Ireland. The first topic (*variation as the basis for natural selection*) relates to the Biological World strand of Junior Cycle science. However, the second topic (*evidence for changes in life on Earth over time*) relates to the strand Exploring the Physical World in Junior Cycle geography.

Figure 5.6 presents the percent correct scores for both topics. The differences between Ireland and the international average were 19 and 16 percentage points, respectively, which demonstrates that Second Year students performed relatively well across each of the topics within this subdomain. Very small gender differences in favour of girls (between one and two percentage points) were observed (Appendix Table A5.4).

There were no released items relating to this subdomain.

**Figure 5.6: Percent correct scores at the topic level for the subdomain *Diversity, adaptation and natural selection* in Ireland and on average internationally**



See Appendix Table A5.3.

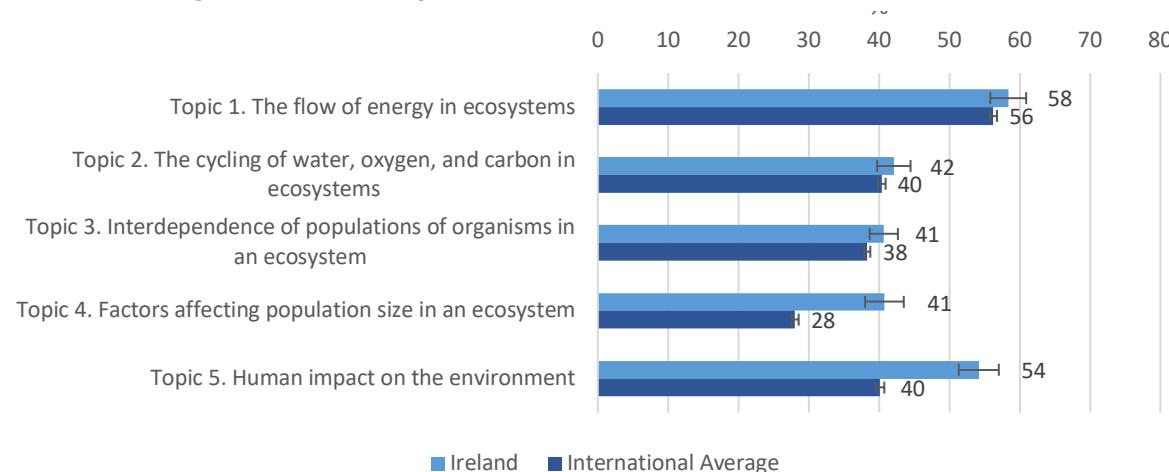
Note. Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

### Biology Subdomain 5: Ecosystems

The fifth subdomain within Biology is *Ecosystems*. As previously described, this is a subdomain where Ireland performed less well relative to the other subdomains in Biology. This subdomain relates to the Biological World strand of Junior Cycle science with the exception of the fourth topic (*factors affecting population size in an ecosystem*), which relates to the Exploring People, Place and Change strand of Junior Cycle geography.

*Ecosystems* includes five topics (Figure 5.7). For the first, second and third topics, students in Ireland achieved a percent correct score two percentage points above the TIMSS average, while the difference for the fourth and fifth topics were 13 and 14 percentage points, respectively. There were small gender differences in favour of boys (ranging from two to six percentage points) for the first, second and third topics, and in favour of girls (one to two percentage points) for the fourth and fifth topics (Appendix Table A5.4).

**Figure 5.7: Percent correct scores at the topic level for the subdomain *Ecosystems* in Ireland and on average internationally**



See Appendix Table A5.3.

Note. Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

A released item relating to *Ecosystems* is presented in Table 5.6 below. This item relates to *the cycling of water, oxygen and carbon in ecosystems* at the topic level, and was categorised at the *High International Benchmark (550)* (see Table 5.1). In Ireland, 48% of Second Year students

answered this item correctly while, internationally, the percent correct score was 56%.

In this item, students are presented with an investigation which Adam is conducting to see how the mass of leaves changes over time. He removes three leaves from a tree and records the mass of each leaf initially and also after one week, finding that the mass of each of the leaves has decreased. Students are asked to indicate which statement (from four options) best explains the decrease in mass.

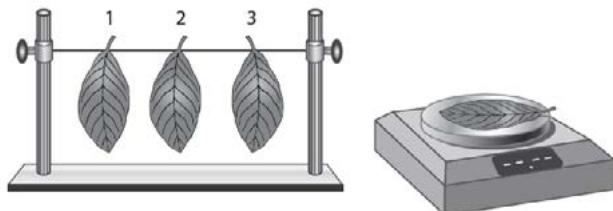
In Ireland, almost half of students could identify correctly that the leaves lost water. Over one-quarter of Second Year students (28%) incorrectly chose option (a), believing that the mass decreased because the leaves released oxygen. Over one-tenth of students chose option (b), indicating that the leaves used glucose, and option (d), believing that the leaves released carbon dioxide.

**Table 5.6: Released Item for *Ecosystems*.**

|                       |                                                                                              |                            |
|-----------------------|----------------------------------------------------------------------------------------------|----------------------------|
| Ecosystems            | The cycling of water, oxygen, and carbon in ecosystems                                       |                            |
| Item Description      | Recognises an explanation for why the mass of leaves removed from a tree decreases over time |                            |
| Benchmark             | Item at High International Benchmark (550)                                                   |                            |
| Percent Correct Score | Ireland: 48%                                                                                 | International Average: 56% |
| Reason for Inclusion  | Item where Ireland performed significantly below the international average                   |                            |

Adam investigates how the mass of leaves changes over time.

He removes three leaves from a tree and finds the mass of each leaf.



After one week Adam finds the mass of each leaf again. He records his results in the table.

| Leaf | Mass at start (grams) | Mass after one week (grams) |
|------|-----------------------|-----------------------------|
| 1    | 2.22                  | 1.65                        |
| 2    | 1.93                  | 1.34                        |
| 3    | 2.08                  | 1.6                         |

Which statement **best** explains this decrease in mass?

- (a) The leaves released oxygen
- (b) The leaves used glucose
- (c) The leaves lost water
- (d) The leaves released carbon dioxide

**Solution: (c)**

See Appendix Table A5.5.

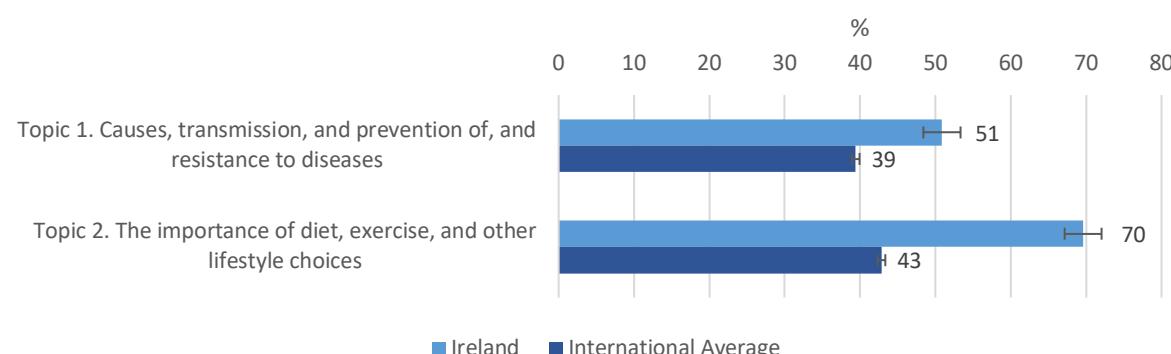
## Biology Subdomain 6: Human Health

The final subdomain within Biology is *Human health*, which contains two topics. One of the topics (*the importance of diet, exercise, and other lifestyle choices*) relates to the Biological World strand in Junior Cycle science, while the other topic (*causes, transmission, and prevention of, and resistance to diseases*) is not included in Junior Cycle science. As previously noted, this is a subdomain where students in Ireland performed relatively well in comparison to the other subdomains within Biology.

Figure 5.8 presents the percent correct scores for the two topics within *Human health*. Second Year students scored 27 percentage points (Topic 1) and 11 percentage points (Topic 2) higher than their international peers. The second topic had the largest gender difference of any topic within TIMSS Grade 8 science among students in Ireland, with a 12 percentage point difference in favour of girls (Appendix Table A5.4).

There were no released items relating to this subdomain.

**Figure 5.8: Percent correct scores at the topic level for the subdomain *Human health* in Ireland and on average internationally**



See Appendix Table A5.3.

Note. Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

## 5.3 CHEMISTRY

In TIMSS 2019, the Chemistry domain accounted for one-fifth of the items (20%). Table 5.7 presents the linkage of Junior Cycle science to the Chemistry content domain of the TIMSS framework. Chemistry is made up of three subdomains: *Composition of matter*; *Properties of matter*; and *Chemical change*. These subdomains relate mainly to the Chemical World strand of Junior Cycle science, but some topics within these subdomains are not included in Junior Cycle science.

The subdomain *Composition of matter* relates to both the building blocks and the systems and interactions elements of the Chemical World strand. Similarly, the subdomain *Properties of matter* relates to the same elements within the Chemical World strand. The final subdomain, *Chemical change*, relates to the building blocks, systems and interactions, and energy elements of the Chemical World strand. However, one of the topics within *Chemical change* is not included in Junior Cycle science. This topic, *chemical bonds*, includes recognising that a chemical bond results from the attraction between atoms in a compound and that the atoms' electrons are involved in this bonding.

Conversely, some learning outcomes in the Chemical World strand of Junior Cycle science are not part of the TIMSS framework. For example, the element of sustainability and its related learning outcome are not included in the TIMSS framework.

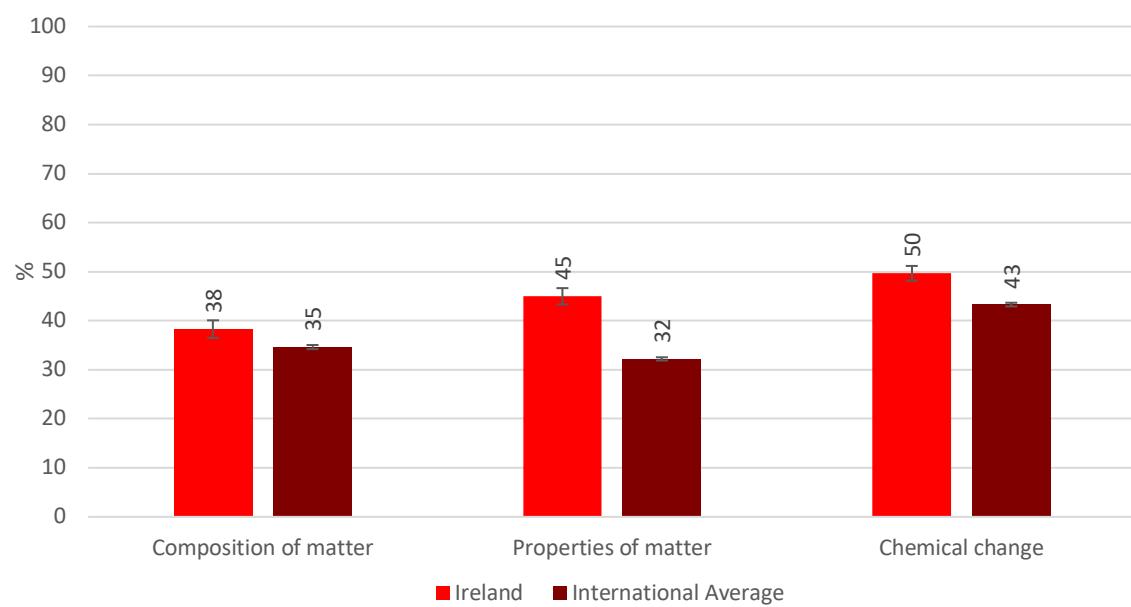
**Table 5.7: Junior Cycle science linked to TIMSS 2019 Framework for the Chemistry content domain**

