IEA TIMSS 2023

28 Years of Trends

TIMSS 2023 Assessment Frameworks

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Editors

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TIMSS & PIRLS
BOSTON COLLEGE

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Introduction

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TIMSS 2023: First Fully Digital TIMSS Assessment

TIMSS (Trends in International Mathematics and Science Study) is a long-standing international assessment of mathematics and science at the fourth and eighth grades that has been collecting trend data every four years since 1995. About 70 countries use TIMSS trend data for monitoring the effectiveness of their education systems in a global context, and more countries join TIMSS with each subsequent assessment cycle.

Because it marks the successful transition to its first fully digital assessment cycle, TIMSS 2023 is a watershed cycle in the 28 year history of TIMSS. Half the TIMSS countries pioneered the transition to digital assessment in TIMSS 2019 paving the way for an "all digital" turning point in TIMSS 2023. Capitalizing on the benefits of technological advances is necessary for TIMSS to remain in sync with global realities, and TIMSS 2023 will set the wheels in motion to improve the quality of TIMSS data, increase efficiency in data collection, and make the data more useful.

To provide deeper insights into how students approach mathematics and science assessment tasks, solve problems, and communicate their responses, TIMSS 2023 will include more complex and innovative item types that capture both responses and process indicators. A digital item designer and translation system will support TIMSS 2023 item development, enabling interactive opportunities and provision of various digital tools for students to use in developing and providing their responses. The idea of Problem Solving and Inquiry (PSI) Tasks introduced in TIMSS 2019 will be further developed (see *Findings from the TIMSS 2019 Problem and Inquiry Tasks*).[1] PSI tasks are based on attractive, interactive scenarios that allow students to follow a series of steps toward a solution or goal. A variety of PSI tasks will be integrated into the mathematics and science assessments. Finally, a concerted effort will be made to increase the degree of automated scoring to improve scoring accuracy and comparability across countries, including research into using machine learning to evaluate graphical and short written responses.

The TIMSS 2023 Mathematics and Science Frameworks

As a major ongoing program of IEA, TIMSS has the benefit of drawing on the cooperative expertise provided by representatives from countries all around the world (see *IEA's TIMSS and PIRLS: Measuring Long-term Trends in Student Achievement*).[2]

Chapters 1 and 2 of the *TIMSS 2023 Assessment Frameworks* contain the *TIMSS 2023 Mathematics and Science Frameworks*, respectively. Since its inception, TIMSS has used participating countries' curricula, broadly defined, as the basis for creating and then subsequently updating the mathematics and science frameworks for each assessment cycle during its 28 year history. As a trend assessment, TIMSS needs stability from cycle to cycle and so the majority of the items (about two-thirds) are carried forward from each assessment to the next. An item typically appears in three adjacent assessment cycles before being retired. However, it is also necessary to keep the assessment frameworks educationally relevant, and so a substantial number of items are newly developed for each cycle in accordance with the updated frameworks. This permits the TIMSS assessment instruments and procedures to evolve gradually into the future.[3]

Consistent with procedures implemented with each new assessment cycle, the *TIMSS 2023 Mathematics and Science Frameworks* for fourth and eighth grades were updated from those used in TIMSS 2019 through an iterative review process. Taking into account curricular information provided by the participating countries in the *TIMSS 2019 Encyclopedia*,[4] the TIMSS & PIRLS International Study Center worked with the TIMSS 2023 expert group, named the Science and Mathematics Item Review Committee (SMIRC), to develop and review the first drafts of the updated frameworks. Listed in the Acknowledgments, the SMIRC members also participated in iterative reviews of the items newly developed for TIMSS 2023.

The TIMSS 2023 National Research Coordinators (NRCs), comprised of the one or two individuals that are responsible for implementing TIMSS within each participating country, also had opportunities to review the frameworks. The TIMSS 2023 NRCs (see Acknowledgments) introduced fresh ideas and current information about curricula, standards, goals, and objectives related to mathematics and science instruction. The TIMSS & PIRLS International Study Center worked with the SMIRC to incorporate the NRCs' recommendations into the frameworks, such that the content of the frameworks evolved gradually.

TIMSS is directed by the **TIMSS & PIRLS International Study Center** established in Boston College's Lynch School of Education and Human Development. PIRLS (Progress in International Reading Literacy Study) is an international assessment of reading, and together **TIMSS and PIRLS** comprise the core cycle of international assessments managed by **IEA (the International Association for the Evaluation of Educational Achievement)**. IEA is an independent international cooperative of national research institutions and government agencies that has been conducting studies of cross-national achievement since 1959. Today, **IEA Amsterdam** manages country participation in a number of international studies and projects, and **IEA Hamburg** is a large research and data processing center.

The TIMSS 2023 Context Questionnaire Framework

Chapter 3 of the *TIMSS 2023 Assessment Frameworks* contains the *TIMSS 2023 Context Questionnaire Framework*. Similar to the process used to update the content area frameworks, the TIMSS & PIRLS International Study Center worked with the TIMSS 2023 Questionnaire Item Review Committee (QIRC) to update the *TIMSS 2019 Context Questionnaire Framework* and the questionnaires for TIMSS 2023. The QIRC members are listed in the Acknowledgments.

To take into account students' opportunities to learn mathematics and science in each country, TIMSS collects an extensive amount of information about students' learning experiences. As part of each assessment cycle, TIMSS publishes an Encyclopedia about countries' curricula and instructional policies. TIMSS also updates and measures trends on the existing questionnaire scales, and develops new context questionnaire scales that address emerging areas of research in educational effectiveness.

Consistent with prior assessment cycles, the forthcoming *TIMSS 2023 Encyclopedia: Education Policy and Curriculum in Mathematics and Science* will contain a chapter prepared by each country and benchmarking participant summarizing the structure of the country's education system, the mathematics and science curricula in the primary and secondary grades, the teacher education requirements, and the types of examinations and assessments employed. To provide standard information about countries that supplements the chapters, countries complete a TIMSS Curriculum Questionnaire about policies associated with their mathematics and science curricula, school organizational approaches, and instructional practices.

TIMSS 2023 also collects information about students' home and school experiences relevant to learning mathematics and science. Students, their parents or caregivers, their teachers, and their school principals are asked to complete questionnaires about the students' mathematics and science instructional contexts. The *TIMSS 2023 Context Questionnaire Framework* and array of questionnaires were updated through a sequence of reviews conducted by the QIRC and NRCs and include some new areas of interest.

A New Assessment Design for TIMSS 2023

Chapter 4 of the *TIMSS 2023 Assessment Frameworks* describes the populations assessed by TIMSS, as well as the organization of the assessment instruments. With the transition to a completely digital assessment, TIMSS 2023 took advantage of the opportunity to introduce a new group adaptive assessment design, which includes items of three difficulty levels—easy, medium, and difficult. For each subject, a student will be assigned a block of easy and a block of medium items, or a block of medium and a block of difficult items. All countries will take all items, but higher performing countries can have higher proportions of students taking more difficult item blocks and countries that perform less well can have higher proportions of students taking less difficult item blocks.

The group adaptive design enables countries to better match the difficulty of the TIMSS assessment items to their students' level of achievement, resulting in less frustration among low achievers and less boredom among more able students. This in turn should lead to greater engagement and higher motivation, with improved response rates and less omitted or not reached data.

References

1 Mullis, I.V.S., Martin, M.O., Fishbein, B., Foy, P., & Moncaleano, S. (2021). *Findings from the TIMSS 2019 problem solving and inquiry tasks*. Retrieved from Boston College, TIMSS & PIRLS International Study Center website: https://timssandpirls.bc.edu/timss2019/psi/

2 Mullis, I.V.S. & Martin, M.O. (2022). IEA's TIMSS and PIRLS: Measuring long-term trends in student achievement. In T. Nilsen, A. Stancel-Piątak, & J. Gustafsson (Eds.), *International handbook of comparative large-scale studies in education: perspectives, methods, and findings*. Springer, forthcoming.

3 Mullis, I.V.S. & Martin, M.O. (2022). IEA's TIMSS and PIRLS: Measuring long-term trends in student achievement. In T. Nilsen, A. Stancel-Piątak, & J. Gustafsson (Eds.), *International handbook of comparative large-scale studies in education: perspectives, methods, and findings*. Springer, forthcoming.

4 Kelly, D.L., Centurino, V.A.S., Martin, M.O., & Mullis, I.V.S. (2020). *TIMSS 2019 encyclopedia: Education policy and curriculum in mathematics and science*. Retrieved from Boston College, TIMSS & PIRLS International Study Center website: https://timssandpirls.bc.edu/timss2019/encyclopedia/

CHAPTER 1

TIMSS 2023 Mathematics Framework

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Overview

All children can benefit from developing an understanding of mathematics and facility with the mathematics needed in today's technological world. Mathematics is essential in daily life as well as in many career fields such as engineering, architecture, accounting, banking, business, medicine, ecology, and aerospace. Mathematics is vital to economics and finance, as well as to computing technology and software development. The ability to learn new skills and to solve problems is paramount in today's changing world.

This chapter presents the assessment frameworks for the two TIMSS 2023 mathematics assessments:

- TIMSS Mathematics—Fourth Grade
- TIMSS Mathematics—Eighth Grade

As described in the Introduction, the *TIMSS 2023 Mathematics Framework* for the fourth and eighth grades builds on TIMSS's 28-year history of assessments every four years since 1995, with this being the eighth assessment in the series.

In general, the fourth and eighth grade frameworks are similar to those used in TIMSS 2019. Minor updates reflect the curricula, standards, and frameworks of the participating countries as reported in the *TIMSS 2019 Encyclopedia*[1] and suggestions from the TIMSS 2023 National Research Coordinators.

TIMSS 2023 is Fully Digital

The transition to digital assessment initiated in about half the TIMSS 2019 countries will be completed in TIMSS 2023, such that TIMSS 2023 is fully digital.

An overarching goal for TIMSS 2023 is capitalizing on the benefits of computer-based assessments, including a fully digital item development system to incorporate new and better assessment items and methods, and knowledge of the improved capacity for innovative item development influenced the present framework. Digital assessment allows:

- Accounting for dynamic aspects of mathematical concepts such as relationships and geometric operations by offering interactive simulations or tools closer to what these concepts really address.

- Improved assessment of the reasoning cognitive processes by relegating some procedural and secondary calculation tasks to the computer, allowing students to focus on strategy and mathematical thinking.
- Process data associated with students' response patterns that can be used to learn more about students' problem solving strategies, misconceptions, and approaches to test taking.
- Enrichment of the overall testing display and response formats, helping to improve students' engagement and motivation to participate in TIMSS.

Expectations for a Range of Problem Solving Contexts

Previous TIMSS Mathematics frameworks have not been clear about the degree of emphasis that should be placed on solving problems in context. Typically, solving problems was included as part of at least one topic within a content domain, implying that some items within a content domain were expected to be situated in contexts. Also, all items in the assessment are classified by cognitive domain— knowing, applying, or reasoning— with 60 to 65 percent of the items requiring applying and reasoning in a problem solving context.

The *TIMSS 2023 Mathematics Framework* specifies that approximately 85 percent of the items covering the topics in each content domain should be situated in a problem solving context. This is consistent with other aspects of the framework, and clarifies that problem solving is an overarching goal of TIMSS Mathematics, and not associated only with particular topics. The contexts can range from straightforward to complex extended scenarios, such as in the Problem Solving and Inquiry Tasks (PSIs). It is important, however, that at least 15 percent of the items are presented without context to be able to examine the possible effects of reading load.

Organization of TIMSS 2023 Mathematics Framework

The mathematics assessment framework for TIMSS 2023 is organized around two dimensions:

- Content dimension, specifying the subject matter domains to be assessed
- Cognitive dimension, specifying the thinking processes to be assessed

Exhibit 1.1 shows the target percentage of testing score points devoted to each content and cognitive domain for the TIMSS 2023 fourth and eighth grade assessments.