| Junior Cycle science: Chemical World Strand |                                 | TIMSS Framework                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|---------------------------------------------|---------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Chemical World                              | <b>Building Blocks</b>          | <p>1. Students should be able to investigate whether mass is unchanged when chemical and physical changes take place</p> <p>2. Students should be able to develop and use models to describe the atomic nature of matter; demonstrate how they provide a simple way to account for the conservation of mass, changes of state, physical change, chemical change, mixtures, and their separation</p> <p>3. Students should be able to describe and model the structure of the atom in terms of the nucleus, protons, neutrons, and electrons; comparing mass and charge of protons, neutrons, and electrons</p> <p>4. Students should be able to classify substances as elements, compounds, mixtures, metals, non-metals, solid, liquids, gases, and solutions</p> |
|                                             | <b>Systems and Interactions</b> | <p>5. Students should be able to use the Periodic Table to predict the ratio of atoms in compounds of two elements</p> <p>6. Students should be able to investigate the properties of different materials including solubility, conductivity, melting points, and boiling points</p> <p>7. Students should be able to investigate the effect of a number of variables on the rate of chemical reactions including the production of common gases and biochemical reactions</p> <p>8. Students should be able to investigate the reactions between acids and bases; use indicators and pH scale</p>                                                                                                                                                                 |
|                                             | <b>Energy</b>                   | <p>9. Students should be able to consider chemical reactions in terms of energy, using the terms exothermic, endothermic and activation energy, and use simple energy profile diagrams to illustrate energy changes</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|                                             | <b>Sustainability</b>           | <p>10. Students should be able to evaluate how humans contribute to sustainability through the extraction, use, disposal, and recycling of materials</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|                                             |                                 | <b>Composition of Matter</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|                                             |                                 | 1. Structure of atoms and molecules                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|                                             |                                 | <b>Chemical Change</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|                                             |                                 | 1. Characteristics of chemical changes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|                                             |                                 | 2. Matter and energy in chemical reactions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|                                             |                                 | <b>Composition of Matter</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|                                             |                                 | 1. Structure of atoms and molecules                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|                                             |                                 | <b>Composition of Matter</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|                                             |                                 | 2. Elements, compounds, and mixtures                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|                                             |                                 | <b>Properties of Matter</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|                                             |                                 | 2. Physical and chemical properties as a basis for classifying matter                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|                                             |                                 | 3. Mixtures and solutions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|                                             |                                 | <b>Composition of Matter</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|                                             |                                 | 3. The periodic table of elements                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|                                             |                                 | <b>Properties of Matter</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|                                             |                                 | 1. Physical and chemical properties of matter                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|                                             |                                 | 2. Physical and chemical properties as a basis for classifying matter                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|                                             |                                 | <b>Properties of Matter</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|                                             |                                 | 3. Mixtures and solutions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|                                             |                                 | <b>Chemical Change</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|                                             |                                 | 2. Matter and energy in chemical reactions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|                                             |                                 | <b>Properties of Matter</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|                                             |                                 | 4. Properties of acids and bases                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|                                             |                                 | <b>Chemical Change</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|                                             |                                 | 2. Matter and energy in chemical reactions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

Figure 5.9 presents the percent correct scores for the three subdomains of Chemistry. There was a 13 percentage point difference in favour of Ireland for *Properties of matter*, while the differences for the other subdomains were six percentage points (*Chemical change*) and four percentage points (*Composition of matter*). This indicates that *Properties of matter* could be considered an area where Second Year students showed a relative strength compared to the other subdomains within Chemistry. Second Year girls outperformed boys by between three and four percentage points for each of these subdomains (Appendix Table A5.2).

Teachers indicated that more than 90% of students had been taught before or during the year of testing about structure, classification, and composition of matter (94%), the periodic table (92%), the physical and chemical properties of matter (96%), and mixtures and solutions (98%). In contrast, topics such as the characteristics of chemical reactions, matter and energy in chemical reactions, and the role of electrons in chemical bonds had not yet been covered by approximately half of the students (Appendix Table A5.6).

**Figure 5.9: Percent correct score for the subdomains of Chemistry in Ireland and on average internationally**



See Appendix Table A5.1.

*Note.* The figure is an amended version of Figure 5.1 with only the subdomains of Chemistry represented. Due to rounding, some differences may appear inconsistent with those reported in text.

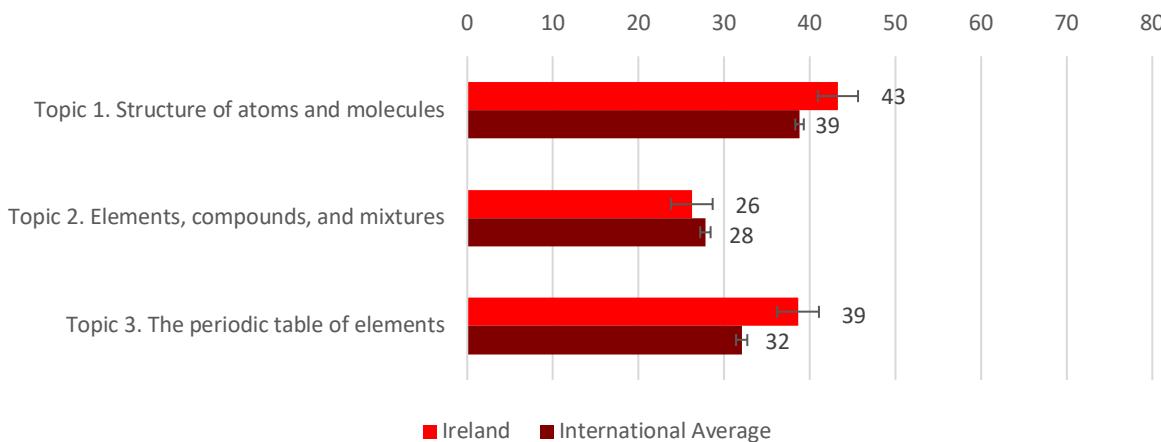
### **Chemistry Subdomain 1: Composition of Matter**

The first subdomain of Chemistry is *Composition of matter* which includes three topics (Figure 5.10). Each of these topics relates to the building blocks and the systems and interactions elements of the Chemical World strand of Junior Cycle science. The TIMSS Teacher Questionnaire shows that the majority of students had covered these concepts either before or during Second Year (Appendix Table A5.6). Differences between Ireland and the international average were comparatively small in this subdomain, with the largest difference in favour of Ireland observed for the third topic (seven percentage points).

Notably, the second topic is the only topic within the entirety of Grade 8 science for which Ireland was below the international average (albeit that the difference was not statistically significant, at two percentage points). This suggests that this topic is an area of relative weakness for Ireland. There

was a six percentage point difference in favour of girls for the first topic and a two percentage point difference, also in favour of girls, for the third topic (Appendix Table A5.4).

**Figure 5.10: Percent correct scores at the topic level for the subdomain *Composition of matter* in Ireland and on average internationally**



See Appendix Table A5.3

*Note.* For Topic 2, Ireland's percent correct score was not significantly different from the international average. For the other topics, Ireland's score was significantly above the international average.

Due to rounding, some differences may appear inconsistent with those reported in text.

Table 5.8 presents a released item relating to *Composition of matter*, which was classified at the *Advanced International Benchmark* (625). Over one-third (35%) of students in Ireland answered this item correctly, compared with one-quarter (24%) internationally.

In this question, students are presented with a subset of the periodic table. The item outlines that hydrogen is the first element of the periodic table and that its atomic number is 1. They are then presented with four other elements and are asked to rank them by their atomic number from smallest to largest. To answer this item correctly, students must understand that in a periodic table, the elements are listed in order of increasing atomic number.

**Table 5.8: Released Item for *Composition of matter***

|                       |                                                                                                                          |                            |
|-----------------------|--------------------------------------------------------------------------------------------------------------------------|----------------------------|
| Composition of matter | The periodic table of elements                                                                                           |                            |
| Item Description      | Uses a portion of the periodic table to order four elements from the smallest atomic number to the largest atomic number |                            |
| Benchmark             | Item at Advanced International Benchmark (625)                                                                           |                            |
| Percent Correct Score | Ireland: 35%                                                                                                             | International Average: 24% |
| Reason for Inclusion  | Item where Ireland performed significantly above the international average                                               |                            |

This is a portion of the periodic table of elements.

|                |    |    |    |   |   |    |    |
|----------------|----|----|----|---|---|----|----|
| <sup>1</sup> H |    |    |    |   |   |    | He |
| Li             | Be | B  | C  | N | O | F  | Ne |
| Na             | Mg | Al | Si | P | S | Cl | Ar |

Hydrogen (H) is the first element of the periodic table. The nucleus of a hydrogen atom contains one proton. The atomic number of hydrogen is 1.

Four elements from the periodic table are shown below. The elements are not ordered by their atomic numbers.

Write each element in the boxes to order them from smallest atomic number to largest atomic number.

| Sodium (Na)          | Fluorine (F)         | Helium (He)          | Carbon (C)           |
|----------------------|----------------------|----------------------|----------------------|
| Smallest             |                      | Largest              |                      |
| <input type="text"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> |

**Solution:**

| Smallest                    |                             |                               | Largest                     |
|-----------------------------|-----------------------------|-------------------------------|-----------------------------|
| <input type="text"/> Helium | <input type="text"/> Carbon | <input type="text"/> Fluorine | <input type="text"/> Sodium |

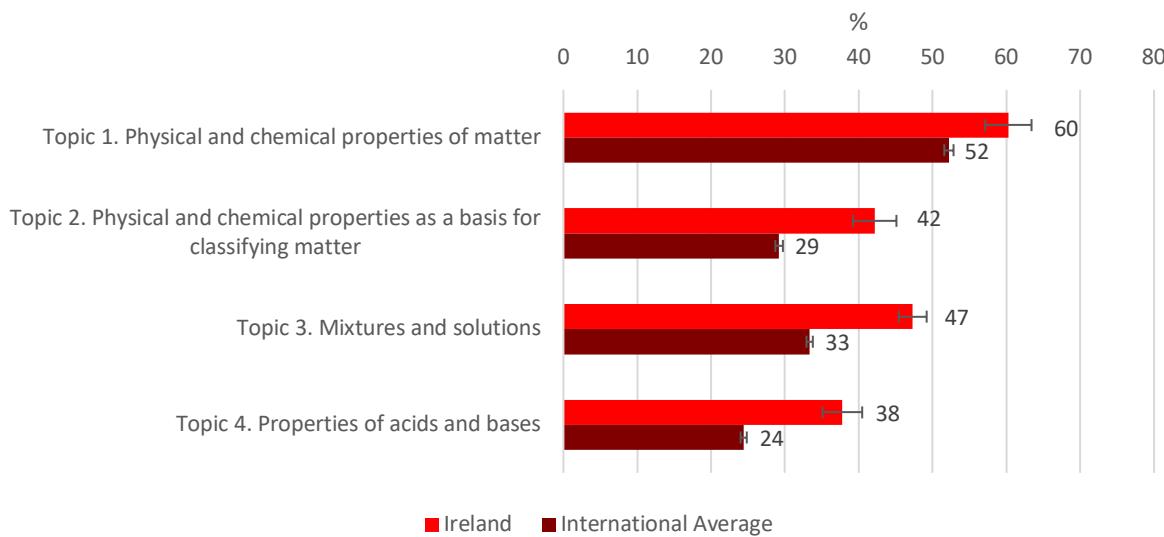
See Appendix Table A5.5

### Chemistry Subdomain 2: Properties of Matter

The second subdomain within Chemistry is *Properties of matter*. This subdomain aligns with both the building blocks and the systems and interactions elements of the Chemical World strand of Junior Cycle science. This subdomain includes four topics, listed in Figure 5.11.

Comparing Ireland and the international average, three of the topics (the second, third and fourth topics in Figure 5.11) showed similar differences, with a 13-14 percentage point difference in favour of students in Ireland in each case. Topic 1 showed an eight percentage point difference between Ireland and the international average. Second Year boys outperformed girls by five to seven percentage points for three of the four topics; the exception was Topic 1 (*physical and chemical properties of matter*) where girls outperformed boys by five percentage points (Appendix Table A5.4).

**Figure 5.11: Percent correct scores at the topic level for the subdomain *Properties of matter* in Ireland and on average internationally**



See Appendix Table A5.3

Note. Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

Table 5.9 presents a released item, which was classified as being *Above the Advanced International Benchmark (625+)*. In this item, students are asked to give three answers to classify three solutions as acidic, basic, or neutral, given both their pH value and the colour of the indicator paper. Almost half of Second Year students (48%) answered for Solution 1 and Solution 2 correctly, while a slightly lower proportion (45%) answered for Solution 3 correctly. One-third of students in Ireland (33%) answered this item completely correctly (with all three parts correct) compared to one-quarter of students internationally (26%).

**Table 5.9: Released Item for *Properties of matter***

| Properties of matter  | Properties of acids and bases                                                                    |                                                                      |
|-----------------------|--------------------------------------------------------------------------------------------------|----------------------------------------------------------------------|
| Item Description      | Interprets information in a table to determine if 3 of 3 solutions are acidic, basic, or neutral |                                                                      |
| Benchmark             | Item Above Advanced International Benchmark (625+)                                               |                                                                      |
| Percent Correct Score | Ireland: Overall 33%<br>Part (a) 48%; (b) 48%; (c) 45%                                           | International Average: Overall 26%<br>Part (a) 40%; (b) 42%; (c) 42% |
| Reason for Inclusion  | Item where Ireland performed significantly above the international average                       |                                                                      |

The table below shows the results of dipping universal pH indicator paper into three different solutions.

|                   | pH | Colour of indicator paper |
|-------------------|----|---------------------------|
| <b>Solution 1</b> | 7  | Green                     |
| <b>Solution 2</b> | 6  | Yellow                    |
| <b>Solution 3</b> | 8  | Blue                      |

Is each solution acidic, basic or neutral?