Exhibit 1.1: Target Percentages of the TIMSS 2023 Mathematics Assessment Devoted to Content and Cognitive Domains at the Fourth and Eighth Grades

Fourth Grade

Content Domains	Percentages
Number	50%
Measurement and Geometry	30%
Data	20%

Eighth Grade

Content Domains	Percentages
Number	30%
Algebra	30%
Geometry and Measurement	20%
Data and Probability	20%

Cognitive Domains	Percentages	
	Fourth Grade	Eighth Grade
Knowing	40%	35%
Applying	40%	40%
Reasoning	20%	25%

The content domains differ for the fourth and eighth grades, reflecting the mathematics widely taught at each grade. There is more emphasis on number at the fourth grade than at the eighth grade. Algebra becomes a topic of its own in eighth grade, whereas the introductory algebraic topics assessed at the fourth grade are included in the number topic area. The eighth grade geometry domain includes measurement but also a deeper inclusion of purely geometric topics. The fourth grade data domain focuses on reading, representing, and interpreting data, whereas at the eighth grade it includes more emphasis on drawing conclusions from data, basic statistics, and the fundamentals of probability.

It is important to highlight that TIMSS assesses a range of situations within mathematics, with well over half (60-65%) the items requiring students to use applying and reasoning skills. The cognitive domains are the same for both grades, but with less emphasis in the eighth grade on the knowing domain and greater emphasis on the reasoning domain.

Following this brief introduction, the chapter begins with the fourth grade content domains, identifying the three main content domains and the assessment topics within each domain. Chapter 1 continues with the description of the eighth grade domains and calculator policy. The chapter ends with the description of the cognitive domains for both grades.

Mathematics Content Domains—Fourth Grade

Exhibit 1.2 shows the TIMSS 2023 Mathematics—Fourth Grade content domains and the target percentages of assessment score points devoted to each. Each content domain consists of topic areas, and each topic area in turn includes several topics. Across the fourth grade mathematics assessment, each topic receives approximately equal weight.

Exhibit 1.2: Target Percentages of the TIMSS 2023 Mathematics Assessment Devoted to Content Domains at the Fourth Grade

Fourth Grade Content Domains	Percentages
Number	50%
Measurement and Geometry	30%
Data	20%

Each of the following topics within each content area can be assessed by items measuring the knowing, applying, or reasoning cognitive domains as appropriate. Also, the items covering the topics in a content domain are expected to be situated in a range of contexts. At least 15 percent should be presented without context, and the remaining should range from straightforward problem solving situations to the complex extended scenarios in the PSIs.

Number

Number provides the foundation of mathematics in primary school. The number content domain consists of three topic areas. The 50 percent of the assessment devoted to number is apportioned as follows:

- Whole numbers (25%)
- Expressions, simple equations, and relationships (15%)
- Fractions and decimals (10%)

Whole numbers are the predominant component of the number domain and students should be able to compute with whole numbers of reasonable size. Introductory algebraic concepts also are part of the TIMSS assessment at the fourth grade, including understanding the use of variables (unknowns) in simple equations and initial understandings of relationships between quantities. However, because objects and quantities often do not come in whole numbers, it is also important for students to understand fractions and decimals. Students should be able to compare, add, and subtract familiar fractions and decimals.

Whole Numbers

1. Recognize place value of numbers to 6 digits, connect representations of numbers (words, symbols, and models including number lines), and compare numbers.
2. Add and subtract up to 4-digit numbers.

3. 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).
4. Solve problems involving odd and even numbers, multiples and factors of numbers, rounding numbers (up to the nearest powers of 10), and making estimates.
5. Combine two or more properties of numbers or operations to solve a problem.

Expressions, Equations, and Relationships

1. Find the missing number or operation in a number sentence (e.g., 17 + w = 29).
2. Match or write expressions or number sentences to represent problem situations that may involve unknowns.
3. Match, describe, or use relationships in a well-defined pattern (e.g., describe the relationship between adjacent terms and generate pairs of whole numbers given a rule).

Fractions and Decimals

1. Describe a fraction as part of a whole or collection; connect different representations of fractions (words, numbers, and models); compare the size of fractions; add and subtract simple fractions with like denominators of 2, 3, 4, 5, 6, 8, 10, 12, or 100.
2. Connect different representations of decimals (words, numbers, and models); compare and order decimals and relate decimals to fractions; round decimals; add and subtract decimals (up to two decimal places).

Measurement and Geometry

We are surrounded by objects of different shapes and sizes, and geometry helps us visualize and understand the relationships between shapes and sizes. Measurement is the process of quantifying attributes of objects and phenomena (e.g., length and time).

The two topic areas in measurement and geometry are as follows:

- Measurement (15%)
- Geometry (15%)

At the fourth grade, students should be able to use a ruler to measure length; perform calculations involving length, mass, volume, and time; calculate areas of shapes based on rectangles; calculate perimeters of polygons; and use cubes to determine volumes. Students should be able to identify the properties and characteristics of lines, angles, and a variety of two- and three-dimensional shapes. Spatial sense is integral to the study of geometry, and students will be asked to describe and draw a variety of geometric figures. They also should be able to analyze geometric relationships and use these relationships to draw conclusions about geometric objects.

Measurement

1. Measure, estimate, add, and subtract lengths (millimeters, centimeters, meters, kilometers).
2. Add and subtract mass (gram and kilogram), volume (milliliter and liter), and time (minutes and hours); select appropriate types and sizes of units and read scales.
3. Determine perimeters of polygons, areas of rectangles, areas of shapes covered with squares or partial squares, and volumes filled with cubes.

Geometry

1. Recognize and draw parallel and perpendicular lines, right angles, and angles smaller or larger than a right angle; compare the relative size of angles.
2. Use elementary properties, including line and rotational symmetry to describe and create common two-dimensional shapes (circle, triangles, quadrilaterals, and other polygons).
3. Use elementary properties to describe three dimensional shapes (cubes, rectangular solids, cones, cylinders, and spheres), the differences among them, and how they relate to their two-dimensional representations.

Data

The explosion of data in today's information society has resulted in a variety of visual displays of quantitative information. Often the internet, newspapers, magazines, textbooks, reference books, and articles have data represented in charts, tables, and graphs. Students need to understand that graphs and charts help organize information or categories and provide a way to compare data.

The data content domain consists of two topic areas:

- Reading and displaying data (10%)
- Interpreting, combining, and comparing data (10%)

At the fourth grade, students should be able to read and create data displays. They should be able to make inferences from data displays and use data from one or more sources to answer questions of interest.

Reading and Displaying Data

1. Read data from tables, pictographs, bar graphs, line graphs, and pie charts.
2. Create or complete tables, pictographs, bar graphs, line graphs, and pie charts.

Interpreting, Combining, and Comparing Data

1. Interpret data and use it to answer questions that go beyond directly reading data displays.
2. Combine or compare data from two or more sources, and draw conclusions based on two or more data sets.

Mathematics Content Domains—Eighth Grade

Exhibit 1.3 shows the TIMSS 2023 Mathematics—Eighth Grade content domains and the target percentages of assessment score points devoted to each. Each content domain consists of topic areas, and each topic area in turn includes several topics. Across the eighth grade mathematics assessment, each topic receives approximately equal weight.

Exhibit 1.3: Target Percentages of the TIMSS 2023 Mathematics Assessment Devoted to Content Domains at the Eighth Grade

Eighth Grade Content Domains	Percentages
Number	30%
Algebra	30%
Geometry and Measurement	20%
Data and Probability	20%

As with fourth grade mathematics, each of the following topics within each content area at the eighth grade can be assessed by items measuring the knowing, applying, or reasoning cognitive domains as appropriate. Also, the items covering the topics in a content domain are expected to be situated in a range of contexts. At least 15 percent should be presented without context, and the remaining should range from straightforward problem solving situations to the complex extended scenarios in the PSIs.

Number

At the eighth grade, the 30 percent of the assessment devoted to number consists of three topic areas:

- Integers (10%)
- Fractions and decimals (10%)
- Proportions, ratios, and percentages (10%)

Building on the number content domain at the fourth grade, eighth grade students should have developed proficiency with more advanced whole number concepts and procedures as well as extended their mathematical understanding of rational numbers (integers, fractions, and decimals). Students also should understand and be able to compute with integers. Fractions and decimals are an important part of daily life and being able to compute with them requires an understanding of the quantities the symbols represent. A single rational number can be represented with many different written symbols, and students need to be able to recognize the distinctions among interpretations of rational numbers, convert between them, and reason with them. Students should be able to apply ratios, proportions, and percentages to whole number amounts.

Integers

1. Recognize and use properties of numbers and operations; find and use multiples and factors, recognize prime numbers, evaluate positive integer powers of number, and square roots of whole numbers.
2. Add and subtract positive and negative numbers, including through movement and position on a number line or using various models (e.g., thermometers, losses and gains).

Fractions and Decimals

1. Using various models and representations, compare and order fractions and decimals, and identify equivalent fractions and decimals.
2. Add, subtract, and multiply with fractions and decimals, and divide fractions and decimals by a whole number.

Proportions, Ratios, and Percentages

1. Determine proportions and ratios of quantities (e.g. rates, scales on maps).
2. Apply or find percentages; convert between percentages and fractions or decimals.

Algebra

The 30 percent of the assessment devoted to algebra is comprised of two topic areas:

- Expressions, operations, and equations (20%)
- Relationships and functions (10%)

Patterns and relationships are pervasive in the world around us. Students should be able to use algebraic models and express relationships algebraically. They need to be able to rearrange formulas and substitute values into formulas. Their conceptual understanding can extend to linear equations for calculations about quantities that change at constant rates. Linear and simple non-linear functions can be used to describe what will happen to a variable when a related variable changes.

Expressions, Operations, and Equations

1. Find the value of an expression or a formula given values of the variables.
2. Simplify algebraic expressions involving sums, products, differences, and positive integer powers; compare expressions to decide if they are equivalent.
3. Write expressions, equations, or inequalities to represent problem situations.
4. Solve linear equations, linear inequalities, and simultaneous linear equations in two variables, including validating values as solutions.

Relationships and Functions

1. Interpret, relate, and generate representations of linear functions in tables, graphs, or words; recognize properties of linear functions including slope and intercepts.

2. Interpret, relate, and generate representations of simple non-linear functions (e.g., quadratic) in tables, graphs, or words; generalize linear and non-linear pattern relationships or sequences, using words, or algebraic expressions.

Geometry and Measurement

The geometry and measurement content domain at the eighth grade consists of one topic area:

- Geometry and Measurement (20%)

Extending the understanding of shapes and measures assessed at the fourth grade, eighth grade students should be able to analyze the properties of a variety of two- and three-dimensional figures and calculate perimeters, areas, and volumes. They should be able to provide explanations based on geometric relationships, such as congruence, similarity, and the Pythagorean Theorem.

Geometry and Measurement

1. Recognize and draw types of angles and pairs of lines and use the relationships between angles on lines and in geometric figures, including those involving the measures of angles and line segments; read and plot points in the Cartesian plane.
2. Recognize two-dimensional shapes and use their geometric properties (e.g. sums of interior angles of triangles and quadrilaterals, properties of isosceles triangles), including to calculate length and area, and use the Pythagorean Theorem.

   Note: Two-dimensional shapes include circles; scalene, isosceles, equilateral, and right-angled triangles; trapezoids, parallelograms, rectangles, rhombuses, and other quadrilaterals; as well as other polygons including pentagons, hexagons, octagons, and decagons.

3. Determine the results of geometric transformations (translations, reflections, and rotations) in the plane; recognize and use properties of congruent and similar triangles and rectangles.
4. Recognize three-dimensional shapes and use their properties to calculate surface area and volume; relate three-dimensional shapes with their two-dimensional representations.

   Note: Three-dimensional shapes include prisms, pyramids, cones, cylinders, and spheres.

Data and Probability

The data and probability content domain contains two topic areas:

- Data (15%)
- Probability (5%)

Increasingly, the more traditional forms of data display (e.g., bar graphs, line graphs, pie graphs, pictographs) are being supplemented by an array of new graphic forms (e.g., infographics). By the eighth grade, students should to be able to read and extract the important meaning from a variety of visual displays. It is also important for eighth grade students to be familiar with the statistics underlying data distributions and how these relate to the shape of data graphs. Students should know how to organize and represent data. Students also should have an initial grasp of some concepts related to probability.

Data

1. Interpret data from one or more sources (e.g., interpolate and extrapolate, make comparisons, draw conclusions).
2. Organize and represent data to help answer questions. Representations include all those at fourth grade (tables, pictographs, bar graphs, line graphs, and pie charts) and in addition, histograms, dot plots, scatter plots, clustered and stacked bar charts, and infographics.
3. Summarize data distributions; calculate, use, or interpret mean and median; recognize the effect of spread and outliers.