Tick one circle for each solution.

|                  | Acidic  | Basic   | Neutral |
|------------------|---------|---------|---------|
| Solution 1 ----- | ---A--- | ---B--- | ---C--- |
| Solution 2 ----- | ---A--- | ---B--- | ---C--- |
| Solution 3 ----- | ---A--- | ---B--- | ---C--- |

**Answer:**

**Solution 1 – (C) Neutral**

**Solution 2 – (A) Acid**

**Solution 3 – (B) Base**

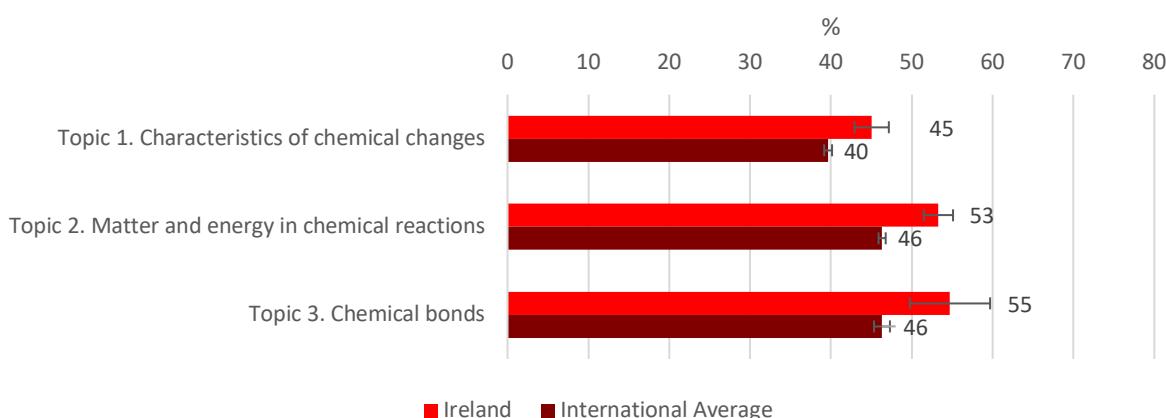
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See Appendix Table A5.5

### Chemistry Subdomain 3: Chemical Change

The final subdomain within Chemistry is *Chemical change*, which includes three topics (Figure 5.12). This subdomain relates to the building blocks, systems and interactions, and energy elements of the Chemical World strand. However, the third topic, *chemical bonds*, is not included as part of Junior Cycle science. The differences between Ireland and the international average were generally similar for each of the topics (from five to eight percentage points in favour of Ireland). There were small gender differences (three to four percentage points) in favour of girls in Second Year for both the first and second topics, with almost no difference for the third topic.

**Figure 5.12: Percent correct scores at the topic level for the subdomain *Chemical change* in Ireland and on average internationally**



See Appendix Table A5.3

*Note.* Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

Table 5.10 presents a released item for this subdomain. This item was classified at the *Advanced International Benchmark (625)*. Approximately half of students in Ireland (52%) who answered this item did so correctly, which did not differ significantly from the international average (49%).

In this item, students are asked to pick which of the illustrations provided shows the result of the chemical reaction of two substances. One-quarter of students in Ireland (26%) incorrectly chose option (c), which does not show a chemical reaction as no new product is created. About one-seventh of students (14%) chose option (b), which contravenes the law of conservation as the number of atoms in the reactants must be the same as the number of atoms in the products. Notably, the Chief Examiner's report on the 2019 Junior Cycle Examination also observed that students performed poorly on an item requiring them to cite evidence for the conservation of mass during a chemical reaction (SEC, 2019).

**Table 5.10: Released Item for *Chemical change***

|                       |                                                                                                     |                            |
|-----------------------|-----------------------------------------------------------------------------------------------------|----------------------------|
| Chemical change       | Matter and energy in chemical reactions                                                             |                            |
| Item Description      | Recognises which model best illustrates the results of a chemical reaction                          |                            |
| Benchmark             | Item at Advanced International Benchmark (625)                                                      |                            |
| Percent Correct Score | Ireland: 52%                                                                                        | International Average: 49% |
| Reason for Inclusion  | Item where performance in Ireland and at the international average was not significantly different. |                            |

Hugo wants to illustrate a chemical reaction. He uses models of Substance 1 and Substance 2 as shown below. Circles represent atoms of each substance.

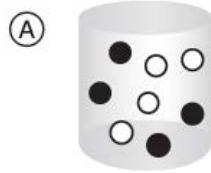


Substance 1

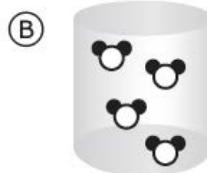


Substance 2

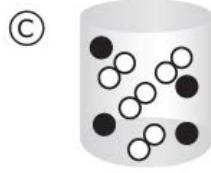
How should he illustrate the results of a chemical reaction after Substance 1 reacted with Substance 2?



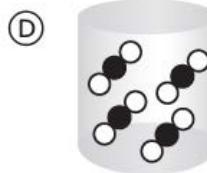
(A)



(B)



(C)



(D)

**Solution: (D)**

See Appendix Table A5.5

## 5.4 PHYSICS

In TIMSS 2019, the Physics domain accounted for approximately one-quarter of the items (25%). Table 5.11 presents the linking of Junior Cycle science to the Physics content domain of the TIMSS framework. Physics is made up of five subdomains including *Physical states and changes in matter*; *Energy transformation and transfer*; *Light and sound*; *Electricity and magnetism*; and *Motion and forces*. These subdomains map mainly to the Physical World strand of Junior Cycle science. However, there are some subdomains and topics which are not covered as part of Junior Cycle science. In particular, topics within the subdomain *Light and sound* are not included in Junior Cycle science.

In addition, within the subdomain *Physical states and changes in matter*, parts of the first topic (*motion of particles in solids, liquids and gases*) are not included in the Junior Cycle, including relating changes in temperature of a gas to changes in its volume and/or pressure and changes in the average speed of its particles. Similarly, for the second topic in this subdomain (*changes in states*

*of matter*), the idea of relating the rate of change of state to physical factors is not part of Junior Cycle science. One of the topics within the subdomain *Electricity and magnetism (properties and uses of permanent magnets and electromagnets)* is not included as part of Junior Cycle science. Finally, parts of the third topic within *Motion and forces (effects of forces)* are not included in Junior Cycle science, including describing the functioning of simple machines, describing pressure in terms of force and area, and describing effects related to pressure.

Conversely, there are some learning outcomes in the Physical World strand of Junior Cycle science which are not in the TIMSS framework, including the element of sustainability and its associated learning outcome, and parts of each of the other elements (Table 5.11).

**Table 5.11: Junior Cycle science linked to TIMSS 2019 Framework for the Physics content domain**

| Junior Cycle science: Physical World Strand |                          | TIMSS Framework                                                                                                                                                                                                                                                                                                                                      |
|---------------------------------------------|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Physical World                              | Building Block           | <p>1. Students should be able to select and use appropriate measuring instruments</p> <p>2. Students should be able to identify and measure/calculate length, mass, time, temperature, area, volume, density, speed, acceleration, force, potential difference, current, resistance, electrical power</p>                                            |
|                                             | Systems and Interactions | <p>3. Students should be able to investigate patterns and relationships between physical observables</p> <p>4. Students should be able to research and discuss a technological application of physics in terms of scientific, societal and environmental impact</p> <p>5. Students should be able to design and build simple electronic circuits</p> |
|                                             | Energy                   | <p>6. Students should be able to explain energy conservation and analyse processes in terms of energy changes and dissipation</p>                                                                                                                                                                                                                    |
|                                             |                          | <b>Physical States and Changes in Matter</b>                                                                                                                                                                                                                                                                                                         |
|                                             |                          | <p>1. Motion of particles in solids, liquids and gases</p> <p>2. Changes in states of matter</p> <p>3. Physical changes</p>                                                                                                                                                                                                                          |
|                                             |                          | <b>Energy Transformation and Transfer</b>                                                                                                                                                                                                                                                                                                            |
|                                             |                          | <p>2. Thermal energy transfer and thermal conductivity of materials</p>                                                                                                                                                                                                                                                                              |
|                                             |                          | <b>Motion and Forces</b>                                                                                                                                                                                                                                                                                                                             |
|                                             |                          | <p>1. Motion</p> <p>2. Common forces and their characteristics</p> <p>3. Effects of forces</p>                                                                                                                                                                                                                                                       |
|                                             |                          | <b>Physical States and Changes in Matter</b>                                                                                                                                                                                                                                                                                                         |
|                                             |                          | <p>1. Motion of particles in solids, liquids and gases</p> <p>2. Changes in states of matter</p>                                                                                                                                                                                                                                                     |
|                                             |                          | <b>Electricity and Magnetism</b>                                                                                                                                                                                                                                                                                                                     |
|                                             |                          | <p>1. Conductors and the flow of electricity in electrical circuits</p>                                                                                                                                                                                                                                                                              |
|                                             |                          | <b>Energy Transformation and Transfer</b>                                                                                                                                                                                                                                                                                                            |
|                                             |                          | <p>1. Forms of energy and the conservation of energy</p> <p>2. Thermal energy transfer and thermal conductivity of materials</p>                                                                                                                                                                                                                     |

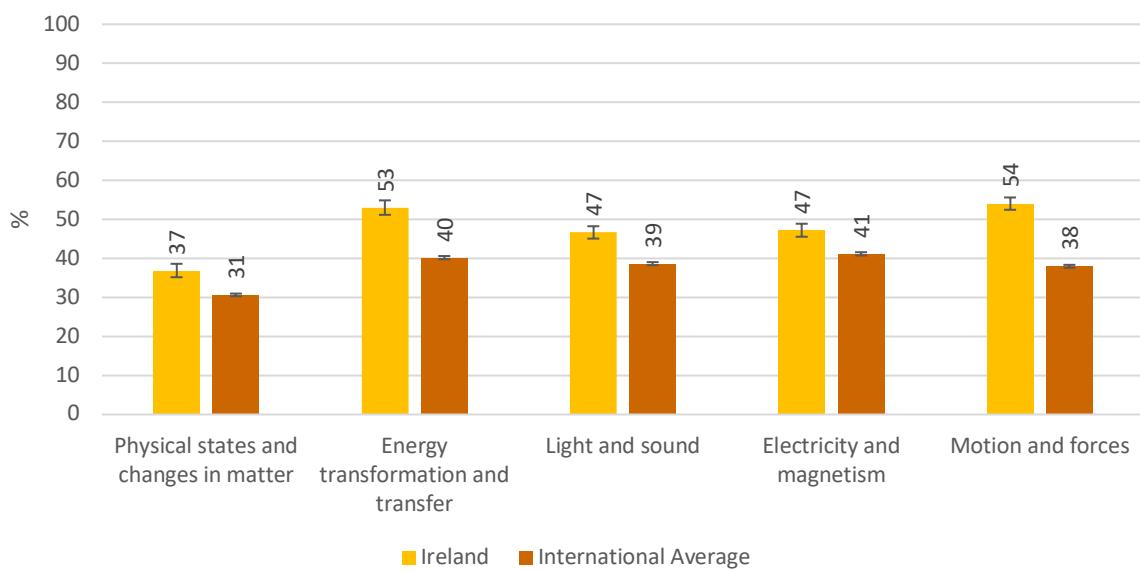
|                       |                                                                                                                                                                                                             |
|-----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                       | 7. Students should be able to design, build, and test a device that transforms energy from one form to another in order to perform a function; describe the energy changes and ways of improving efficiency |
| <b>Sustainability</b> | 8. Students should be able to research and discuss the ethical and sustainability issues that arise from our generation and consumption of electricity                                                      |

Figure 5.13 presents the percent correct scores for the five subdomains of Physics. Second Year students showed a 16 percentage point advantage over the international average for *Motion and forces*, a 13 percentage point advantage for *Energy transformation and transfer*, an eight percentage point advantage for *Light and sound*, and a six percentage point advantage for both *Physical states and changes in matter* and *Electricity and magnetism*. This could be interpreted as indicating that *Motion and forces* was an area of relative strength for Ireland (i.e., the difference in favour of Ireland was larger than for many other subdomains), while the performance of students in Ireland on both *Physical states and changes in matter* and *Electricity and magnetism* were closer to the international average.

Boys outperformed girls by three to four percentage points in each of *Energy transformation and transfer*, *Electricity and magnetism*, and *Motion and forces*, while girls outperformed boys by two percentage points in *Physical states and changes in matter* (Appendix Table A5.2). It may be noted that similar gender differences were observed in the Grade 4 subdomains corresponding to both *Energy transformation and transfer* and *Motion and forces* (see Chapter 3).

Teachers reported that almost all students (over 90%) had been taught the concepts of physical states and changes in matter either before or during Second Year, notwithstanding the fact that the observed advantage of Second Year students over their international peers in this subdomain was relatively small. A high proportion of students (over three-quarters) had not covered the basic properties or behaviours of light and sound, which is not part of the Junior Cycle science curriculum. Almost 80% of students had covered concepts relating to *Energy transformation and transfer* and *Motion and forces*, which may partially explain their relatively strong performance in these subdomains.

**Figure 5.13: Percent correct scores by subdomain of Physics in Ireland and on average internationally**



See Appendix Table A5.1.

*Note.* The figure is an amended version of Figure 5.1 with only the subdomains of Physics represented.

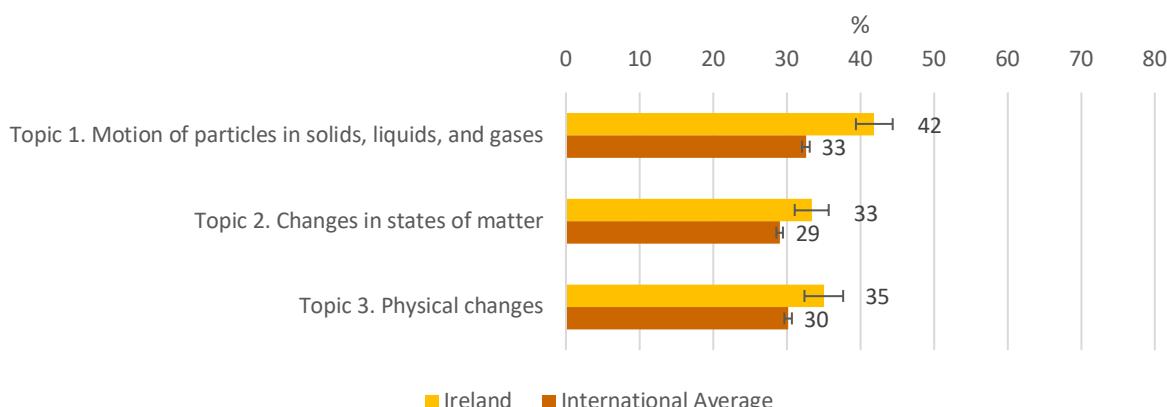
Due to rounding, some differences may appear inconsistent with those reported in text.

### **Physics Subdomain 1: Physical States and Changes in Matter**

The first subdomain within Physics is *Physical states and changes in matter*, which relates to the building blocks and systems and interactions elements of the Physical World strand of Junior Cycle science. However, as noted above, parts of the first and second topics are not included in Junior Cycle science, including relating changes in temperature of a gas to changes in its volume and/or pressure and changes in the average speed of its particles; relating expansion of solids and liquids to temperature change in terms of the average spacing between particles; and relating the rate of change of state to physical factors.

Figure 5.14 presents the percent correct scores for the topics within *Physical states and changes in matter*. Second Year students showed a larger advantage over their international peers on the first topic than on the second or third topics. Gender differences in favour of girls (four percentage points) were observed for the topics *motion of particles in solids, liquids and gases* and *changes in states of matter* (Appendix Table A5.4).

**Figure 5.14: Percent correct scores at the topic level for the subdomain *Physical states and changes in matter* in Ireland and on average internationally**



See Appendix Table A5.3

*Note.* Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

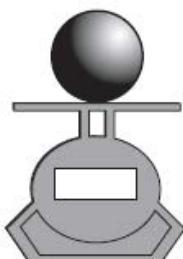
A released item relating to this subdomain is presented in Table 5.12. This item was categorised at the *Advanced International Benchmark* (625). Students in Ireland had a percent correct score of 29%, which was significantly below the international average (37%).

In this item, students are shown an image of a ball on an electronic balance (or scales). It is explained that a heated metal ball is placed on the balance, and students are asked to indicate which graph best shows what happens to the reading on the balance as the metal ball cools down. Students must understand that the temperature of the metal ball does not impact the mass of the ball.

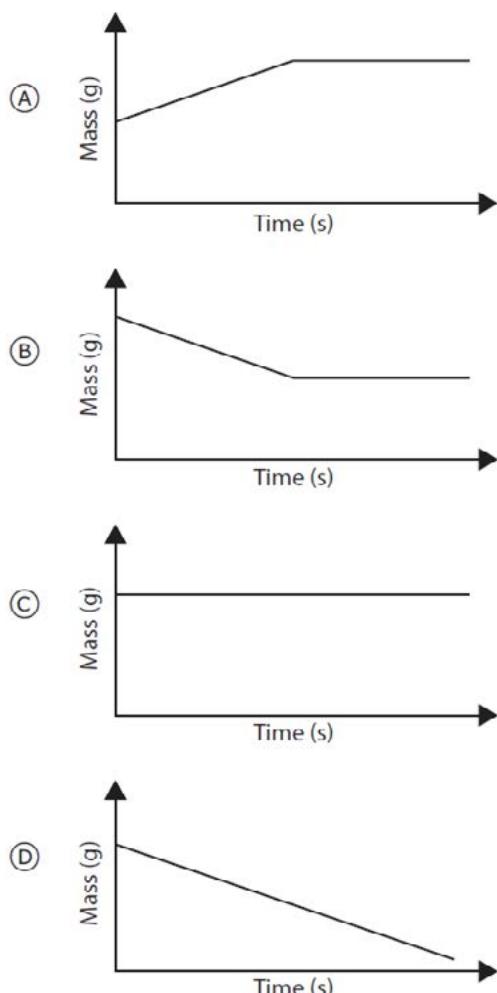
**Table 5.12: Released Item for *Physical States and Changes in Matter***

|                                       |                                                                                   |                            |
|---------------------------------------|-----------------------------------------------------------------------------------|----------------------------|
| Physical States and Changes in Matter | Physical changes                                                                  |                            |
| Item Description                      | Recognises how the mass of a metal ball will change as it cools down              |                            |
| Benchmark                             | Item at Advanced International Benchmark (625)                                    |                            |
| Percent Correct Score                 | Ireland: 29%                                                                      | International Average: 37% |
| Reason for Inclusion                  | Ireland's percent correct score was significantly below the international average |                            |

A metal ball is heated and placed on an electronic balance.



Which graph best shows what happens to the reading of the balance as the metal ball cools down?



**Solution: (C)**

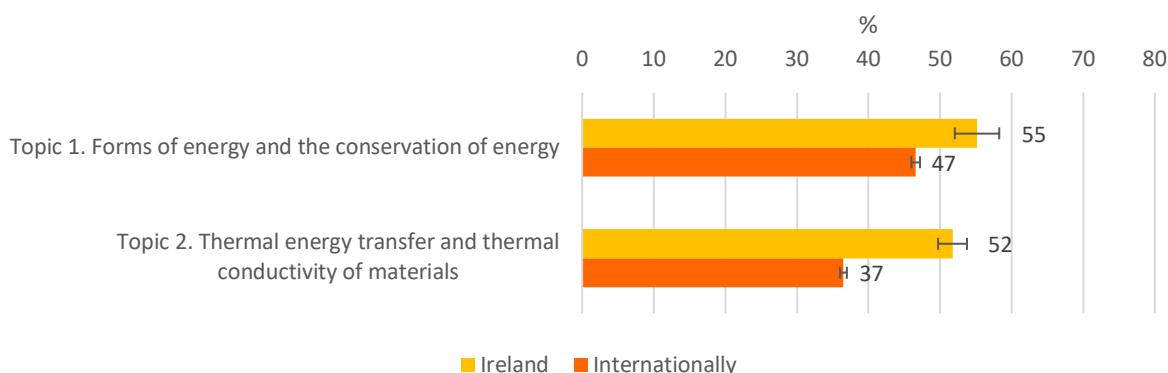
See Appendix Table A5.5

## Physics Subdomain 2: Energy Transformation and Transfer

The second subdomain within Physics is *Energy transformation and transfer*. This subdomain has two topics: *forms of energy and the conservation of energy* and *thermal energy transfer and thermal conductivity of materials*. This subdomain aligns mainly with the energy element of the Physical World strand of Junior Cycle science, and somewhat with the building blocks element of the same strand.

Students in Ireland had a nine percentage point advantage over the international average for Topic 1, and a 15 percentage point advantage for Topic 2. Boys in Ireland had a ten percentage point advantage over girls for *forms of energy and the conservation of energy*, which is the second biggest gender difference observed for any topic in Second Year (Grade 8) science (Appendix Table A5.4).

**Figure 5.15: Percent correct scores at the topic level for the subdomain of *Energy transformation and transfer* in Ireland and on average internationally**



See Appendix Table A5.3.

*Note.* Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

A released item is presented in Table 5.13. It relates to the topic *thermal energy transfer and thermal conductivity of materials*. In Ireland, over three in five students (61%) answered this item fully correctly, which was significantly above the international average (36%). The item was categorised at the *High International Benchmark (550)*.

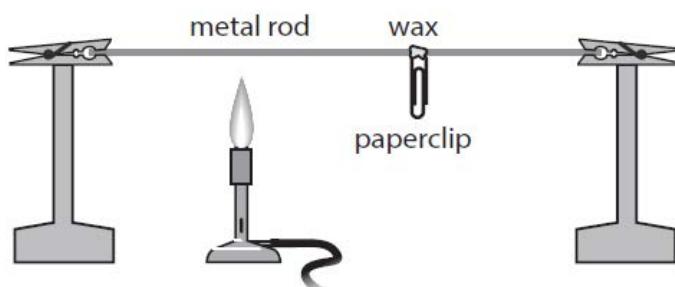
In this item, students are asked to respond Yes or No to a series of statements to ensure that the experiment will show whether iron or copper is a better conductor of heat. Approximately 90% of Second Year students answered parts (A), (B) and (D) correctly, while approximately 80% of students answered parts (E) and (F) correctly. The lowest percent correct was for part (C), which three-quarters of students in Ireland answered correctly.

**Table 5.13: Released Item for *Energy transformation and transfer***

|                                    |                                                                                                                                |                                                                                                    |
|------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|
| Energy transformation and transfer | Thermal energy transfer and thermal conductivity of materials                                                                  |                                                                                                    |
| Item Description                   | Recognises steps that should be taken to ensure an experiment will show whether iron or copper is the better conductor of heat |                                                                                                    |
| Benchmark                          | Item at High International Benchmark (550)                                                                                     |                                                                                                    |
| Percent Correct Score              | Ireland: Overall 61%<br>Part (a) 89%; (b) 86%; (c) 75%;<br>(d) 91%; (e) 83%; (f) 83%                                           | International Average: Overall 36%<br>Part (a) 76%; (b) 69%; (c) 66%;<br>(d) 75%; (e) 67%; (f) 68% |
| Reason for Inclusion               | Item where Ireland was significantly above the international average                                                           |                                                                                                    |

Tom investigates whether iron conducts heat better than copper. He uses wax to attach one paperclip to an iron rod and another paperclip to a copper rod.

He heats each rod until the wax melts and the paperclip falls off. Tom measures how much time it takes for each paperclip to fall off its rod.



How should Tom design his experiment?

Tick one circle in each row to show the things Tom should do to make sure he will be able to tell which metal is a better conductor of heat.

|                                                                                | Yes     | No      |
|--------------------------------------------------------------------------------|---------|---------|
| (A) Use the same type of wax on both rods. -----                               | ---A--- | ---B--- |
| (B) Use a higher flame for the copper rod than the iron rod. -----             | ---A--- | ---B--- |
| (C) Use paperclips made from different materials for each rod. -----           | ---A--- | ---B--- |
| (D) Attach the paperclip the same distance from the flame for both rods. ----- | ---A--- | ---B--- |
| (E) Use a thick iron rod and a thin copper rod. -----                          | ---A--- | ---B--- |
| (F) Use more wax on the iron rod than on the copper rod. -----                 | ---A--- | ---B--- |

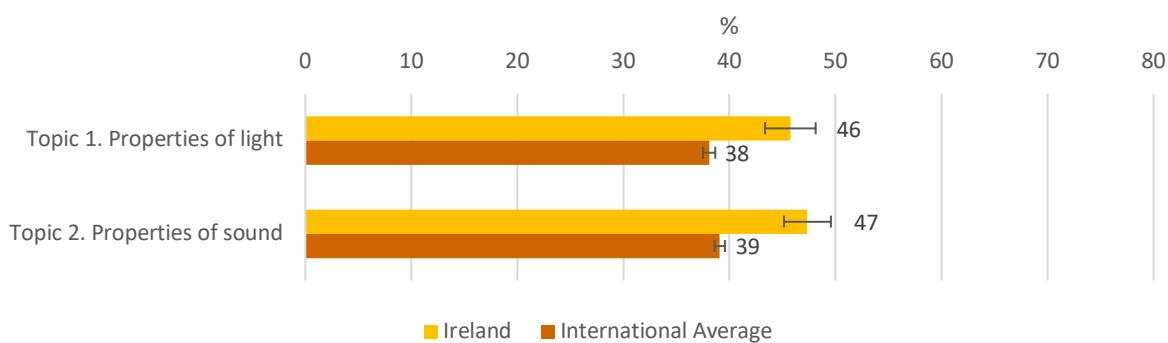
**Solution: Yes, No, No, Yes, No, No**

See Appendix Table A5.5.