Probability

1. For simple and compound events: determine theoretical probability (based on proportions of favorable outcomes, e.g., rolling a fair die or drawing marbles of a particular color from a bag); estimate empirical probability (based on experimental outcomes).

Calculator Use at the Eighth Grade

At the eighth grade, students will be permitted to use the TIMSS on-screen calculator. This calculator has the four basic functions (+, −, ×, ÷), a square root key, and the negative sign. Students will not be permitted to bring their own calculators. On the whole the mathematics items are developed to be calculator neutral and do not advantage or disadvantage students whether or not they use calculators. A notable exception is the (very few) items that require the taking of a square root.

Mathematics Cognitive Domains—Fourth and Eighth Grades

In order to respond correctly to TIMSS test items, students need to be familiar with the mathematics content being assessed, but they also need to draw on a range of cognitive skills. These include the ability to select and carry out procedures, apply knowledge to solve problems, make logical deductions, and give reasons for an assertion. Describing these skills plays a crucial role in the development of an assessment like TIMSS 2023, ensuring that the survey covers the appropriate range of cognitive skills across the content domains already outlined.

The first domain, *knowing*, covers the facts, concepts, and procedures students need to know, while the second, *applying*, focuses on the ability of students to apply knowledge and conceptual understanding in a range of situations. The third domain, *reasoning*, involves the logical, systematic thinking that students need to use to generate and justify solutions to problems, make inferences, and deal with complex relationships between mathematical objects.

Knowing, applying, and reasoning are exercised in varying degrees when students display their mathematical competency, which goes beyond content knowledge. These TIMSS cognitive domains encompass the competencies of providing a mathematical argument to support a strategy or solution, representing a situation mathematically (e.g., using symbols and graphs), creating mathematical models of a problem situation, and using tools such as a ruler or a calculator.

The three cognitive domains are used for both grades, with each item categorized into one of the three domains. Reflecting the difference in age and experience of students, the balance of score points differs between fourth and eighth grade (see Exhibit 1.4). For both grades, each content domain will include some items developed to address each of the three cognitive domains. For example, the number domain will include knowing, applying, and reasoning items as will the other content domains.

Exhibit 1.4 shows the target percentages of score points devoted to each cognitive domain for the fourth and eighth grade assessments.

Exhibit 1.4: Target Percentages of the TIMSS 2023 Mathematics Assessment Devoted to Cognitive Domains at the Fourth and Eighth Grades

Cognitive Domains	Percentages	
	Fourth Grade	Eighth Grade
Knowing	40%	35%
Applying	40%	40%
Reasoning	20%	25%

The following sections describe the types of cognitive skills particular to each of the three cognitive domains. Items are classified according to cognitive skills to ensure a range of coverage within each cognitive domain. However, there are no specified targets for the percentages of score points for each cognitive skill.

Knowing

Facility in applying mathematics, or reasoning about mathematical situations, depends on familiarity with mathematical concepts and fluency in mathematical skills. The more relevant knowledge a student is able to recall and the wider the range of concepts he or she understands, the greater the potential for engaging with a wide range of problem situations.

Without access to a knowledge base that enables easy recall of the language and basic facts and conventions of number, symbolic representation, and spatial relations, students would find purposeful mathematical thinking impossible. Facts encompass the knowledge that provides the basic language of mathematics, as well as the essential mathematical concepts and properties that form the foundation for mathematical thought.

Procedures form the foundation of the mathematics needed for solving problems, especially those encountered by many people in their daily lives. In essence, a fluent use of procedures entails recall of sets of actions and how to carry them out. Students need to be efficient and accurate in using a variety of computational procedures and tools in relatively familiar and routine tasks. They need to see that particular procedures can be used to solve entire classes of problems, not just individual problems.

Recall	Recall definitions, terminology, number properties, units of measurement, geometric properties, and notation (e.g., $a \times b = ab$, $a + a + a = 3a$).
Identify	Identify numbers, expressions, quantities, and shapes. Recognize when entities are mathematically equivalent. Read information from graphs, tables, texts, or other sources.
Order	Order and classify numbers, expressions, quantities, and shapes by common properties.
Compute	Compute arithmetic operations with whole numbers, fractions, decimals, and integers using algorithmic procedures. Carry out straightforward algebraic manipulation.

Applying

The applying domain involves the application of mathematics in a range of situations. Problem solving is central to this domain. Students will need to select suitable operations, strategies, and tools for solving problems. Many of the problems are set in real life situations, requiring students to formulate the problem in mathematical terms before implementing a solution. In these problems, students need to apply mathematical knowledge of facts, skills, and procedures or understanding of mathematical concepts to create representations. Representation of ideas forms the core of mathematical thinking and communication, and the ability to create representations is fundamental to success in the subject.

Other problems may be concerned with purely mathematical questions involving, for example, numeric or algebraic expressions, functions, equations, geometric figures, or statistical data sets. With these problems, a mathematical representation might be given and students might need to interpret the representation or generate an equivalent representation in order to solve the problem.

Formulate	Determine efficient/appropriate operations, strategies, and tools for solving problems.
Implement	Implement suitable strategies and operations to produce solutions to problems.
Represent	Represent data in tables or graphs; create equations, inequalities, geometric figures, or diagrams that model problem situations; and generate equivalent representations for a given mathematical entity or relationship.

Reasoning

Reasoning mathematically involves logical, systematic thinking. It includes intuitive and inductive reasoning based on patterns and regularities that can be used to arrive at solutions to problems. Evidence of reasoning processes can be found in the explaining or justifying of a solution method, or the making of valid inferences on the basis of information and evidence. Reasoning is required in analyzing or generalizing mathematical relationships.

Even though many of the cognitive skills listed in the reasoning domain may be drawn on when thinking about and solving complex problems, each by itself represents a valuable outcome of mathematics education, with the potential to influence learners' thinking more generally. For example, reasoning involves the ability to observe and make conjectures. It also involves making logical deductions based on specific assumptions and rules, and justifying results.

Analyze	Analyze, describe, or use relationships among numbers, expressions, quantities, and shapes.
Integrate	Link different elements of knowledge, related representations, and procedures.
Generalize	Make statements that represent relationships in more general and more widely applicable terms.
Justify	Provide mathematical arguments to support a strategy or solution.

References

1 Kelly, D.L., Centurino, V., Martin, M.o., & Mullis, I.V. S. (Eds.) (2020). *TIMSS 2019 encyclopedia: Education policy and curriculum in mathematics and science*. Retrieved from Boston College, TIMSS & PIRLS International Student Center website: http://timssandpirls.bc.edu/timss2019/encyclopedia/

IEA TIMSS 2023

CHAPTER 2

TIMSS 2023 Science Framework

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Overview

Innovations in technology and science constantly shape and reshape our daily life experiences: the availability of clean water; the food we eat; the quality of the air we breathe; the vaccines, medicines, and medical diagnostic tools available; the ways we communicate; the modes of transportation we use; and more. Children in primary and lower-secondary grades today have lived all of their lives in a science- and technology-enhanced world. Perhaps more than any previous generation, they have boundless opportunities to engage in activities and experiences and with information that can satisfy their natural curiosity about the world and their place in it. Science education in the primary grades capitalizes on this curiosity and starts young students on a path of systematic inquiry about the world in which they live. As their understanding of science develops, students in the lower-secondary grades are increasingly able to make informed decisions about themselves and their world so that, as adults, they can become informed and scientifically literate citizens capable of distinguishing scientific fact from fiction and understanding the scientific basis of important social, economic, and environmental issues. Across the world, there is an increased demand for those qualified to pursue the careers in science, technology, and engineering to continue to drive the innovation necessary to solve global problems (e.g., mitigating the environmental impacts of human activities, increasing access to clean water and nutritious food, preparing next-generation medical therapies), grow economies, and improve quality of life. To meet this demand, it is increasingly important to prepare students to enter advanced study in these areas.

This chapter presents the assessment framework for the two TIMSS 2023 science assessments:

- TIMSS Science—Fourth Grade
- TIMSS Science—Eighth Grade

The *TIMSS 2023 Science Frameworks* for the fourth and eighth grades extends the 28-year history of TIMSS assessments, beginning in 1995 and taking place every four years since. TIMSS 2023 is the eighth assessment in the series.

The TIMSS 2023 science frameworks are similar to those used in TIMSS 2019. However, there have been minor updates to reflect countries' evolving science curricula, frameworks, and learning goals as reported in the *TIMSS 2019 Encyclopedia*.[1] TIMSS 2023 completes the transition to digital assessment, which began in TIMSS 2019. The science frameworks have been updated to reflect that TIMSS 2023 will be developed in and for a digital environment, including capitalizing on innovative technology-based approaches to the assessment of inquiry and investigation in science. TIMSS 2023 will capitalize on the benefits of digital assessment by:

- Incorporating a variety of technology-enhanced item formats to promote student engagement.
- Including simulated real-world and laboratory situations where students can integrate and apply process skills and content knowledge to perform scientific investigations or experiments.
- Improving measurement of higher-order cognitive processes using interactive scenarios that present students with adaptive and responsive ways to work through science problems.
- Collecting information about how students interact with the achievement items to learn more about how students engage in the practice of science, their misconceptions, and their test-taking strategies.

The Introduction to the *TIMSS 2023 Frameworks* provides further detail on the new interactive item types and response types planned for TIMSS 2023. It also describes the initiative begun in TIMSS 2019 to develop and begin administering longer, scenario based Problem Solving and Inquiry Tasks (PSIs) in the mathematics and science assessments, and the plans for incorporating the PSIs into the TIMSS 2023 assessments and beyond.

At each grade, the science assessment framework for TIMSS 2023 is organized around two dimensions:

- Content dimension, specifying the subject matter to be assessed
- Cognitive dimension, specifying the thinking processes to be assessed

Exhibit 2.1 shows the target percentage of score points devoted to each content and cognitive domain for the TIMSS 2023 fourth and eighth grade assessments.

Exhibit 2.1: Target Percentages of the TIMSS 2023 Science Assessment Devoted to Content and Cognitive Domains at the Fourth and Eighth Grades

Fourth Grade

Content Domains	Percentages
Life Science	45%
Physical Science	35%
Earth Science	20%

Eighth Grade

Content Domains	Percentages
Biology	35%
Chemistry	20%
Physics	25%
Earth Science	20%

Cognitive Domains	Percentages	
	Fourth Grade	Eighth Grade
Knowing	40%	35%
Applying	40%	35%
Reasoning	20%	30%

The content domains differ for the fourth and eighth grades, reflecting the nature and difficulty of the science taught at each grade. There is more emphasis at the fourth grade on life science than its counterpart, biology, at the eighth grade. At the eighth grade, physics and chemistry are assessed as separate content domains and receive more emphasis than at fourth grade, where they are assessed as one content domain (physical science). The Earth science content domain has the same level of emphasis at both grades, but the objectives at the eighth grade are more sophisticated than at the fourth grade.

The three cognitive domains (knowing, applying, and reasoning) are the same at both grades, encompassing the range of cognitive processes involved in learning science concepts, and then applying these concepts and reasoning with them.

In 2023, TIMSS Science also will assess key science practices. These practices include skills from daily life and school studies that students use in a systematic way to conduct scientific inquiry and investigation and that are fundamental to all science disciplines. Increasing emphasis has been placed on science practices and science inquiry in many countries' current science curricula, standards, and frameworks.[2] Facility with science practices is essential for students to learn and understand science concepts and to understand and appreciate the nature of science and scientific knowledge.

The practice of science is, by its very nature, strongly connected to the area of science under study and, therefore, cannot be assessed in isolation. Some items in the TIMSS 2023 science assessment at both the fourth and eighth grades will assess one or more of these important science practices together with content specified in the content domains and thinking processes specified in the cognitive domains. The science practices will primarily be assessed through the science PSIs, however. In the PSIs, students conduct extended investigations and inquiries in a science content area and in doing so engage in one or more of the science practices.

The next two sections of this chapter present the TIMSS 2023 science content domains for fourth and eighth grades, followed by a description of the cognitive domains, which are applicable to both grades. The chapter concludes with a description of the science practices.

Science Content Domains—Fourth Grade

Three major content domains define the science content for the TIMSS Science fourth grade assessment: life science, physical science, and Earth science. Exhibit 2.2 shows the target percentages of testing time for each of the three content domains in the TIMSS 2023 Science assessment.

Exhibit 2.2: Target Percentages of the TIMSS 2023 Science Assessment Devoted to Content Domains at the Fourth Grade

Fourth Grade Content Domains	Percentages
Life Science	45%
Physical Science	35%
Earth Science	20%

Each of these content domains includes several major topic areas, and each topic area in turn includes one or more topics. Each topic is further described by specific objectives that represent the students' expected knowledge, abilities, and skills assessed within each topic.

Across the fourth grade assessment, each objective receives approximately equal weight in terms of the number of assessment items. The verbs used in the objectives are intended to represent typical performances expected of fourth grade students, but are not intended to limit performances to a particular cognitive domain. Each objective can be assessed drawing on any of the three cognitive domains (knowing, applying, and reasoning). Some objectives include additional parenthetical information. Illustrative examples appear after an "e.g.," such as in "Relate major structures in animals to their functions (e.g., bones support the body, lungs take in air, the heart circulates blood, the stomach digests food, muscles move the body)." In some cases, the additional information indicates the scope of the objective appropriate for fourth grade students and appears after an "i.e.," such as in "Recognize that matter can be changed from one state to another by heating or cooling; describe changes in the state of water (i.e., melting, freezing, boiling, evaporation, and condensation)."

Life Science

The study of life science at the fourth grade provides students with an opportunity to capitalize on their innate curiosity and begin to understand the living world around them. In TIMSS 2023, life science is represented by five topic areas:

- Characteristics and life processes of organisms
- Life cycles, reproduction, and heredity
- Organisms, environment, and their interactions
- Ecosystems
- Human health

By the fourth grade, students are expected to be building a base of knowledge about general characteristics of organisms, how they function, and how they interact with other organisms and with their environment. Students also should be familiar with fundamental science concepts related to life cycles, heredity, and human health that in later grades will lead to a more sophisticated understanding of how the human body functions.

Characteristics and Life Processes of Organisms

1. Differences between living and non-living things and what living things require to live:
   - A. Recognize and describe differences between living and non-living things (i.e., living things can reproduce, grow and develop, respond to stimuli, and die; and non-living things cannot).
   - B. Identify what living things require in order to live (i.e., air, food or nutrients, water, and an environment in which to live).
2. Physical and behavioral characteristics of major groups of living things:
   - A. Compare and contrast physical and behavioral characteristics that distinguish major groups of living things (i.e., insects, birds, mammals, fish, reptiles, and flowering plants); distinguish groups of animals with backbones from groups of animals without backbones.
   - B. Identify or provide examples of members of major groups of living things (i.e., insects, birds, mammals, fish, reptiles, and flowering plants).
3. Functions of major structures in living things:
   - A. Relate major structures in animals to their functions (e.g., bones support the body, lungs take in air, the heart circulates blood, the stomach digests food, muscles move the body).
   - B. Relate major structures in plants to their functions (i.e., roots absorb water and nutrients and anchor the plant, leaves make food, the stem supports the plant and transports water, food, and nutrients, petals attract pollinators, flowers produce seeds, and seeds produce new plants).

Life Cycles, Reproduction, and Heredity

1. Stages of life cycles and differences among the life cycles of common plants and animals:
   - A. Identify stages of the life cycles of flowering plants (i.e., germination, growth and development, reproduction, and seed dispersal).
   - B. Recognize, compare, and contrast the life cycles of familiar plants and animals (e.g., trees, beans, humans, frogs, butterflies).
2. Inheritance and reproduction strategies:
   - A. Recognize that plants and animals reproduce with their own kind to produce offspring with features that closely resemble those of the parents; distinguish between features of plants and animals that are inherited from their parents (e.g., number of petals, color of petals, eye color, hair color), and those that are not (e.g., some broken branches in a tree, length of human hair).
   - B. Identify and describe different strategies that increase the number of offspring that survive (e.g., a plant producing many seeds, mammals caring for their young).

Organisms, Environment, and Their Interactions

1. Physical features or behaviors of living things that help them survive in their environment:
   - A. Associate physical features of plants and animals with the environments in which they live

and describe how these features help them to survive (e.g., a thick stem, a waxy coating, and a deep root help a plant survive in an environment with little water; the coloring of an animal helps camouflage it from predators).

B. Associate behaviors of animals with the environments in which they live and describe how these behaviors help them to survive (e.g., migration or hibernation helps an animal to stay alive when food is scarce).

2. Responses of living things to environmental conditions:
   A. Recognize and describe how plants respond to environmental conditions (e.g., amount of available water, amount of sunlight).
   B. Recognize and describe how different animals respond to changes in environmental conditions (e.g., light, temperature, danger); recognize and describe how the human body responds to changes in environmental conditions and how it reacts to physical activity (e.g., exercise).
3. The impact of humans on the environment:
   A. Recognize that human behavior has negative and positive effects on the environment (e.g., negative effects of air and water pollution, positive effects of reducing air and water pollution); provide general descriptions and examples of the effects of pollution on humans, plants, and animals.

Ecosystems

1. Common ecosystems:
   A. Relate common plants and animals (e.g., evergreen trees, frogs, lions) to common ecosystems (e.g., forests, ponds, grasslands).
2. Relationships in simple food chains:
   A. Recognize that plants need (sun)light, air, and water to provide energy for life processes (i.e., growth and repair, movement, and reproduction); explain that animals eat plants or other animals to get the food they need to supply energy for life processes (i.e., growth and repair, movement, and reproduction).
   B. Complete a model of a simple food chain using common plants and animals from common ecosystems, (e.g., a forest, a desert, a river, an ocean).
   C. Describe the roles of living things at each link in a simple food chain (e.g., plants produce their own food; some animals eat plants, while other animals eat the animals that eat plants).
   D. Identify common predators and their prey and describe their relationships.
3. Competition in ecosystems:
   A. Recognize and explain that some living things in an ecosystem compete with others for resources (e.g., food, light, space).

Human Health

1. Ways of maintaining good health:
   A. Describe everyday behaviors that promote good health (e.g., a balanced diet, exercising regularly, brushing teeth, getting enough sleep, wearing sunscreen); identify common food sources included in a balanced diet (e.g., fruits, vegetables, grains).
   B. Relate the transmission of common communicable diseases to human contact (e.g., touching, sneezing, coughing); identify or describe some methods of preventing disease transmission (e.g., vaccination, washing hands, keeping a physical distance from people who are sick).

Physical Science

At the fourth grade, students learn how many physical phenomena that they observe in their everyday lives can be explained through an understanding of physical science concepts. The topic areas for the physical science content domain at fourth grade are:

- Classification and properties of matter and changes in matter
- Forms of energy and energy transfer
- Forces and motion

Fourth grade students should have an understanding of physical states of matter (solid, liquid, and gas), as well as common changes in the state and form of matter; this forms a foundation for the study of both chemistry and physics in the middle and upper grades. At this level, students also should know common forms and sources of energy and their practical uses, and understand basic concepts about light, sound, electricity, and magnetism. The study of forces and motion emphasizes an understanding of forces as they relate to movements students can observe, such as the effect of gravity or pushing and pulling.

Classification and Properties of Matter and Changes in Matter

1. States of matter and characteristic differences of each state:
   A. Identify and describe three states of matter (i.e., a solid has a definite shape and volume, a liquid has a definite volume but not a definite shape, and a gas has neither a definite shape nor a definite volume).
2. Physical properties as a basis for classifying matter:
   A. Compare and sort objects and materials on the basis of physical properties (e.g., weight/mass, volume, state of matter, ability to conduct heat or electricity, ability to float or sink in water, ability to be attracted by a magnet). [Note: Students in the fourth grade are not expected to differentiate between mass and weight.]
   B. Identify properties of metals (i.e., conducting electricity and conducting heat) and relate these properties to uses of metals (e.g., a copper electrical wire, an iron cooking pot).
   C. Describe examples of mixtures and how they can be physically separated (e.g., sifting, filtration, evaporation, magnetic attraction).

3. Magnetic attraction and repulsion:
   A. Recognize that magnets have two poles and that like poles repel and opposite poles attract.
   B. Recognize that magnets can be used to attract some metal objects.
4. Physical changes observed in everyday life:
   A. Identify observable changes in materials that do not result in new materials with different properties (e.g., dissolving, crushing an aluminum can).
   B. Recognize that matter can be changed from one state to another by heating or cooling; describe changes in the state of water (i.e., melting, freezing, boiling, evaporation, and condensation).
   C. Identify ways of increasing how quickly a solid material dissolves in a given amount of water (i.e., increasing the temperature, stirring, and breaking the solid into smaller pieces); distinguish between weak and strong concentrations of simple solutions (e.g., water sweetened with one versus two lumps of sugar).
5. Chemical changes observed in everyday life:
   A. Identify observable changes in materials that make new materials with different properties (e.g., decaying, such as food spoiling; burning; rusting).

Forms of Energy and Energy Transfer

1. Common sources and uses of energy:
   A. Identify sources of energy (e.g., the Sun, flowing water, wind, coal, oil, gas), and recognize that energy is needed for movement and transportation, manufacturing, heating, lighting, and powering electronic devices.
2. Light and sound in everyday life:
   A. Relate common physical phenomena (i.e., shadows, reflections, and rainbows) to the behavior of light.
   B. Relate common physical phenomena (i.e., vibrating objects and echoes) to the production and behavior of sound.
3. Heat transfer:
   A. Describe what will happen when a hot object and a cold object are brought into contact (i.e., the temperature of the hot object decreases and the temperature of the cold object increases).
4. Electricity and simple electrical systems:
   A. Recognize that electrical energy in a circuit can be transformed into other forms of energy (e.g., heat, light, sound).
   B. Explain that simple electrical systems (e.g., a flashlight) require a complete (unbroken) electrical pathway.

Forces and Motion

1. Familiar forces and the motion of objects:
   A. Identify gravity as the force that draws objects to Earth.
   B. Recognize that forces (i.e., pushing and pulling) may cause an object to change its motion; compare the effects of these forces (pushes and pulls) of different strengths in the same or opposite directions acting on an object; and recognize that friction force works against the direction of motion (e.g., friction working against a push or a pull makes it more difficult to move an object along a surface).
2. Simple machines:
   A. Recognize that simple machines, (e.g., levers, pulleys, gears, ramps) help make motion easier (e.g., make lifting things easier, reduce the amount of force required, change the distance, change the direction of the force).

Earth Science

Earth science is the study of Earth and its place in the Solar System, and at fourth grade focuses on the study of phenomena and processes that students can observe in their everyday lives. While there is no single picture of what constitutes an Earth science curriculum that applies to all countries, the three topic areas included in this domain are generally considered to be important for students at the fourth grade to understand as they learn about the planet on which they live and its place in the Solar System:

- Earth's physical characteristics, resources, and history
- Earth's weather and climates
- Earth in the Solar System

At this level, students should have some general knowledge about the structure and physical characteristics of Earth's surface, and about the use of Earth's most important resources. Students also should be able to describe some of Earth's processes in terms of observable changes and understand the time frame over which such changes have occurred. Fourth grade students should also demonstrate some understanding about Earth's place in the Solar System based on observations of patterns of change on Earth and in the sky.

Earth's Physical Characteristics, Resources, and History

1. Physical characteristics of the Earth system:
   A. Recognize that Earth's surface is made up of land and water in unequal proportions (more water than land) and is surrounded by air; describe where fresh and salt water are found.
2. Earth's resources:
   A. Identify some of Earth's resources that are used in everyday life (e.g., water, wind, soil, forests, oil, natural gas, minerals).
   B. Explain the importance of using Earth's renewable and non-renewable resources responsibly (e.g., fossil fuels, forests, water).

3. Earth's history:
   A. Recognize that wind and water change Earth's landscape and that some features of Earth's landscape (e.g., mountains, river valleys) result from changes that happen very slowly over a long time.
   B. Recognize that some remains (fossils) of animals and plants that lived on Earth a long time ago are found in rocks and ice and make simple deductions about changes in Earth's surface from the location of these remains.