### Physics Subdomain 3: Light and Sound

The third subdomain within Physics is *Light and sound*. It contains two topics: *properties of light* and *properties of sound*. Neither of these topics, nor the subdomain in general, are part of Junior Cycle science. Nonetheless, for each of the topics, students in Ireland showed an eight percentage point advantage over the international average (Figure 5.16). Gender differences at Second Year were less than or equal to two percentage points, in favour of girls for the first topic and boys for the second topic (Appendix Table A5.4).

**Figure 5.16: Percent correct scores at the topic level for the subdomain *Light and sound* in Ireland and on average internationally**



See Appendix Table A5.3.

*Note.* Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

Table 5.14 presents a released item relating to *Light and sound*. This item was deemed to be outside the scope of the curriculum in Ireland by subject experts, as part of the TCMA. Despite this, students in Ireland achieved a percent correct score which was significantly above the international average.

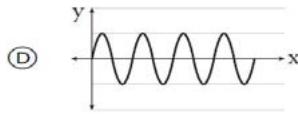
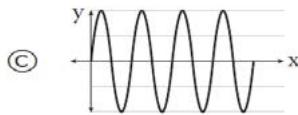
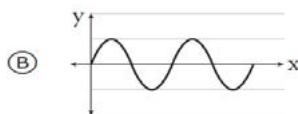
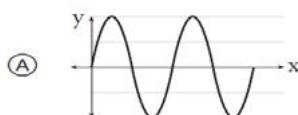
In this item, students are presented with four graphs and are asked to indicate which one represents a musical note with the softest volume and lowest pitch. The item explains that time is represented on the x-axis and magnitude on the y-axis.

**Table 5.14: Released Item for *Light and sound***

|                       |                                                                                                                                            |                            |
|-----------------------|--------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|
| Light and sound       | Properties of sound                                                                                                                        |                            |
| Item Description      | Recognises which graph represents a musical note with given specifications for volume and pitch                                            |                            |
| Benchmark             | Item at High International Benchmark (550)                                                                                                 |                            |
| Percent Correct Score | Ireland: 65%                                                                                                                               | International Average: 53% |
| Reason for Inclusion  | Item where Ireland was significantly above the international average and was judged as not included on the Junior Cycle science curriculum |                            |

Each graph below represents a musical note. Time is represented on the x-axis and magnitude is represented on the y-axis. All of the graphs have the same scale.

Which graph represents the note that has both the softest volume and the lowest pitch?



**Solution: (B)**

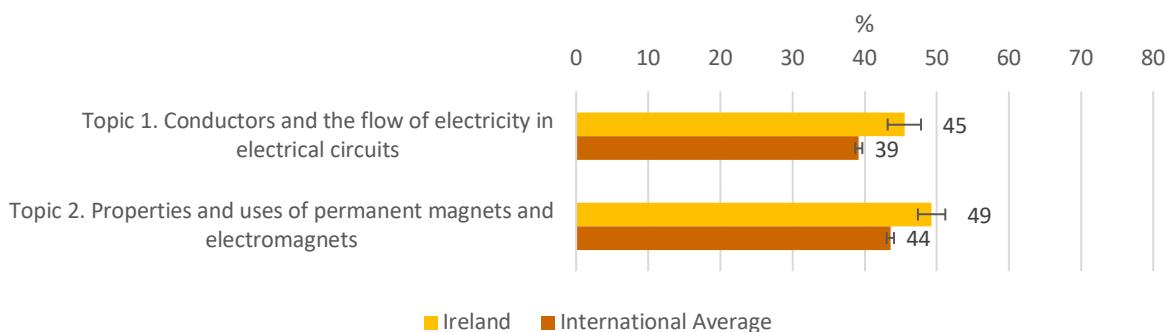
See Appendix Table A5.5

#### **Physics Subdomain 4: Electricity and Magnetism**

The fourth subdomain within Physics is *Electricity and magnetism*. *Electricity and magnetism* is one of two subdomains within Physics where students in Ireland showed a relatively smaller advantage over their international peers than for the other subdomains within Physics. This may partly be explained by the fact that one of the two topics in this subdomain (*properties and uses of permanent magnets and electromagnets*) is not included as part of the Junior Cycle science curriculum.

Within the subdomain *Electricity and magnetism* (Figure 5.17), the score of students in Ireland, for both topics, was six percentage points above the international average. In Ireland, gender differences ranging from three to five percentage points in favour of boys were observed (Appendix Table A5.4).

**Figure 5.17: Percent correct scores at the topic level for the subdomain *Electricity and magnetism* in Ireland and on average internationally**



See Appendix Table A5.3.

Note. Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

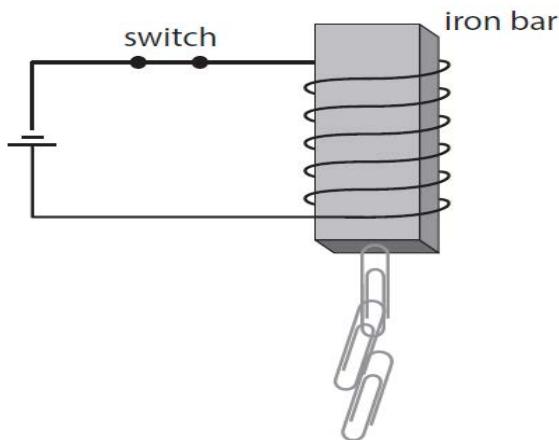
A released item relating to *Electricity and magnetism* is presented in Table 5.15. As part of the TCMA, subject experts in Ireland categorised this specific item as being outside the scope of Junior Cycle science. The score of students in Ireland on this item (14%) was significantly below the international average (21%) (Table 5.15).

In this item, students are presented with a diagram and are asked to describe one way to increase the strength of an electromagnet. To receive credit, students must reference one of the following: increasing the number of turns of the wire; increasing the strength or number of batteries; or replacing the wire with a wire of less resistance.

**Table 5.15: Released Item for Electricity and magnetism**

|                           |                                                                                                                          |                            |
|---------------------------|--------------------------------------------------------------------------------------------------------------------------|----------------------------|
| Electricity and magnetism | Properties and uses of permanent magnets and electromagnets                                                              |                            |
| Item Description          | Uses a diagram to explain one way to increase the strength of an electromagnet                                           |                            |
| Benchmark                 | Item Above Advanced International Benchmark (625+)                                                                       |                            |
| Percent Correct Score     | Ireland: 14%                                                                                                             | International Average: 21% |
| Reason for Inclusion      | Item where Ireland was significantly below the international average and was deemed outside the scope of the curriculum. |                            |

The diagram shows an electromagnet. When the switch is closed, the electromagnet can pick up a few metal paper clips.



Write one change that can be made to the electromagnet so that it can pick up more metal paper clips.

**Solution: States at least one of the following acceptable changes:**

1. Increase the number of turns of the wire.
2. Increase the strength of the batteries or the number of batteries.
3. Replace the wire with a wire of less resistance.

**Example:**

- Lengthen the wires so that more wire can be coiled around the bar.
- Put more batteries in the circuit.
- Use a wire with less resistance.
- Replace the batteries with stronger ones.

See Appendix Table A5.5.

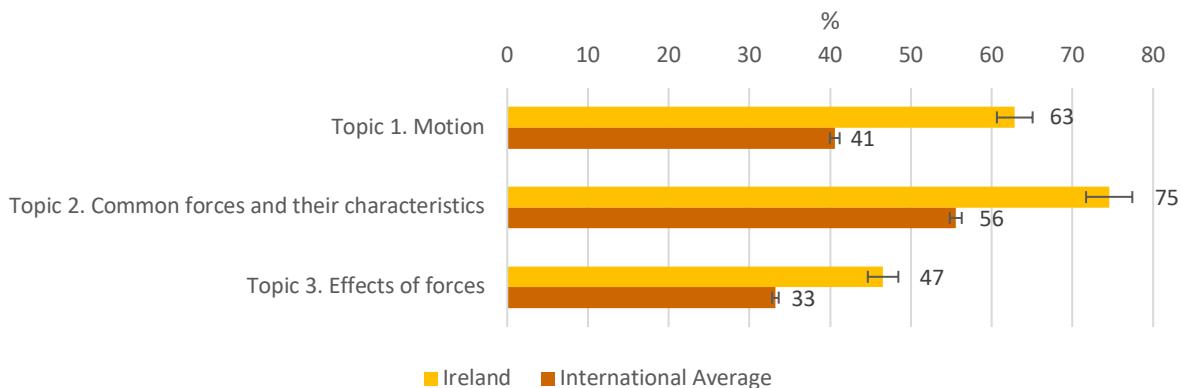
### Physics Subdomain 5: Motion and Forces

The final subdomain within Physics is *Motion and forces*. As noted in the introduction to Section 5.4, this subdomain could be considered an area of relative strength for students in Ireland. Interestingly, the comparable subdomain at Grade 4, *Forces and motion*, was also an area of relative strength for Fourth Class pupils (see Chapter 3).

This subdomain relates to the building blocks element of the Physical World strand of Junior Cycle science. However, part of the third topic, *effects of forces*, is not included in the Junior Cycle science curriculum. This topic includes describing the functioning of simple machines, describing pressure in terms of force and area, and describing effects related to pressure.

Figure 5.18 presents the percent correct score for the topics within *Motion and forces*. There were large differences in favour of Ireland over the international average on the first (22 percentage points) and second topics (19 percentage points). A difference of 13 percentage points was observed for the third topic. Gender differences of between three and six percentage points in favour of boys were observed for each of these topics (Appendix Table A5.4).

**Figure 5.18: Percent correct scores at the topic level for the subdomain of *Motion and forces* in Ireland and on average internationally**



See Appendix Table A5.3.

Note. Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

Table 5.16 presents an item classified at the *High International Benchmark (550)*, which relates to the third topic: *effect of forces*.

In this item, students are asked to identify which of the four diagrams represents a force acting towards the right. Students must recognise that they need to add the forces on each side for each diagram and identify the one with the greater force (higher number) on the right-hand side. Over half of students in Ireland (55%) who answered this question did so correctly by selecting option (d). This was significantly above the international average (47%).

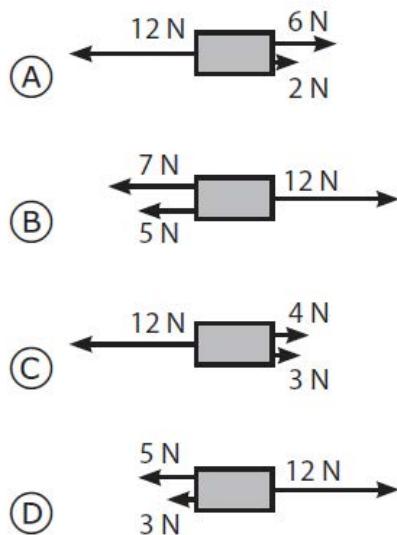
One-fifth of students (20%) in Ireland incorrectly chose option (b), which displays a balance of forces in each direction. A slightly lower proportion (17%) incorrectly chose option (c), which shows a net force acting towards the left.

**Table 5.16: Released Item for *Motion and forces*.**

| Motion and Forces     | Effect of forces                                                               |                            |
|-----------------------|--------------------------------------------------------------------------------|----------------------------|
| Item Description      | Recognises a free-body diagram that has a total force acting towards the right |                            |
| Benchmark             | Item at High International Benchmark (550)                                     |                            |
| Percent Correct Score | Ireland: 54%                                                                   | International Average: 47% |
| Reason for Inclusion  | Item where Ireland was significantly below the international average           |                            |

A box is being pulled by three forces.

Which combination of forces produces a total force acting towards the right?



**Solution: (D)**

See Appendix Table A5.5.

## 5.5 EARTH SCIENCE

The final content domain for Grade 8 science is Earth Science. This accounts for one-fifth of the items on the TIMSS assessment.

Unlike the other domains, Earth Science relates to two Junior Cycle curricula: science (Table 5.17) and geography (Table 5.18). Within Junior Cycle science, it relates to the Earth and Space strand; within Junior Cycle geography, it relates to the Exploring the Physical World strand.

**Table 5.17: Junior Cycle science linked to TIMSS 2019 Framework for the Earth Science content domain**

| Junior Cycle science: Earth and Space Strand |                                 | TIMSS Framework                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----------------------------------------------|---------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Earth and Space                              | <b>Building Blocks</b>          | <p>1. Students should be able to describe the relationships between various celestial objects including moons, asteroids, comets, planets, stars, Solar Systems, galaxies, and space</p> <p>2. Students should be able to explore a scientific method to illustrate the origin of the universe.</p> <p>3. Students should be able to interpret data to compare the Earth with other planets and moons in the Solar System, with respect to properties including mass, gravity, size, and composition</p> |
|                                              | <b>Systems and Interactions</b> | <p>4. Students should be able to develop and use a model of the Earth-sun-moon system to describe predictable phenomena observable on Earth, including seasons, lunar phases, and eclipses of the sun and moon</p> <p>5. Students should be able to describe the cycling of matter, including that of carbon and water, associating it with biological and atmospheric phenomena</p>                                                                                                                     |
|                                              | <b>Energy</b>                   | <p>6. Students should be able to research different energy sources; formulate and communicate an informed view of ways that current and future energy needs on Earth can be met</p>                                                                                                                                                                                                                                                                                                                      |
|                                              | <b>Sustainability</b>           | <p>7. Students should be able to illustrate how earth processes and human factors influence the Earth's climate, evaluate effects of climate change and initiatives that attempt to address those effects</p> <p>8. Students should be able to examine some of the current hazards and benefits of space exploration and discuss the future role and implications of space exploration in society</p>                                                                                                    |
|                                              |                                 | <b>Earth in the Solar System and the Universe</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|                                              |                                 | <p>1. Observable phenomena on Earth results from movements of Earth and the moon</p> <p>2. The sun, stars, Earth, Moon, and planets</p>                                                                                                                                                                                                                                                                                                                                                                  |
|                                              |                                 | <b>Earth's structure and Physical Features</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|                                              |                                 | <p>1. Components of Earth's atmosphere and atmospheric conditions</p>                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|                                              |                                 | <b>Earth in the Solar System and the Universe</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|                                              |                                 | <p>2. The sun, stars, Earth, Moon, and planets</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|                                              |                                 | <b>Earth in the Solar System and the Universe</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|                                              |                                 | <p>1. Observable phenomena on Earth results from movements of Earth and the moon</p>                                                                                                                                                                                                                                                                                                                                                                                                                     |
|                                              |                                 | <b>Earth's Processes, Cycles and History</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|                                              |                                 | <p>2. Earth's water cycle</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|                                              |                                 | <b>Earth's Resources, Their Use and Conservation</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|                                              |                                 | <p>2. Land and water use</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|                                              |                                 | <b>Earth's Resources, Their Use and Conservation</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|                                              |                                 | <p>1. Managing Earth's resources</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|                                              |                                 | <b>Earth's Resources, Their Use and Conservation</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|                                              |                                 | <p>1. Managing Earth's resources</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

**Table 5.18: Junior Cycle Geography linked to TIMSS 2019 Framework for the Earth Science content domain**

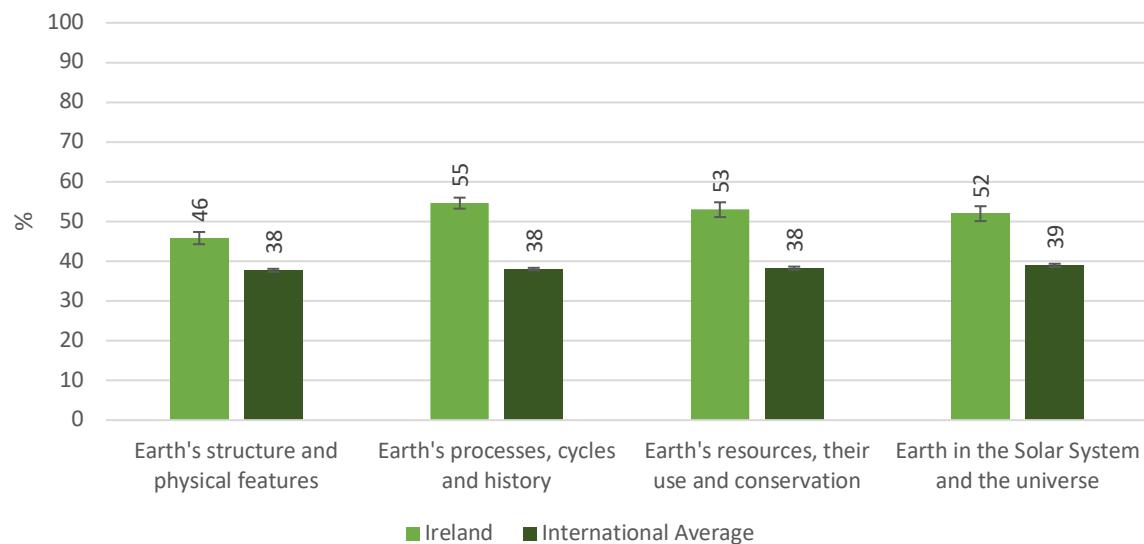
|                              | Junior Cycle Geography: Exploring the Physical World Strand                                                                                                   | TIMSS Framework                                                |
|------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------|
| Exploring the Physical World | 1.1 Describe the formation and global distribution of volcanoes, earthquakes, and fold mountains in the context of plate tectonics and structure of the Earth | <b>Earth's Structure and Physical Features</b>                 |
|                              | 1.2 Distinguish between different categories of rock type, referring to composition and formation                                                             | 1. Earth's structure and physical characteristics              |
|                              | 1.3 Analyse the processes and effects of weathering and mass movement on our landscape                                                                        | <b>Earth's Processes, Cycles and History</b>                   |
|                              | 1.4 Assess a soil type in a local area in relation to composition and vegetation                                                                              | 1. Geological processes                                        |
|                              | 1.5 Explain how the processes of erosion, deposition and transportation shape our fluvial, marine, and glacial landscapes                                     | <b>Earth's Processes, Cycles and History</b>                   |
|                              | 1.6 Classify global climates, and analyse the factors that influence the climate in Ireland                                                                   | 1. Geological processes                                        |
|                              | 1.7 Investigate the formation and behaviour of a significant weather event                                                                                    | <b>Earth's Structure and Physical Features</b>                 |
|                              | 1.8 Gather, record and interpret weather data                                                                                                                 | 2. Components of Earth's atmosphere and atmospheric conditions |
|                              | 1.9 Differentiate between the types of energy resources produced by the physical world                                                                        | <b>Earth's Processes, Cycles and History</b>                   |
|                              | 1.10 Investigate a range of physical processes active in a chosen location and the connections between them                                                   | 3. Weather and climate                                         |

Figure 5.19 presents the percent correct score for the subdomains of Earth Science. Second Year students scored 17 percentage points above the international average for *Earth's processes, cycles and history*. Students in Ireland had a similar advantage for both *Earth's resources, their use and conservation* (15 percentage points) and *Earth in the Solar System and the universe* (13 percentage points). The remaining subdomain, *Earth's structure and physical features*, had the smallest difference between Ireland and the international average (eight percentage points).

Boys in Ireland had a five percentage point advantage over girls for *Earth in the Solar System and the universe*. Differences on the other subdomains were small, at two percentage points or less, each in favour of girls (Appendix Table A5.2).

Teachers of over half of students reported not yet having taught the concepts of *Earth's structure and physical features*, or *Earth's processes, cycles and history*. A smaller proportion of students (45%) had not yet been taught about *Earth's resources, their use and conservation*. Conversely, almost three-quarters of students had been taught before or during Second Year about concepts relating to *Earth in the Solar System and the universe* (Appendix Table A5.6).

**Figure 5.19: Percent correct score for the subdomains of Earth Science in Ireland and on average internationally**



See Appendix Table A5.1.

*Note.* The figure is an amended version of Figure 5.1 with only the subdomains of Earth Science represented. Due to rounding, some differences may appear inconsistent with those reported in text.

### ***Earth Science Subdomain 1: Earth's Structure and Physical Features***

The first subdomain of Earth Science is *Earth's structure and physical features*, which has two topics (Figure 5.20). This subdomain links to both Junior Cycle science and Junior Cycle geography.

Students in Ireland had a 13 percentage point advantage over the international average for Topic 1. The difference between Ireland and the international average for the second topic, *components of Earth's atmosphere and atmospheric conditions*, was much smaller, at three percentage points. There were gender differences in Ireland of five percentage points for both topics, in favour of girls for the first topic and boys for the second topic (Appendix Table A5.4).

**Figure 5.20: Percent correct scores at the topic level for the subdomain *Earth's structure and physical features* in Ireland and on average internationally**



See Appendix Table A5.3.

*Note.* Ireland's percent correct scores at each of these topic levels were significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

Table 5.19 presents a released item relating to this subdomain. It relates to the topic *components of Earth's atmosphere and atmospheric conditions*. The item was judged by subject experts, as part of the TCMA, to be outside the scope of the Junior Cycle in Ireland. Students in Ireland had a percent correct score (37%) which was not significantly different to the international average (36%).

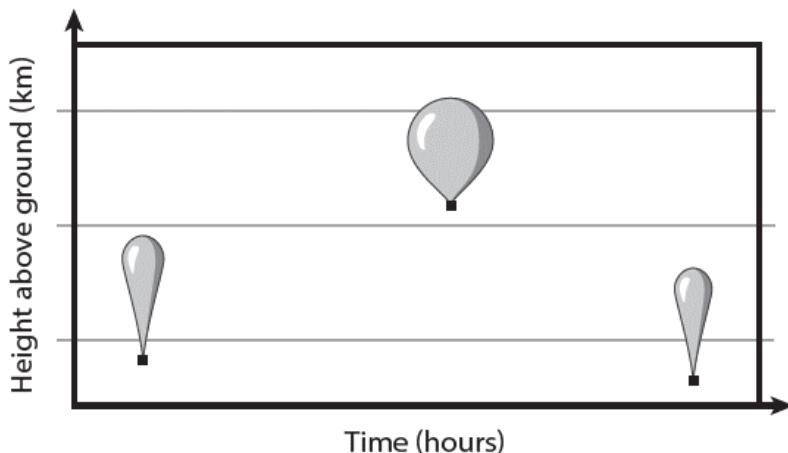
This item presents students with a diagram displaying the height above the ground of a helium-filled weather balloon over several hours. They are asked what causes the balloon to become bigger as the height above the ground increases, and are provided with four options. The correct answer, option (b) – decreasing atmospheric pressure – was selected by over one-third of Second Year students (37%).

Students who answered this item incorrectly were relatively evenly divided between the three distractor (wrong) response options. One quarter of students (25%) incorrectly chose option (c), thinking that the balloon expands because it is heated by the sun, while one-fifth (20%) incorrectly chose option (d), believing that the balloon absorbs additional air. The remaining students (15%) incorrectly chose option (a), believing that the balloon expands because gravity had decreased.

**Table 5.19: Released Item for *Earth's structure and physical features***

|                                         |                                                                                              |                            |
|-----------------------------------------|----------------------------------------------------------------------------------------------|----------------------------|
| Earth's structure and physical features | Components of Earth's atmosphere and atmospheric conditions                                  |                            |
| Item Description                        | Recognises why a balloon gets bigger as its height above the ground increases                |                            |
| Benchmark                               | Item Advanced International Benchmark (625)                                                  |                            |
| Percent Correct Score                   | Ireland: 37%                                                                                 | International Average: 36% |
| Reason for Inclusion                    | Ireland's percent correct score was not significantly different to the international average |                            |

The diagram shows the height above the ground of a helium-filled weather balloon during a period of several hours.



What causes the balloon to become bigger as its height above the ground increases?

- (a) Gravity decreases
- (b) Atmospheric pressure decreases
- (c) The balloon is heated by the sun
- (d) The balloon absorbs air

**Solution: (b) Atmospheric pressure decreases**

See Appendix Table A5.5

### ***Earth Science Subdomain 2: Earth's Processes, Cycles and History***

The second subdomain within Earth Science is *Earth's processes, cycles and history*, which includes three topics. The first and third topics relate to the Exploring the Physical World strand of Junior

Cycle geography, while the second topic relates to the Earth and Space strand of Junior Cycle science. Figure 5.21 presents the percent correct scores for these topics.

The largest difference between Ireland and the international average (21 percentage points) was observed for the third topic, while smaller differences were observed for the first and second topics (13 and nine percentage points, respectively). Gender differences at Second Year ranged from one to three percentage points (Appendix Table A5.4).

**Figure 5.21: Percent correct scores at the topic level for the subdomain *Earth's processes, cycles and history* in Ireland and on average internationally**



See Appendix Table A5.3.

Note. Ireland's percent correct score was significantly above the international average. Due to rounding, some differences may appear inconsistent with those reported in text.

Table 5.20 presents a released item which relates to the third topic (*weather and climate*), a relatively strong topic for students in Ireland within this subdomain. The item was classified at the *High International Benchmark (550)*.

For this item, students are asked to identify which of four options provided evidence that the Earth is becoming warmer over time. Almost four-fifths of students in Ireland (80%) who answered this item did so correctly, which was significantly above the international average of 48%.