Earth's Weather and Climates

1. Weather and climates on Earth:
   A. Apply knowledge of changes of state of water to common weather events (e.g., cloud formation, dew formation, the evaporation of puddles, snow, rain).
   B. Describe how weather (i.e., daily variations in temperature, humidity, precipitation in the form of rain or snow, clouds, and wind) can vary with geographic location.
   C. Describe how average temperature and precipitation can change with the seasons and location; recognize that the average temperature on Earth has increased over the last century and some effects of this increase on Earth's physical characteristics (e.g., ocean levels have increased, ice caps have melted, rivers have dried up, deserts have grown bigger).

Earth in the Solar System

1. Objects in the Solar System and their movements:
   A. Describe the Solar System as the Sun and the planets that revolve around it; recognize that the Earth has a moon that revolves around it, and from Earth the Moon looks different at different times of the month.
2. Earth's motion and related patterns observed on Earth:
   A. Explain how day and night are related to Earth's daily rotation about its axis, and use the changing appearance of shadows during the day as evidence of this rotation.
   B. Recognize that seasons in Earth's northern and southern hemispheres are related to Earth's annual movement around the Sun (and the tilt of Earth's axis).

Science Content Domains—Eighth Grade

Four major content domains define the science content for the TIMSS Science eighth grade assessment: biology, chemistry, physics, and Earth science. Exhibit 2.3 shows the target percentages for each of the four content domains in the TIMSS 2023 science assessment.

Exhibit 2.3: Target Percentages of the TIMSS 2023 Science Assessment Devoted to Content Domains at the Eighth Grade

Eighth Grade Content Domains	Percentages
Biology	35%
Chemistry	20%
Physics	25%
Earth Science	20%

Each of these content domains includes several major topic areas, and each topic area in turn includes one or more topics. Each topic is further described by specific objectives that represent the students' expected knowledge, abilities, and skills assessed within each topic. Across the eighth grade assessment, each objective receives approximately equal weight in terms of assessment items. The verbs used in the objectives are intended to represent typical performances expected of eighth grade students, but are not intended to limit performances to a particular cognitive domain. Each objective can be assessed drawing on each of the three cognitive domains (knowing, applying, and reasoning). Some objectives include additional parenthetical information. Illustrative examples appear after an "e.g.," such as in "Locate and identify major organs (e.g., lungs, stomach, brain) and the components of major organ systems (e.g., respiratory system, digestive system) in the human body." In some cases, the additional information indicates the scope of the objective appropriate for eighth grade students and appears after an "i.e.," such as in "Describe the basic process of photosynthesis (i.e., requires light, carbon dioxide, water, and chlorophyll; produces glucose/sugar; and releases oxygen)."

Biology

At the eighth grade, students build on the foundational life science knowledge they learned in the primary grades, and develop an understanding of many of the most important concepts in biology. The biology domain includes six topic areas:

- Characteristics and life processes of organisms
- Cells and their functions
- Life cycles, reproduction, and heredity
- Diversity, adaptation, and natural selection
- Ecosystems
- Human health

Concepts learned in each of these topic areas are essential for preparing students for more advanced study. Eighth grade students are expected to understand how structure relates to function in organisms. They also should have a foundational understanding of cell structure and function and the processes of photosynthesis and cellular respiration. At this level, the study of reproduction and heredity provides a foundation for later, more advanced study of molecular biology and molecular genetics. Learning the concepts of adaptation and natural selection provides a foundation for understanding evolution, and an understanding of processes and interactions in ecosystems is essential for students to begin to think about how to develop solutions to many environmental challenges. Finally, developing a science-based understanding of human health enables students to improve the condition of their lives and the lives of others.

Characteristics and Life Processes of Organisms

1. Differences among major taxonomic groups of organisms:
   A. Identify the defining characteristics that differentiate among major taxonomic groups of organisms (i.e., plants, animals, fungi; mammals, birds, reptiles, amphibians, fish, and insects).
   B. Recognize and categorize organisms that are examples of major taxonomic groups of organisms (i.e., plants, animals, fungi; mammals, birds, reptiles, amphibians, fish, and insects).
2. Structures and functions of major organ systems:
   A. Locate and identify major organs (e.g., lungs, stomach, brain) and the components of major organ systems (e.g., respiratory system, digestive system) in the human body.
   B. Compare and contrast major organs and major organ systems in humans and other vertebrates (e.g., lungs in humans compared with gills in fish).
   C. Explain the role of major organs and major organ systems in sustaining life (e.g., organs involved in circulation and respiration).
3. Physiological processes in animals:
   A. Recognize responses of animals that work to maintain stable body conditions under external and internal changes (e.g., increased heart rate during exercise, feeling thirsty when dehydrated, feeling hungry when requiring energy, sweating in heat, shivering in cold).

Cells and Their Functions

1. The structures and functions of cells:
   A. Explain that living things are made of cells that both carry out life functions and reproduce by division.
   B. Identify major cell structures (i.e., cell wall, cell membrane, nucleus, cytoplasm, chloroplast, vacuole, and mitochondria) and describe the primary functions of these structures.

   C. Recognize that cell walls and chloroplasts differentiate plant cells from animal cells.
   D. Explain that tissues, organs, and organ systems are formed from groups of cells with specialized structures and functions.
2. The processes of photosynthesis and cellular respiration:
   A. Describe the basic process of photosynthesis (i.e., requires light, carbon dioxide, water, and chlorophyll; produces glucose/sugar; and releases oxygen).
   B. Describe the basic process of cellular respiration (i.e., requires oxygen and glucose/sugar; produces energy; and releases carbon dioxide and water).

Life Cycles, Reproduction, and Heredity

1. Life cycles and patterns of development:
   A. Compare and contrast the life cycles and patterns of growth and development of different types of organisms (i.e., mammals, birds, amphibians, insects, and plants).
2. Sexual reproduction and inheritance in plants and animals:
   A. Recognize that sexual reproduction involves the fertilization of an egg cell by a sperm cell to produce offspring that are similar but not identical to either parent; relate the inheritance of traits to organisms passing on genetic material to their offspring.
   B. Recognize that an organism's traits are encoded in its DNA; recognize that DNA is genetic information found in chromosomes located in the nucleus of each cell.
   C. Distinguish inherited characteristics from acquired or learned characteristics.

Diversity, Adaptation, and Natural Selection

1. Variation as the basis for natural selection:
   A. Recognize that variations in physical and behavioral characteristics among individuals in a population give some individuals an advantage in surviving and passing on their characteristics to their offspring.
   B. Relate species survival or extinction to reproductive success in a changing environment (natural selection).
2. Evidence for changes in life on Earth over time:
   A. Draw conclusions about the relative lengths of time different organisms and groups of organisms have existed on Earth using fossil evidence.
   B. Describe how similarities and differences among living species and fossils provide evidence of the changes that occur in living things over time, and recognize that the degree of similarity of characteristics provides evidence of common ancestry.

Ecosystems

1. The flow of energy in ecosystems:
   A. Identify and provide examples of producers, consumers, and decomposers; construct or interpret food web diagrams.

   B. Describe the flow of energy in an ecosystem (e.g., energy flows from producers to consumers, and only a small part of the energy is passed from one level to the next); construct or interpret energy pyramids.

2. The cycling of water, oxygen, and carbon in ecosystems:
   A. Describe the role of living things in cycling water through an ecosystem (i.e., plants take in water from the soil and give off water through their leaves (transpiration); and animals take in water and release water during respiration and as waste).
   B. Describe the role of living things in cycling oxygen and carbon through an ecosystem (i.e., plants take in carbon dioxide from the air and release oxygen into the air as part of photosynthesis and store carbon in their cells; and animals take in oxygen from the air and release carbon dioxide into the air as part of respiration).

3. Relationships among populations of organisms in an ecosystem:
   A. Describe and provide examples of competition among populations or organisms in an ecosystem.
   B. Describe and provide examples of predation in an ecosystem.
   C. Describe and provide examples of symbiosis (e.g., mutualism and parasitism) among populations of organisms in an ecosystem (e.g., birds or insects pollinating flowers, ticks living on deer or cattle).

4. Factors affecting population size in an ecosystem:
   A. Describe factors that affect the growth of plants and animals; identify factors that limit population size (e.g., disease, predators, food resources, drought, competition).
   B. Predict how changes in an ecosystem (e.g., changes in the water supply, the introduction of a new population, hunting, migration) can affect available resources, and thus the balance among populations.

5. Human impact on the environment:
   A. Describe and explain how human behavior (e.g., re-planting forests, reducing air and water pollution, protecting endangered species) can have positive effects on the environment.
   B. Describe and explain how human behavior (e.g., allowing factory waste water to enter water systems, burning fossil fuels that release greenhouse gases and pollutants into the air) can have negative effects on the environment; describe and provide examples of the effects of air, water, and soil pollution on humans, plants, and animals (e.g., water pollution can reduce plant and animal life in the water system).

Human Health

1. Causes, transmission, prevention of, and resistance to diseases:
   A. Describe causes, transmission, and prevention of common viral, bacterial, and parasite diseases (e.g., influenza, measles, HIV, COVID-19, tetanus, malaria).
   B. Describe the role of the body's immune system in resisting disease and promoting healing (e.g., antibodies in the blood help the body resist infection and white blood cells fight

infection); recognize that antibiotics can help the immune system suppress bacterial infections and antibiotics may become less effective when bacteria change.

2. The importance of diet, exercise, and other lifestyle choices:
   A. Explain the importance of diet, exercise, and other lifestyle choices in maintaining health and preventing illness (e.g., heart disease, high blood pressure, diabetes, skin cancer, lung cancer).
   B. Identify the dietary sources and roles of nutrients in a healthy diet (i.e., vitamins, minerals, proteins, carbohydrates, and fats).

Chemistry

At the eighth grade, students' study of chemistry extends beyond developing an understanding of everyday phenomena to learning the central concepts and principles that are needed for understanding practical applications of chemistry and undertaking later, more advanced study. The chemistry domain includes three topic areas:

- Composition of matter
- Properties of matter
- Chemical change

The composition of matter topic area focuses on differentiating elements, compounds, and mixtures and understanding the particulate structure of matter. Included in this area also is the use of the periodic table as an organizing principle for the elements. At a more macroscopic level, the properties of matter topic area focuses on distinguishing between physical and chemical properties of matter and understanding the properties of mixtures and solutions and the properties of acids and bases. The study of chemical change focuses on the characteristics of chemical changes and the conservation of matter during chemical changes.

Composition of Matter

1. Structure of atoms and molecules:
   A. Describe atoms as composed of subatomic particles (i.e., negatively charged electrons surrounding a nucleus containing positively charged protons and neutrons with no charge).
   B. Describe the structure of matter in terms of particles (i.e., atoms and molecules) and describe molecules as combinations of atoms (e.g., H2O, O2, CO2).
2. Elements, compounds, and mixtures:
   A. Describe the differences among elements, compounds, and mixtures; differentiate between pure substances (i.e., elements and compounds) and mixtures (homogeneous and heterogeneous) on the basis of their formation and composition.
3. The periodic table of elements:
   A. Recognize that the periodic table is an arrangement of the known elements; recognize and

describe that the elements are arranged in order of the number of protons in the nuclei of the atoms of each element.

B. Recognize that an element's properties (e.g., metal or non-metal, reactivity) can be predicted from its location in the periodic table (i.e., row, or period, and column, or group/family) and that elements in the same group have some properties in common.

Properties of Matter

1. Physical and chemical properties of matter:
   A. Distinguish between physical and chemical properties of matter.
   B. Relate uses of materials to their physical properties (e.g., melting point, boiling point, solubility, thermal conductivity).
   C. Relate uses of materials to their chemical properties (e.g., tendency to rust, flammability).
2. Physical and chemical properties as a basis for classifying matter:
   A. Classify substances according to physical properties that can be demonstrated or measured (e.g., density, melting or boiling point, solubility, magnetic properties, electrical or thermal conductivity).
   B. Classify substances according to their chemical properties (e.g., reactivity, flammability).
3. Mixtures and solutions:
   A. Explain how physical methods can be used to separate mixtures into their components.
   B. Describe solutions in terms of substance(s) (i.e., solid, liquid, or gas solutes) dissolved in a solvent and relate the concentration of a solution to the amounts of solute and solvent present.
   C. Explain how temperature, stirring, and surface area in contact with the solvent affect the rate at which solutes dissolve.
4. Properties of acids and bases:
   A. Recognize everyday substances as acids or bases based on their properties (e.g., acids have pH less than 7; acidic foods usually have a sour taste; bases usually do not react with metals; bases feel slippery).
   B. Recognize that both acids and bases react with indicators to produce different color changes.
   C. Recognize that acids and bases neutralize each other.