**Table 5.20: Released Item for *Earth's processes, cycles and history***

|                                       |                                                                            |                            |
|---------------------------------------|----------------------------------------------------------------------------|----------------------------|
| Earth's processes, cycles and history | Weather and climate                                                        |                            |
| Item Description                      | Identifies evidence that the Earth is becoming warmer over time            |                            |
| Benchmark                             | Item at High International Benchmark (550)                                 |                            |
| Percent Correct Score                 | Ireland: 80%                                                               | International Average: 48% |
| Reason for Inclusion                  | Item where Ireland performed significantly above the international average |                            |

Scientists have evidence of changes in Earth's climate over the last 650,000 years.

Which of the following statements would be evidence that the Earth is becoming warmer?

- (a) A decrease in the size of Earth's polar ice caps
- (b) A decrease in the average depth of Earth's oceans
- (c) An increase in the number of volcanoes erupting
- (d) An increase in the number of sunspots

**Solution: (a) A decrease in the size of Earth's polar ice caps**

See Appendix Table A5.5.

### Earth Science Subdomain 3: Earth's Resources, Their Use and Conservation

The third subdomain within Earth Science is *Earth's resources, their use and conservation* (Figure 5.22), comprising two topics.

For Topic 1, Ireland had a 18 percentage point advantage over the international average. This topic relates to both the energy and sustainability elements of the Earth and Space strand. Second Year students had a nine percentage point advantage for Topic 2, which relates to the systems and interactions element of the Earth and Space strand of Junior Cycle science. In Ireland, boys had a higher percent correct score than girls for the first topic (by five percentage points), while girls had a higher score (by two percentage points) for the second topic (Appendix Table A5.4).

**Figure 5.22: Percent correct scores at the topic level for the subdomain *Earth's resources, their use and conservation* in Ireland and on average internationally**



See Appendix Table A5.3.

*Note.* Ireland's percent correct score was significantly above the international average.

Due to rounding, some differences may appear inconsistent with those reported in text.

A released item for this subdomain is presented in Table 5.21. It was classified at the *Advanced International Benchmark (625)* (Table 5.21). As part of the TCMA, subject experts judged that this item was not part of the Junior Cycle curriculum. Despite this, students in Ireland achieved a 55% correct score, which was significantly above the international average (29%).

This is a constructed response item, where students are asked to describe one important geographic factor that a country must consider when choosing the safest location for a nuclear power plant. To receive credit, students had to reference the seismic stability of an area, the likelihood of extreme weather, or the location of population centres.

**Table 5.21: Released Item for *Earth's resources, their use and conservation***

|                                               |                                                                                                                                                |                            |
|-----------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|
| Earth's resources, their use and conservation | Managing Earth's resources                                                                                                                     |                            |
| Item Description                              | Describes one geographic factor to consider when selecting a safe location for a nuclear power plant                                           |                            |
| Benchmark                                     | Item at Advanced International Benchmark (625)                                                                                                 |                            |
| Percent Correct Score                         | Ireland: 55%                                                                                                                                   | International Average: 29% |
| Reason for Inclusion                          | Students in Ireland were significantly above the international average on this item despite it not being included as part of the Junior Cycle. |                            |

Describe one important geographic factor that a country must consider when selecting the safest location for a new nuclear power plant.

**Solution: States at least one of the following factors:**

1. **Seismic stability of the area**
2. **Likelihood of extreme weather (tornadoes, floods)**
3. **Location of population centres**

**Examples:**

- **Where the big cities are**
- **Do earthquakes happen nearby or not**
- **Where tsunamis might happen**
- **A place where natural disasters occur**
- **It must be remote, not near any homes with people living in them in case it explodes**
- **It must be away from populated areas in case of a radiation leak**

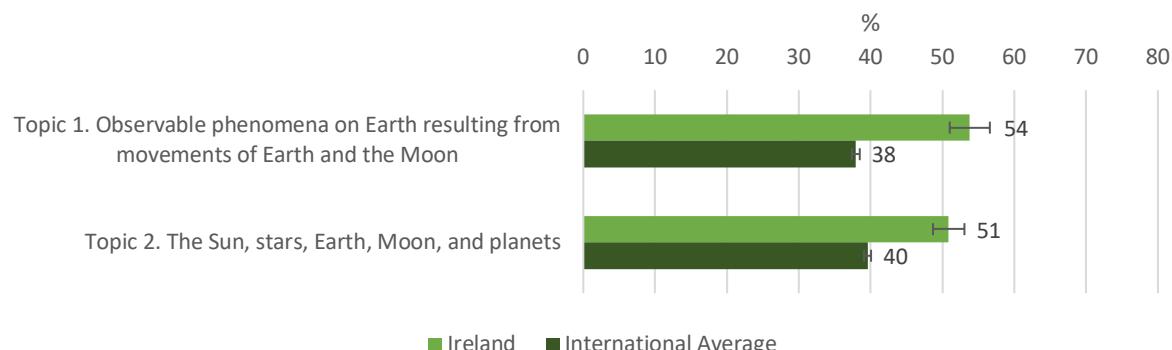
See Appendix Table A5.5

#### **Earth Science Subdomain 4: Earth in the Solar System and the Universe**

The final subdomain within Earth Science is *Earth in the Solar System and the universe*. This included two topics, both relating to the Earth and Space strand of Junior Cycle science (Figure 5.23). The difference between Ireland and the international average was 16 percentage points for the first topic and 11 percentage points for the second topic. There was a large gender difference (10 percentage points) in favour of boys for the first topic, but a smaller difference (two percentage points) for the second (Appendix Table A5.4).

There are no released items relating to this subdomain.

**Figure 5.23: Percent correct scores at the topic level for the subdomain *Earth in the Solar System and the universe* in Ireland and on average internationally**



See Appendix Table A5.3.

*Note.* Ireland's percent correct score was significantly above the international average.

Due to rounding, some differences may appear inconsistent with those reported in text.

# Chapter 6 - Summary & Conclusions

In this final chapter, a summary of the main findings is presented, followed by some conclusions arising.

## 6.1 SUMMARY

Section 6.1 summarises the main findings of the analyses presented in earlier chapters for Fourth Class mathematics, Fourth Class science, Second Year mathematics, and Second Year science (respectively). Readers are reminded that students who participated in TIMSS 2019 engaged with the 1999 primary mathematics and science curricula (for Fourth Class pupils) and the Junior Certificate mathematics (Project Maths) and Junior Cycle science curricula (for Second Year students).<sup>17</sup> The performance of students who studied under subsequent iterations of the relevant curricula will be assessed by future cycles of TIMSS.

### ***Fourth Class Mathematics***

Previous reporting described how Fourth Class pupils showed a relative strength in Number and relative weaknesses in Data and in Measurement & Geometry (Perkins & Clerkin, 2020). In this report, we see that for all three content domains the percent correct scores of pupils in Ireland were above the international average of the countries participating in *paperTIMSS* and *TIMSS less difficult*.

The content domain of **Number** relates to both the Number and Algebra strands in the 1999 Fourth Class mathematics curriculum. Number has three subdomains: *Whole numbers; Expressions, simple equations and relationships; and Fractions and decimals*. Comparing Ireland and the international average, *Fractions and decimals* was an area of relative strength for Ireland. At the topic level, areas of relative strength included *identify and use relationships in well-defined patterns* and *recognise, represent, compare, order, add, and subtract fractions*.

**Measurement & Geometry**, the second content domain, relates to both the Shape & Space and Measures strands of the Fourth Class mathematics curriculum. Measurement & Geometry has two subdomains. The first of these is *Measurement*, which was identified here as an area of relative weakness for Ireland. This subdomain also includes the only topic in Grade 4 mathematics where Ireland fell below the international average: *measure and estimate lengths (mm, cm, m, km) and solve problems involving lengths*. This topic was therefore an area of relative weakness. The second subdomain is *Geometry*, which has three topics. Among these topics, pupils in Ireland showed areas of both relative strength and weakness, highlighting the value of conducting analyses at this micro level for more nuanced interpretation. *Identifying and drawing lines and angles* was an area of relative strength, while *using elementary properties to describe, compare and create common 2-D shapes* was an area of relative weakness.

The last content domain is **Data**. This relates to the Data strand in the Fourth Class mathematics curriculum. Data has two subdomains: *Reading, interpreting and representing data* and *Using data to solve problems*. The latter was an area of relative weakness in Ireland. At the topic level, *organising and representing data to help answer questions* (part of the *Reading, interpreting and representing data* subdomain) was an area of relative strength.

<sup>17</sup> The Junior Certificate mathematics (Project Maths) curriculum was phased in nationally from 2010 until being replaced by a new Junior Cycle mathematics specification from 2018, and the Junior Cycle science curriculum was introduced in 2017.

## Fourth Class Science

In TIMSS 2019, pupils in Ireland showed a relative strength in Earth Science and a relative weakness in Physical Science (Perkins & Clerkin, 2020). In terms of percent correct scores, Ireland was above the international average on both of these domains as well as on the third domain, Life Science.

**Life Science** has five subdomains and relates to the Living Things strand of the Third/Fourth Class curriculum. However, some topics are not introduced until Fifth/Sixth Class, including the basic life processes of plants and reproduction of plants and animals. *Organisms, environment and their interactions* and *Human health* were subdomains where pupils in Ireland performed relatively well in comparison to the other subdomains within Life Science. In particular, relative strengths were seen for the topics *response of living things to environmental conditions, the impact of humans on the environment, and transmission, prevention, and symptoms of communicable diseases* (a topic which also had the largest gender difference in Ireland, in favour of girls). Areas of relative weakness included the subdomains of *Characteristics and life processes of organisms* and *Life cycles, reproduction and heredity* and, in particular, the topic *differences between living and non-living things and what living things require to live*.

**Physical Science** includes three subdomains: *Classification and properties of matter and changes in matter; Forms of energy and energy transfer; and Forces and motion*. Physical Science relates mainly to the Energy and Forces and Materials strands of the Third/Fourth Class curriculum. However, some topics are not introduced until Fifth/Sixth Class, link with the Environmental Awareness and Care strand, or are not part of the primary school science curriculum at all. *Forces and motion* was a subdomain where pupils in Ireland showed a relatively stronger performance than the other subdomains, while performance was relatively weaker on *Classification and properties of matter and changes in matter*. Within *Classification and properties of matter and changes in matter*, there is variation at the topic level, with the largest difference in favour of Ireland over the international average for any topic in Grade 4 science observed for *chemical changes observed in everyday life* (a topic which is not included in the primary science curriculum). By contrast, differences between Ireland and the international average for the topics *physical properties as a basis for classifying matter* and *physical changes observed in everyday life* were small.

**Earth Science** also has three subdomains. *Earth's weather and climates* was an area where pupils in Ireland performed relatively well in comparison to the other subdomains within Earth Science, while *Earth in the Solar System* was an area where pupils in Ireland performed relatively less well. This content domain relates both to the Environmental Awareness and Care strand of the Third/Fourth Class science curriculum and to the primary school Geography curriculum (Third/Fourth Class and Fifth/Sixth Class).

## Second Year Mathematics

Number, Algebra, Geometry, and Data & Probability are the four content domains for Grade 8 mathematics. The content domains differ slightly from Grade 4: Data also includes Probability, and Algebra is a separate domain rather than being included within Number. Both Number and Data & Probability were previously identified as areas of relative strength for Ireland, while Algebra and Geometry were identified as areas of relative weakness (Perkins & Clerkin, 2020).

**Number** includes three subdomains: *Integers; Fractions and decimals; and Ratio, proportion and percent*. Number aligns with the Number strand of Junior Cycle mathematics. Topics where students

in Ireland showed relatively stronger performance included *compute and solve problems with positive and negative numbers, compute with fractions and decimals, including those set in problem situations* and solve problems involving proportions or percents.

**Algebra** includes two subdomains which relate to the Algebra and Functions strand of Junior Cycle mathematics. Topics where the difference between Ireland and the international average was relatively smaller (compared to other topics within the subdomains) included *simplify algebraic expressions and comparing expressions to determine if they are equivalent* and *interpret, relate and generate representations of simple non-linear functions*.

**Geometry** only has one subdomain, which relates to the Geometry and Trigonometry strand of Junior Cycle mathematics. Some variation was observed among the topics within this subdomain. One topic where students in Ireland performed relatively less well included *recognise and draw images of geometric transformations (translations, reflections, and rotations) in the plane; identify congruent and similar triangles and rectangles and solve related problems*.

**Data and Probability** relates to the Statistics and Probability strand of Junior Cycle mathematics. It includes two subdomains, of which *Probability* was an area of relative strength in Ireland. Within the other subdomain (*Data*), Second Year students performed similarly well across each of the topics.