Chemical Change

1. Characteristics of chemical changes:
   A. Differentiate chemical from physical changes in terms of the transformation (reaction) of one or more pure substances (reactants) into different pure substances (products).
   B. Identify and describe evidence (i.e., temperature changes, gas production, precipitate formation, color change, or light emission) that a chemical change has taken place.

2. Matter and energy in chemical reactions:
   A. Recognize that matter is conserved during a chemical reaction and that all of the atoms present at the beginning of the reaction are present at the end of the reaction, but they are rearranged to form new substances.
   B. Recognize that some chemical reactions release energy (heat) while others absorb it, and classify common chemical reactions (e.g., burning, neutralization, the mixing of substances in a chemical cold pack) as either releasing heat or absorbing energy (heat).
   C. Recognize that chemical reactions occur at different rates and that the rate of reaction can be affected by changing the conditions under which the reaction is taking place (i.e., surface area, temperature, and concentration).
3. Chemical bonds:
   A. Recognize that a chemical bond results from the attraction between atoms in a compound and that the atoms' electrons are involved in this bonding.

Physics

As in the chemistry domain, students' study of physics at the eighth grade extends beyond understanding the scientific basis of common everyday observations to learning many of the central physics concepts that are needed for understanding practical applications of physics or for undertaking advanced study later in their education. The physics domain includes five topic areas:

- Physical states and changes in matter
- Energy transformation and transfer
- Light and sound
- Electricity and magnetism
- Motion and forces

Eighth grade students are expected to be able to describe processes involved in changes in the state of matter and relate states of matter to the distance and movement among particles. They also should be able to identify different forms of energy, describe simple energy transformations, apply the principle of conservation of total energy in practical situations, and understand the difference between thermal energy (heat) and temperature. Students at this level also are expected to know some basic properties of light and sound, relate these properties to observable phenomena, and solve practical problems involving the behavior of light and sound. In the topic area of electricity and magnetism, students should be familiar with the electrical conductivity of common materials, current flow in electric circuits, and the difference between simple series and parallel circuits. They also should be able to describe properties and uses of permanent magnets and electromagnets. Students' understanding of motion and forces should include knowing general types and characteristics of forces and how simple machines function. They should understand the concepts of pressure and density and be able to predict qualitative changes in motion based on the forces acting on an object.

Physical States and Changes in Matter

1. Motion of particles in solids, liquids, and gases:
   A. Recognize that atoms and molecules in matter are in constant motion and recognize the differences in relative motion and distance between particles in solids, liquids, and gases; apply knowledge about the movement of and distance between atoms and molecules to explain the physical properties of solids, liquids, and gases (i.e., volume, shape, density, and compressibility).
   B. Relate changes in temperature of a gas to changes in its volume and/or pressure and changes in the average speed of its particles; relate expansion of solids and liquids to temperature change in terms of the average spacing between particles.
2. Changes in states of matter:
   A. Describe changes of state (i.e., melting, freezing, boiling, evaporation, condensation, and sublimation) as resulting from an increase or decrease of thermal energy; explain that mass remains constant during changes of state.
   B. Relate the rate of change of state to physical factors (e.g., surface area, the temperature of the surroundings).

Energy Transformation and Transfer

1. Forms of energy and the conservation of energy:
   A. Identify different forms of energy (e.g., kinetic, potential, light, sound, electrical, thermal, chemical).
   B. Describe the energy transformations that take place in common processes (e.g., combustion in an engine to move a car, photosynthesis, the production of hydroelectric power); recognize that the total energy of a closed system is conserved.
2. Thermal energy transfer and thermal conductivity of materials:
   A. Recognize that temperature remains constant during melting, boiling, and freezing, but thermal energy increases or decreases during a change of state.
   B. Relate the transfer of thermal energy from an object or an area at a higher temperature to one at a lower temperature to cooling and heating; recognize that hot objects cool off and cold objects warm up until they reach the same temperature as their surroundings.
   C. Compare the relative thermal conductivity of different materials.

Light and Sound

1. Properties of light:
   A. Describe or identify basic properties of light (i.e., speed; transmission through different media; reflection, refraction, absorption, and splitting of white light into its component colors); relate the apparent color of objects to reflected or absorbed light.
   B. Solve practical problems involving the reflection of light from plane mirrors and the formation of shadows; interpret simple ray diagrams to identify the path of light.

2. Properties of sound:
   A. Describe or identify some basic properties of sound (i.e., is a wave phenomenon caused by vibrations, is characterized by loudness (amplitude) and pitch (frequency), requires a medium for transmission, is reflected and absorbed by surfaces, and has a relative speed through different media, which is always slower than light).
   B. Relate common phenomena (e.g., echoes, hearing thunder after seeing lightning) to the properties of sound.

Electricity and Magnetism

1. Conductors and the flow of electricity in electrical circuits:
   A. Classify materials as electrical conductors or insulators; identify electrical components or materials that can be used to complete circuits.
   B. Identify diagrams representing complete circuits.
2. Properties and uses of permanent magnets and electromagnets:
   A. Relate properties of permanent magnets (i.e., two opposite poles, attraction/repulsion, and strength of the magnetic force varies with distance) to uses in everyday life (e.g., a directional compass).
   B. Describe the properties that are unique to electromagnets (i.e., the strength varies with current, number of coils, and type of metal in the core; the magnetic attraction can be turned on and off; and the poles can switch) and relate properties of electromagnets to uses in everyday life (e.g., doorbell, recycling factory).

Motion and Forces

1. Motion:
   A. Recognize the speed of an object as change in position (distance) over time and acceleration as change in speed over time.
2. Common forces and their characteristics:
   A. Describe common mechanical forces (e.g., normal, friction, elastic, buoyant); recognize and describe weight as a force due to gravity.
   B. Recognize that forces have strength and direction; recognize that for every action force there is an equal and opposite reaction force; recognize and describe the difference in the force of gravity on an object when it is located on different planets (or moons).
3. Effects of forces:
   A. Describe the functioning of simple machines (e.g., levers, inclined planes, pulleys, gears).
   B. Explain floating and sinking in terms of density differences and the effect of buoyant force.
   C. Describe pressure in terms of force and area; describe effects related to pressure (e.g., water pressure increasing with depth, a balloon expanding when inflated).

D. Predict qualitative one-dimensional changes in motion (speed and direction) of an object based on the forces acting on it; recognize and describe how the force of friction affects motion (e.g., the contact area between surfaces can increase friction and impede motion).

Earth Science

Topics covered in the teaching and learning of Earth science draw on the fields of geology, astronomy, meteorology, hydrology, and oceanography, and are related to concepts in biology, chemistry, and physics. Although separate courses in Earth science covering all of these topics are not taught in all countries, it is expected that understandings related to Earth science topic areas will have been included in a science curriculum covering the physical and life sciences or in separate courses such as geography and geology. The *TIMSS 2023 Science Framework* identifies the following topic areas that are universally considered to be important for students at the eighth grade to understand as they learn about the planet on which they live and its place in the universe:

- Earth's structure and physical features
- Earth's processes, cycles, and history
- Earth's resources, their use, and conservation
- Earth in the Solar System and the universe

Eighth grade students are expected to have some general knowledge about the structure and physical features of Earth, including Earth's structural layers, and the atmosphere. Students also should have a conceptual understanding of processes, cycles, and patterns, including geological processes that have occurred over Earth's history, the water cycle, and patterns of weather and climate. Students should demonstrate knowledge of Earth's resources and their use and conservation, and relate this knowledge to practical solutions to resource management issues. At this level, the study of Earth and the Solar System includes understanding how observable phenomena relate to the movements of Earth and the Moon, and describing the features of Earth, the Moon, and other planets.

Earth's Structure and Physical Features

1. Earth's structure and physical characteristics:
   A. Describe the structure of the Earth (i.e., crust, mantle, inner core, and outer core) and the physical characteristics of these distinct parts.
   B. Describe the distribution of water on Earth in terms of its physical state (i.e., ice, water, and water vapor), and fresh versus salt water.
2. Components of Earth's atmosphere and atmospheric conditions:
   A. Recognize that Earth's atmosphere is a mixture of gases; identify the relative abundance of its main components (i.e., nitrogen, oxygen, water vapor, and carbon dioxide), relate these components to everyday life processes involving oxygen, water vapor, and carbon dioxide (e.g., human lung function, photosynthesis).
   B. Relate changes in atmospheric conditions (i.e., temperature and pressure) to changes in altitude.

Earth's Processes, Cycles, and History

1. Geological processes:
   A. Describe the general processes involved in the rock cycle (e.g., the cooling of lava, heat and pressure transforming sediment into rock, weathering, erosion).
   B. Identify or describe changes to Earth's surface (e.g., mountain building), resulting from major geological events (e.g., glaciation, the movement of tectonic plates and subsequent earthquakes and volcanic eruptions).
   C. Explain the formation of fossils and fossil fuels; use evidence from the fossil record to explain how the environment has changed over long periods of time.
2. Earth's water cycle:
   A. Describe the processes in Earth's water cycle (i.e., evaporation, condensation into clouds, transportation, and precipitation) and recognize the Sun as the source of energy for the water cycle.
   B. Describe the role of cloud movement and water flow in the circulation and renewal of fresh water on Earth's surface.
3. Weather and climate:
   A. Distinguish between weather (i.e., day-to-day variations in temperature, humidity, precipitation in the form of rain or snow, clouds, and wind) and climate (i.e., long-term typical weather patterns in a geographic area).
   B. Interpret data or maps of weather patterns to identify climate types; relate the climate and seasonal variations in weather patterns to global and local factors (e.g., latitude, altitude, geography).
   C. Identify or describe evidence for climate changes (e.g., changes related to ice ages, changes related to global warming).

Earth's Resources, Their Use and Conservation

1. Managing Earth's resources:
   A. Provide examples of Earth's renewable and nonrenewable resources.
   B. Discuss advantages and disadvantages of different energy sources (e.g., sunlight, wind, flowing water, geothermal, oil, coal, gas, nuclear).
   C. Describe methods of conservation of Earth's resources and methods of waste management (e.g., reduce, reuse, recycle).
2. Land and water use:
   A. Explain how common methods of land use (e.g., farming, logging, mining) can affect land and water resources.
   B. Explain the importance of water conservation, and describe methods for ensuring that fresh water is available for human activities (e.g., desalination, purification).

Earth in the Solar System and the Universe

1. Observable phenomena on Earth resulting from movements of Earth and the Moon:
   A. Describe the effects of the Earth's annual revolution around the Sun, given the tilt of its axis (e.g., different seasons, different constellations visible at different times of the year).
   B. Recognize that tides are caused by the gravitational pull of the Moon, and relate phases of the Moon and eclipses to the relative positions of Earth, the Moon, and the Sun.
2. The Sun, stars, Earth, Moon, and planets:
   A. Recognize that the Sun is a star and provides light and heat to each member of the Solar System; explain that the Sun and other stars produce their own light, but that other members of the Solar System are visible because of light reflected from the Sun.
   B. Compare and contrast certain physical features of Earth with those of the Moon and other planets (e.g., presence and composition of an atmosphere, average surface temperature, presence of water, mass, gravity, distance from the Sun, period of revolution and rotation, ability to support life); recognize that the force of gravity keeps planets and moons in their orbits.

Science Cognitive Domains—Fourth and Eighth Grades

The cognitive dimension is divided into three domains that describe the thinking processes students are expected to engage in when encountering the science items developed for TIMSS 2023. The first domain, *knowing*, addresses the student's ability to recall, recognize, describe, and provide examples of facts, concepts, and procedures that are necessary for a solid foundation in science. The second domain, *applying*, focuses on using this knowledge to compare, contrast, and classify groups of objects or materials; relating knowledge of a science concept to a specific context; generating explanations; and solving practical problems. The third domain, *reasoning*, includes using evidence and science understanding to analyze, synthesize, and generalize, often in unfamiliar situations and complex contexts.

These three cognitive domains are used at both grades, however, the target percentages for each domain vary between fourth and eighth grade in accordance with the increased cognitive ability, instruction, experience, and breadth and depth of understanding of students at the higher grade level. The percentage of items that involve knowing is higher at the fourth grade compared to the eighth grade, while the percentage of items that ask students to engage in reasoning is higher at the eighth grade compared to the fourth grade. While there is some hierarchy in the thinking processes across the three cognitive domains (from knowing to applying to reasoning), each cognitive domain contains items representing a full range of difficulty. Exhibit 2.4 shows the target percentages in terms of assessment time for each of the three cognitive domains at the fourth and eighth grades.

Exhibit 2.4: Target Percentages of the TIMSS 2023 Science Assessment Devoted to Cognitive Domains at the Fourth and Eighth Grades

Cognitive Domains	Percentages	
	Fourth Grade	Eighth Grade
Knowing	40%	35%
Applying	40%	35%
Reasoning	20%	30%

For the fourth and eighth grades, each content domain includes items developed to address each of the three cognitive domains. For example, the life science content domain includes knowing, applying, and reasoning items, as do the other content domains. The following sections further describe the thinking processes that define the cognitive domains.

Knowing

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

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

Applying

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

Compare/ Contrast/ Classify	Identify or describe similarities and differences between groups of organisms, materials, or processes; and distinguish, classify, or sort individual objects, materials, organisms, and processes based on characteristics and properties.
Relate	Relate knowledge of an underlying science concept to an observed or inferred property, behavior, or use of objects, organisms, or materials.
Interpret Models	Use a diagram or other model to demonstrate knowledge of science concepts, to illustrate a process, cycle, relationship, or system, or to find solutions to science problems.

Interpret Information	Use knowledge of science concepts to interpret relevant textual, tabular, pictorial, and graphical information.
Explain	Provide or identify an explanation for an observation or a natural phenomenon using a science concept or principle.

Reasoning

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

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

Science Practices in TIMSS 2023

Scientific knowledge is developed through rigorous investigation of the natural world using key science practices to answer questions and solve problems. Students of science must become proficient at these practices to develop knowledge and understanding of scientific concepts. Engaging in science practices also enables students to develop an understanding of how the scientific enterprise is conducted and, by extension, understand and appreciate the nature of science and scientific knowledge. Science practices, which are fundamental to all science disciplines, incorporate skills from daily life and school studies that students use in a systematic way to conduct scientific inquiry.

TIMSS 2023 assesses a range of science practices in the context of the TIMSS science content objectives and cognitive domain areas. While these practices are presented below as an ordered list, the complexity of scientific inquiry means that the process of employing them is, in reality, most often nonlinear and carried out in an iterative fashion.

Practice 1: Asking questions based on observations and theories

Observations of phenomena in the natural world, when considered together with scientific theory, often lead to scientific questions. These questions are used to formulate testable hypotheses that guide the development of investigations designed to help answer them.

Practice 2: Designing investigations and generating evidence

Testing hypotheses requires designing and executing systematic investigations and controlled experiments in order to generate evidence to support or refute the hypothesis. Scientists create models to relate their theories to properties that can be observed or measured in order to determine the evidence to be gathered, the equipment and procedures needed to collect the evidence, and the measurements to be recorded. They make choices about the factors to include and exclude from their models.

Practice 3: Working with data

Once data are collected, scientists summarize it in various types of visual displays and describe or interpret patterns in the data and explore relationships between variables.

Practice 4: Answering research questions

Scientists use evidence from observations and investigations, together with their theories and models, to support or refute hypotheses and answer questions. They also recognize limitations of their investigations, evidence, and answers.

Practice 5: Making arguments from evidence

Scientists use evidence together with science knowledge to construct explanations, justify and support the reasonableness of their explanations and conclusions, and extend their conclusions to new situations.

TIMSS assesses the science practices primarily with the science PSIs, in which students conduct extended investigations and inquiries, and in doing so engage in one or more of the science practices. However, regular items in TIMSS can also incorporate one or more of the science practices.

References

1 Kelly, D., Centurino, V. A. S., Martin, M. O., & Mullis, I. V. S. (2020). *TIMSS 2019 encyclopedia: Education policy and curriculum in mathematics and science*. Retrieved from Boston College, TIMSS & PIRLS International Study Center website: https://timssandpirls.bc.edu/timss2019/encyclopedia/

2 Kelly, D., Centurino, V. A. S., Martin, M. O., & Mullis, I. V. S. (2020). *TIMSS 2019 encyclopedia: Education policy and curriculum in mathematics and science*. Retrieved from Boston College, TIMSS & PIRLS International Study Center website: https://timssandpirls.bc.edu/timss2019/encyclopedia/

CHAPTER 3

TIMSS 2023 Context Questionnaire Framework

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Overview

In addition to measuring trends in students' mathematics and science achievement, TIMSS collects important information about contexts for student learning. Educational research, including previous cycles of TIMSS, has long demonstrated substantive relationships among learning environments and student achievement across countries. Students with more opportunities to learn and more supportive learning environments consistently have higher mathematics and science achievement than those who do not. While the indicators and components of these factors may shift (particularly with the ongoing introduction of new technological tools and approaches for digital learning), these relationships have remained stable over time.

Previous cycles of the TIMSS assessment have provided high-quality measures of mathematics and science achievement for fourth and eighth grade students, as well as extensive information about those students' in- and out-of-school experiences. These data are an important resource for research on improving mathematics and science education. TIMSS 2023 builds upon this foundation, collecting information that allows for measurement of contextual factors that have remained relevant over time, while also addressing new areas of research and policy relevance.

The *TIMSS 2023 Context Questionnaire Framework* outlines the information to be collected in the TIMSS 2023 Questionnaires with brief rationales and selected references. It begins with an overview of the questionnaires and a brief summary of their development process. A discussion of the analytic approach employed in the construction of scales for TIMSS 2023 follows this introduction. Similar to previous TIMSS cycles, the bulk of the framework is organized by five areas of influence on students' mathematics and science achievement: home contexts, school contexts, classroom contexts, student attributes, and national contexts.

The Data Collection Instruments

TIMSS 2023 includes four context questionnaires with the fourth grade assessment, and three with the eighth grade assessment. Each is described below:

- The Home Questionnaire, entitled the Early Learning Survey, is completed by the parents or primary caregivers of fourth grade students participating in TIMSS 2023. This questionnaire collects information about students' home contexts, including participation in early childhood education, early literacy and numeracy activities, language(s) spoken at home, and parents'/guardians' educational and professional backgrounds. The questionnaire requires about 20 minutes to complete.

- The School Questionnaire is completed by the principal of each participating school sampled for TIMSS 2023. This questionnaire collects information about school characteristics, including student demographics and school resources. The questionnaire requires about 30 minutes to complete and is administered as a part of TIMSS 2023 for both the fourth and eighth grades.
- The Teacher Questionnaire is completed by students' mathematics and science teachers. This is typically one classroom teacher for fourth grade students and separate mathematics and science teachers for eighth grade students. This questionnaire asks about classroom contexts, such as instructional approaches and integration of technology, as well as teacher characteristics, including teacher preparation, career satisfaction, and professional development. The questionnaire takes about 35 minutes to complete.
- The Student Questionnaire is completed by all fourth and eighth grade students participating in TIMSS 2023 following the mathematics and science assessment. This questionnaire collects information about students' home environment, such as resources for learning, as well as students' experiences in school (e.g., sense of school belonging, bullying) and attitudes towards mathematics and science. The questionnaire takes up to 30 minutes to complete. Two versions of this questionnaire are provided at the eighth grade: one for students who take science as an integrated subject and one for students enrolled in separate science subjects (biology, chemistry, physics, and earth science).

In addition to the four questionnaires described above, TIMSS 2023 collects information about national contexts shaping mathematics and science education. As with previous cycles of TIMSS, representatives from each country provide information for the *TIMSS 2023 Encyclopedia*. This includes the completion of a curriculum questionnaire about mathematics and science education policies and curricula, as well as contribution of a country-specific encyclopedia chapter providing additional qualitative information about these topics.

The Development Process

The TIMSS questionnaires focus on policy relevant and potentially malleable attributes of students' learning contexts that can aid interpretation of mathematics and science achievement across and within countries.

The TIMSS and PIRLS International Study Center works with the TIMSS 2023 Questionnaire Item Review Committee (QIRC) and National Research Coordinators (NRCs) to update the context questionnaire framework and questionnaires for each successive TIMSS assessment. This includes adding new topics, refining measurement of existing topics, and deleting topics that are no longer useful. Development for TIMSS 2023 began in January 2021, when staff at the TIMSS and PIRLS International

Study Center drafted an updated context questionnaire framework and suggested revisions for each of the questionnaires. The TIMSS 2023 QIRC reviewed the updated framework at its first meeting in March 2021. This was followed by an online asynchronous review by NRCs prior to publication. The questionnaire instruments were reviewed at the second QIRC meeting in August 2021, as well as by the NRCs prior to field testing. Following the field test, the QIRC and NRCs reviewed and finalized the questionnaires in 2022 for the TIMSS 2023 data collection.

The Analytic Approach

Since 2011, TIMSS has used item response theory methods to develop background scales measuring constructs that are related to students' mathematics and science achievement.[1] These scales summarize select questionnaire data more reliably than the responses to individual questions and enhance the interpretability of relationships with achievement. All four of the TIMSS 2023 questionnaires (Home, School, Teacher, and Student) include several scales. Through each assessment cycle, work continues on improving the content and measurement properties of the context questionnaire scales. For TIMSS 2023, this includes evaluating measurement invariance of the context scales across countries, use of the generalized partial credit model[2] for scale calibration, and exploring more complex types of reporting to better capture the interrelatedness of unidimensional constructs measured in individual scales. Constructs that TIMSS 2023 intends to measure utilizing scales are noted throughout the remainder of this framework, along with the names of the intended scales.

Home Contexts

Home Environment Support

Home Resources

Parents' or guardians' socioeconomic status has long had consistent relationships with students' academic achievement.[3,4,5] This pattern holds across both developed and developing countries, and socioeconomic academic achievement gaps have grown within the past few decades.[6,7] Socioeconomic status is often indicated through proxy variables, including parental level of education and occupation. TIMSS expands this classic definition by also collecting information about various resources for learning that are available in the home, such as the number of books, a quiet place to do schoolwork, and access to the internet and various digital devices.

For fourth grade students, TIMSS collects and summarizes information about home resources through the *Home Resources for Learning* scale, which is created from items in the Home and Student Questionnaires. The eighth grade counterpart is the *Home Educational Resources* scale, which is created from items in the Student Questionnaire.

Language(s) Spoken at Home

Internationally, there are many reasons why children might speak a different language at home than they do in school. Some countries have numerous national languages, and immigrant families may be unfamiliar with a given national language. Some parents may also prize multilingualism and deliberately expose their children to more than one language at home. Learning mathematics or science in a language other than that which is primarily spoken at home can pose difficulties for students because they are learning both curricular concepts and a less familiar or unfamiliar language.[8,9]

For fourth grade students, TIMSS collects information about the language(s) spoken in the home through both the Home and Student Questionnaires. For eighth grade students, this information is collected through the Student Questionnaire.

Expectations for Further Education

Parents and guardians have expectations for their children's educational attainment. These adults can play a key role in setting educational goals for their children, as well as in teaching their children about the value of education.[10,11] Research has shown positive relationships between these expectations and academic achievement at various levels of schooling.[12,13,14]

TIMSS collects information about parent/guardian expectations for their children's education through the Home Questionnaire. Parents are asked to indicate the level of education they expect their child to attain. Eighth grade students are asked to indicate the level of education they expect themselves to attain in the Student Questionnaire.