### Second Year Science

There are four content domains at Grade 8 science: Biology, Chemistry, Physics and Earth Science. (Chemistry and Physics are considered separate domains, rather than being assessed together as Physical Science as at Grade 4.) Perkins and Clerkin (2020) reported that in Ireland, Earth Science was an area of relative strength and Chemistry and Physics were areas of relative weakness, when comparing mean overall science achievement against achievement within each content domain. In terms of percent correct scores, Ireland was above the *paper TIMSS* international average for each content domain.

**Biology** includes six subdomains. This domain relates mainly to the Biological World strand of Junior Cycle science. However, certain aspects of the TIMSS Framework are not part of Junior Cycle science (e.g., comparing and contrasting major organs and organ systems in humans and other vertebrates) or instead relate to Junior Cycle Geography. *Diversity, adaptation and natural selection* and *Human health* were subdomains of relative strength in Ireland, while *Ecosystems* was an area of relative weakness. At the topic level, *physiological processes in animals and the importance of diet, exercise, and other lifestyle choices* were topics where students in Ireland performed relatively well. By contrast, within *Ecosystems*, topics including *the flow of energy in ecosystems, the cycling of water, oxygen and carbon in ecosystems* and *the interdependence of populations of organisms in an ecosystem* were areas where the difference between Ireland and the international average was very small (despite the stronger overall performance of Second Year students).

**Chemistry** has three subdomains: *Composition of matter*; *Properties of matter*; and *Chemical change*. Chemistry relates mainly to the Chemical World strand of Junior Cycle science but some topics are not part of the curriculum, including the topic *chemical bonds*. *Properties of matter* was a subdomain where students in Ireland showed relatively stronger performance, while *Composition of matter* was a subdomain where students in Ireland showed relatively weaker performance in comparison to the other subdomains within Chemistry. Notably, the topic *elements, compounds and mixtures* (within *Composition of matter*) was the only topic anywhere on the Grade 8 science

assessment where Ireland was below the international average (albeit not significantly so).

**Physics** has five subdomains: *Physical states and changes in matter; Energy transformation and transfer; Light and sound; Electricity and magnetism; and Motion and forces*. This domain relates mainly to the Physical World strand of Junior Cycle science, but some subdomains (*Light and sound*) and topics (*properties and uses of permanent magnets and electromagnets*) are not part of the curriculum. Similar to the pattern observed at Grade 4, *Motion and forces* and *Energy transformation and transfer* had the largest differences between Ireland and the international average, indicating that these were subdomains within Physics where students in Ireland performed relatively well. *Physical states and changes in matter*, and *Electricity and magnetism*, were subdomains within Physics where Second Year students had a relatively weaker performance. Topics where Ireland had the largest advantage over the international average included *motion*.

**Earth Science** includes four subdomains and relates to both the Earth and Space strand of Junior Cycle science and the Exploring the Physical World strand of Junior Cycle Geography. *Earth's structure and physical features* is a subdomain where Second Year students performed relatively less well, while *Earth's processes, cycles and history* was a subdomain where students in Ireland performed relatively well in comparison to the other subdomains within this domain. *Weather and climate* was the topic within Earth Science with the largest difference in favour of Second Year students over the international average. (Similarly, as presented in Chapter 3, the subdomain *Earth's weather and climates* was an area where Fourth Class pupils also performed relatively well.)

## 6.2 CONCLUSIONS

Finally, some overall conclusions are presented. Teachers and other readers working in the areas of mathematics education, science education, curriculum development, initial teacher education, teacher professional learning, school leadership, and educational policymaking are invited to consider the findings presented here and to draw on their own professional expertise to gain further insights.

### Mathematics

The domain of Number has previously been identified as an area of relative strength for Ireland at both Fourth Class and Second Year (Perkins & Clerkin, 2020), and that finding is echoed here. This is consistent with the outcomes of other studies such as Ireland's National Assessments of Mathematics and English Reading (NAMER) in 2021, where the content area of Number & Algebra had the highest percent correct score among Sixth Class pupils (Kiniry et al., 2023). The more detailed analyses presented here (in Chapters 3 and 5) indicate that, within Number, *Fractions and decimals* were particular areas of relative strength at both grade levels.

Previous reporting had highlighted that performance in the domain of Data was somewhat mixed, with Data being an area of relative weakness at Fourth Class but Data & Probability being an area of relative strength at Second Year (Perkins & Clerkin, 2020). At the more granular topic level reported here, *organising and representing data to help answer questions* was nonetheless an area of relative strength for Fourth Class pupils. The finding of relative strength in this domain at Second Year is also consistent with the outcomes of the Programme for International Student Assessment (PISA) 2022, where, across the mathematics content subscales, 15-year-old students in Ireland achieved the highest mean score on the Uncertainty & Data subscale (Donohue et al., 2023). At a more detailed level, the current analyses show consistent performance for Second Year students on the subdomain of *Data*, with percent correct scores for Ireland above the international average

to a similar degree for all topics. Notably, the subdomain of *Probability* was an area of relative strength for Second Year students, despite teachers' reporting that between two-fifths and three-fifths of students had not yet covered the probability of simple and compound events. However, the strand unit 'chance' is introduced in the Third Class 1999 mathematics curriculum, progressing to more formal probability (of simple events) at Fifth and Sixth Class. This could partly explain the strong performance of Second Year students in this subdomain. The introduction of the Junior Cycle mathematics specification in September 2018 may allow students to engage with this content earlier in the three-year programme, building on the strong foundation that many students already have when they enter post-primary school. The Second Year students who participated in TIMSS 2023 were the first cohort of TIMSS participants to experience Junior Cycle mathematics from First Year, and it will be instructive to examine the performance of this cohort as part of the reporting on new data from TIMSS 2023 (due in December 2024).

Within Algebra, the topic *simplify algebraic expressions and compare expressions to determine if they are equivalent* was an area of relative weakness for Second Year students, even though 99% of students had covered this topic by the time of TIMSS testing according to their teachers. This is in contrast to the strong performance of Fourth Class pupils on the related subdomain of *Expressions, simple equations and relationships*. This suggests the need for an increased alignment of these skills in the transition from primary to post-primary school. There may be an opportunity to build on the algebra content of the 2023 primary mathematics curriculum (Department of Education, 2023), where the use of letter-symbols to represent unknowns is introduced at Stage 3 (Third and Fourth Class), at an earlier point than in the 1999 curriculum.

Among Fourth Class pupils, the topic *measuring and estimating lengths, and solving problems using lengths* was the only topic in all of Grade 4 mathematics where Ireland's percent correct score was below the international average. This weakness on some aspects of the subdomain of *Measurement* is noteworthy, considering the outcomes of NAMER 2021, where Measures was found to be the most difficult content area in terms of percent correct for Sixth Class pupils (Kiniry et al., 2023). Measurement does not feature as a separate subdomain at Grade 8. Rather, elements of the measurement of 2-D and 3-D geometric shapes are integrated within the content domain of Geometry.

The domain of Geometry was an area of relative weakness at Second Year. This is consistent with the findings of PISA 2022 where, across all of the content subscales within mathematics, students in Ireland had the lowest mean score on the corresponding Space & Shape subscale (Donohue et al., 2023). The current analyses show that Second Year students performed particularly poorly on the topic related to geometric transformations and congruent and similar triangles. Responses to the Teacher Questionnaire indicated that more than 70% of students had not yet been taught these concepts. This finding in relation to transformations is of note in the context of the 2023 primary mathematics curriculum, where a new strand unit of 'transformation' has been included in the curriculum and will be implemented in schools from September 2024. In the infant classes, the focus is on an understanding of shape movements, whereas reflections, rotations and translations are introduced in Stage 2 (First and Second Class). As this work on transformations at primary level becomes embedded, there may be a positive impact on performance in this area among Second Year students.

While the analyses here point to many areas of strength within the mathematical skill and knowledge demonstrated by students in Ireland, areas of relative weakness are also evident. Initial teacher

education programmes and courses of teacher professional learning could usefully include additional focus on the areas of relative weakness identified here to provide teachers with additional support and enhanced pedagogical content knowledge in these areas.

A final point worth noting is that – despite the strong overall performance of Fourth Class and Second Year students in many respects in TIMSS 2019, relative to students in the other countries that took part in *paper TIMSS* – the released items included here demonstrate that students in Ireland showed no advantage, or were significantly below the international average, for several of the most difficult items on the assessment (those at the Advanced or Above Advanced Benchmarks). This pattern reinforces the previous observation that higher-achieving students in Ireland appear to be underperforming relative to higher-achieving students in other countries, and relative to Ireland's strong performance among lower-achieving students (Perkins & Clerkin, 2020). The more detailed information provided in this report may assist practitioners and policymakers in providing additional supports to help higher-achieving students in mathematics to reach their full potential, including developing stronger problem-solving and reasoning skills in mathematics.

## Science

Some consistent patterns can be observed across grade levels in terms of relative strengths and weaknesses, both at the content domains and at lower levels of analysis. Among the content domains, Earth Science is an area where students in Ireland performed relatively well at both grade levels, while Physical Science (at Grade 4) and Physics and Chemistry (at Grade 8) are areas where students in Ireland showed relative weaknesses compared to their overall performance in science. Performance in Life Science at Grade 4, and Biology at Grade 8, were similar to overall performance in science (Perkins & Clerkin, 2020).

As the more granular analyses presented here show, consistency in performance across both grades was also observed at the subdomain and topic levels. For example, the subdomains *Forms of energy and energy transfer* and *Forces and motion* (Fourth Class) and their comparable subdomains *Energy transformation and transfer* and *Motion and forces* (Second Year) are areas where students in Ireland showed a relatively strong performance. *Human health* is another area of strength in Ireland, despite not being explicitly part of the science curriculum at either grade level. Conversely, a consistent pattern of relative weakness was seen in students' performance on *Classification and properties of matter and changes in matter* at Fourth Class and the corresponding subdomain at Second Year (*Physical states and changes in matter*) in Ireland.

The content domains, subdomains and topics included in the TIMSS 2019 Assessment Framework do not align exactly with the structure and content of the Irish curriculum, and some concepts in the framework are not part of the Irish curriculum at the target levels (Mullis & Martin, 2017). Despite this, the analyses presented here indicate that students in Ireland are often performing similarly well in these topics as in those that are specified in the curriculum.

At the time of writing, a new specification for Science, Technology and Engineering at primary level is currently in development to complement the primary mathematics curriculum published in 2023 (Department of Education, 2023). The findings of these subdomain-, topic-, and item-level analyses may indicate areas that could usefully be considered by curriculum developers for inclusion, amendment, or change of emphasis in the forthcoming curriculum. Similarly, future evaluations and reviews of the Junior Cycle science curriculum should be informed by these findings of areas of relative strength and weakness in Ireland from TIMSS 2019.

Similar to mathematics, several areas of relative weakness in scientific knowledge and understanding can be seen in the performance of students in Ireland on TIMSS 2019. Additional support to teachers addressing these areas of relative weakness in student performance may be merited, particularly in the domains of Chemistry and Physics.

Also similarly to mathematics, higher-achieving students in science in Ireland appear to have substantial scope for improvement (Perkins & Clerkin, 2020). This is demonstrated in some detail here with examples of released items, in particular the most difficult items at the Advanced and Above Advanced benchmarks. On the basis of these findings, further attention to the needs of higher-achieving students in science appears to be warranted, alongside continuing supports for students at lower levels of achievement.

### ***Looking Ahead***

Findings at the overall content domain level – as previously reported by Perkins and Clerkin (2020) for Ireland and Mullis et al. (2020) internationally – provide useful information and feedback on the performance of students in various respects for policymakers, curriculum developers and teachers. At the same time, the top-level content domains may be too broadly construed to meaningfully influence practice in the classroom and to inform curriculum (re-)development to the optimal extent.

The aim of this report has been to examine variation in performance at the subdomain level and, in particular, at the topic and item levels, with a view to helping teachers, curriculum developers and policymakers better understand where improvements can be made and to identify areas of mathematics and science where students (and teachers) in Ireland are in need of additional support. These efforts are particularly timely in the context of the recent publication of the new *Literacy, Numeracy and Digital Literacy Strategy (2024-2033)* in May 2024 (Department of Education, 2024). This *Strategy* signals a renewed focus on enhancing outcomes in numeracy, particularly in areas such as Geometry/Shape & Space. The detailed analyses of students' skills, illustrated by the released items presented here, should assist educators and policymakers in their response to the *Strategy* over the coming decade.

As a final point, the findings presented here come from one study, for which data were gathered in 2019. Curricular developments and other changes since then – not least the Covid-19 pandemic and its enduring impacts on teaching and learning – suggest that there would be merit in completing a similarly granular analysis of student performance following the forthcoming release of data from the TIMSS 2023 study. Similar exercises drawing on the data and frameworks of other large-scale assessments, including the National Assessments (which are most closely-aligned with the Irish curriculum), should also be considered in future as a means of triangulating findings and providing the most robust conclusions possible for educators and policymakers.

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