Early Learning Experiences

Early Literacy and Numeracy Activities

Considerable research has documented the importance of early childhood learning activities and their relationships with student achievement and other education outcomes.[15,16,17,18] Early numeracy activities at home may influence later mathematics performance not only directly, but also through the enhancing students' mathematics self-efficacy.[19] Engaging children in early numeracy activities can also stimulate their interest in mathematics and enhance development of numeracy skills.[20,21] Past analyses of TIMSS and PIRLS data have shown that both early numeracy and literacy activities are related to children's fourth grade achievement in mathematics, science, and reading.[22] The association between mathematics and science achievement and literacy skills may be attributable to the fact that students' understanding of mathematics and science tasks typically requires reading.[23]

TIMSS collects and summarizes information about early literacy and numeracy activities through the *Early Literacy and Numeracy Activities Before Primary School* scale. This is complemented by information on how well students could perform different literacy and numeracy tasks upon school entry in the *Could Do Early Literacy and Numeracy Tasks When Beginning Primary School* scale. Both scales are included in the Home Questionnaire; these data are only available for fourth grade students.

Preprimary Education

Research has shown the importance of preprimary education (e.g., preschool, kindergarten) in influencing later academic outcomes.[24,25] High-quality preprimary education and other early childhood interventions can be especially beneficial for students from disadvantaged socioeconomic backgrounds.[26,27]

TIMSS gathers information about the types of preprimary education programs in which fourth grade students have participated, as well as the duration of their enrollment in these programs through the Home Questionnaire.

The COVID-19 Pandemic

Staying Home from School

The COVID-19 pandemic has been an immense disruption to students' educational experiences. It is impossible to predict what the state of the pandemic will be when students participate in TIMSS 2023; however, TIMSS still aims to gather some information about school that students missed because of COVID-19 disruptions. Parents are asked to indicate the amount of time during various school years (beginning with the 2019 – 2020 school year) where their child had to stay home from school for reasons related to COVID-19.

At-Home Learning

TIMSS also aims to gather information about the specific learning resources that were available to fourth grade students while they were home from school because of the COVID-19 pandemic. Parents are asked to indicate the resources their child's school provided during the pandemic. Parents are also asked if they provided particular learning resources for their child, and if they believe their child's learning progress has been negatively impacted by the COVID-19 pandemic.

School Contexts

School Characteristics

Size and Geographic Location

Internationally, schools vary in size and are located in a variety of different geographical areas (e.g., urban, suburban, rural). Smaller schools can provide more intimate learning environments, which may be beneficial for students.[28] Smaller schools in rural areas may also face particular challenges, such as lower budgets and difficulty recruiting highly qualified teachers; however, there is still great diversity in resources among rural schools.[29,30,31] Depending on the country, schools in urban or suburban areas may also have access to more educational resources outside the school (e.g., museums, libraries, bookstores) than schools in rural areas.

TIMSS obtains information about school size and geographic area through the School Questionnaire for the both fourth and eighth grades.

Composition of the Student Body

Socioeconomic Background

The relationship between socioeconomic composition of a school's student body and individual student achievement has been of sustained interest since the Coleman Report.[32,33,34] There is evidence that students from disadvantaged backgrounds may have higher achievement if they attend schools where the majority of students are from advantaged backgrounds, which some have attributed to peer effects.[35,36,37]

In some countries, schools with high proportions of disadvantaged students have difficulty attracting highly qualified teachers.[38,39]

TIMSS obtains information about the socioeconomic backgrounds of students within schools through the School Questionnaire for both fourth and eighth grades, which asks principals to report the percentages of students from economically disadvantaged and affluent homes.

Languages Spoken in the School

Schools vary in their linguistic diversity. Students who speak a language other than the primary language of instruction may require additional support and resources to support their academic success, and schools vary in the resources and support they provide.

TIMSS obtains information about the percentage of students for whom the language of the TIMSS assessment is their native language through the School Questionnaire for both fourth and eighth grades.

Literacy and Numeracy Skills of Entering Student Body

Students who enter the first grade of primary school with literacy and numeracy skills have a stronger foundation for formal mathematics and science education. The TIMSS 2023 School Questionnaire asks principals to estimate the percentage of students who can do various literacy and numeracy tasks when they enter first grade, including reading words and sentences, recognizing written numbers, and doing simple arithmetic. This information is only collected for the fourth grade and is summarized in the *Schools Where Students Enter the Primary Grades with Literacy and Numeracy Skills* scale.

School Resources

Resources for Mathematics and Science Instruction

Adequate facilities and sufficient instructional resources are important for maintaining favorable school learning environments.[40] Although "adequacy" of resources can be relative, the supply and quality of school resources have been shown to be critical for quality instruction.[41,42] Important resources include well-maintained school facilities, qualified staff, and access to adequate technologies (e.g., computers, tablets, software) for instruction.

TIMSS conceptualizes school resources as both general and subject-specific, collecting information on general resources such as school building facilities and instructional space or materials, as well as resources specific to mathematics and science instruction. These subject-specific resources include teachers with specialized training in mathematics or science, relevant library resources for mathematics and science, and materials for carrying out hands-on science experiments or investigations. The *Instruction Affected by Mathematics Resource Shortages – Principals' Reports* and *Instruction Affected by Science Resource Shortages – Principals' Reports* scales summarize this information for both the fourth and eighth grades.

School Climate

School Emphasis on Academic Success

A school atmosphere of academic optimism and emphasis on student success can contribute positively to overall school climate, and academic achievement.[43,44,45] Such an atmosphere includes an overarching emphasis on academics, collective efficacy in promoting academic performance, and trust among a school's staff, students, and parents.[46,47]

TIMSS collects information about school emphasis on academic success through both the School and Teacher Questionnaires for the fourth and eighth grades and summarizes this information in the *School Emphasis on Academic Success – Principals' Reports* and *Teachers' Reports* scales.

School Emphasis on Mathematics and Science

Schools can vary in the degree to which they emphasize mathematics and science. Some schools may offer special initiatives to promote student interest in mathematics and science, such as after-school activities or targeted exposure to careers utilizing mathematics and science. TIMSS collects information about these kinds of initiatives through the eighth grade School Questionnaire.

Teacher Job Satisfaction and Challenges

Fostering teacher job satisfaction is important in retaining qualified teachers in the classroom.[48] Research has shown that teachers who remain in the classroom are often motivated by collaboration with colleagues, strong principal leadership, and meaningful relationships with students.[49,50,51] Conversely, challenges that teachers encounter may lead them to leave the classroom or diminish the quality of instruction they provide. Such challenges include large class sizes, lack of planning time, and keeping up with curricular changes.

TIMSS gathers information about both fourth and eighth grade teachers' job satisfaction through the *Teacher Job Satisfaction* scale. Several questions in the Teacher Questionnaire also ask teachers to indicate the degree to which they experience various challenges.

Students' Sense of School Belonging

Students' sense of school belonging, also referred to as school connectedness, has been found to contribute to general well-being and academic achievement.[52,53,54] Students with a strong sense of school belonging feel safe at school, enjoy school, and have good relationships with their teachers and peers.

TIMSS collects information about fourth and eighth grade students' sense of school belonging through the *Students' Sense of School Belonging* scale on the Student Questionnaire.

Parents' Perceptions of Their Child's School

Parents and guardians can vary in their perceptions of their children's schools, although research shows that many are satisfied with the schools their children attend.[55,56] TIMSS collects this information for the fourth grade only via the *Parent's Perceptions of Their Child's School* scale.

School Discipline, Safety, and Bullying

School Discipline and Safety

School safety is an important prerequisite for student achievement in many countries.[57,58] Respect for individual students and teachers, a safe and orderly environment, and constructive interactions among teachers and administrators are all associated with higher student achievement.[59,60] Research shows that schools where rules are clear and enforced fairly tend to have atmospheres of greater discipline and safety.[61]

TIMSS collects information regarding school discipline and safety from both principals and teachers at the fourth and eighth grade. These data are summarized in the *School Discipline – Principals' Reports* scale and the *Safe and Orderly Schools – Teachers' Reports* scale.

Student Bullying

Bullying is a unique aspect of school safety because it involves repeated aggressive behavior intended to intimidate or harm students. Bullying can take a variety of forms, both mental and physical, and may occur in person or virtually. Cyberbullying through both online games and social media has become more prevalent as access to digital devices among children has increased.[62,63,64] Experiencing in-person or cyberbullying causes distress to victims and is associated with poorer academic achievement.[65,66,67]

TIMSS collects information regarding the frequency of student bullying from fourth and eighth grade students and summarizes this information in the *Student Bullying* scale for each grade.

Principal Preparation and Years of Experience

Principals act as leaders in schools by overseeing school staff, students, and the school environment. Research has shown that strong principal leadership can foster student achievement by creating an atmosphere of collective efficacy through a positive school climate and trust among teachers.[68,69] Additionally, rapid principal turnover can lead to decreases in student achievement.[70,71]

TIMSS collects information about principal preparation and years of experience through the School Questionnaire for both the fourth and eighth grades.

The COVID-19 Pandemic

School Closure and Remote Learning

TIMSS 2023 also aims to collect information regarding the COVID-19 pandemic at the school level. Principals are asked to indicate how long their schools were fully closed for in-person instruction because of the pandemic during relevant school years (beginning with the 2019 – 2020 school year). They are also asked to indicate whether or not specific resources related to remote learning were provided for students and teachers during these times.

Classroom Contexts

Teacher Characteristics

Preparation and Years of Experience

Quality teacher preparation is critical for effective teaching.[72] Teachers' subject-specific knowledge can have positive impacts on student achievement in conjunction with their pedagogical skills.[73] Teaching experience is also important for teacher development, especially in the early years of teaching.[74,75] Research has shown that teachers continue to develop pedagogical skills after five years of experience, which can positively impact student achievement.[76]

TIMSS collects information about teacher preparation, including the highest level of education completed and any subject-matter specializations, through the Teacher Questionnaire for both the fourth and eighth grades. Teachers are also asked to indicate the number of years they have spent teaching.

Professional Development

Professional development is an important component of continuing education for the teaching profession, and teacher participation in effective professional development activities can lead to positive changes in teacher practices.[77] Effective professional development engages teachers through concrete tasks, is sustained and ongoing, and provides teachers space to reflect on their teaching.[78] Teachers are more likely to participate in professional development when they are encouraged and supported to do so.[79]

TIMSS obtains teacher professional development information through the Teacher Questionnaire for both the fourth and eighth grades. Teachers are asked to indicate topics for which they have participated in professional development, as well as those for which they feel they need professional development.

Mathematics and Science Instruction

Instructional Time

The amount of instructional time that teachers have to teach the mathematics and science curricula is an important aspect of curriculum implementation. Research has found instructional time to be related to student achievement, although such relationships depend on how efficiently and effectively instructional time is used.[80,81]

TIMSS gathers information about instructional time through the Teacher Questionnaire for fourth and eighth grades. Teachers indicate the number of minutes spent on mathematics and science instruction each week with the students participating in the TIMSS assessment.

Instructional Strategies

Teachers vary in their instructional strategies, both internationally and within countries.[82] Effective instruction in mathematics can include practices such as asking students to explain their answers or purposefully practice mathematical procedures.[83,84] Hands-on activities and experiments can be helpful in promoting students' understanding of science, although research suggests that such activities should be appropriately scaffolded and supported.[85,86]

TIMSS obtains information about instructional practices in teaching mathematics and science through the Teacher Questionnaire for the fourth and eighth grades. Teachers indicate how often they perform or ask students to perform various activities during instruction, including working out practice mathematics problems or making observations about the world around them.

Instructional Clarity

Instructional clarity concerns students' perceptions of teachers' instructional strategies.[87] Teachers with a high degree of instructional clarity provide straightforward explanations of content and effectively monitor student understanding, employing a variety of pedagogical techniques as required.[88,89] Linking instruction to students' prior knowledge is also likely to increase instructional clarity.[90] Instructional clarity is also related to establishing a supportive classroom climate where teachers engage in practices such as providing helpful feedback and clearly addressing student questions.[91] Instructional clarity has been shown to have positive relationships with student achievement.[92]

TIMSS measures students' perceptions of their teachers' instructional clarity through the Student Questionnaire at the fourth and eighth grades as a complement to teachers' reports of their instructional strategies. Their responses are summarized in the *Instructional Clarity* scales for mathematics and science lessons. Eighth grade students enrolled in separate science subjects provide information for each subject in which they are enrolled.

Emphasis on Science Inquiry

Student inquiry is an important component of science education; however, its relationships with academic achievement are not necessarily straightforward.[93] Some research utilizing TIMSS data from past cycles suggests that frequency of inquiry may not be the most effective aspect to capture, as its relationship with achievement is not necessarily linear.[94] There are many aspects of scientific inquiry in which teachers can engage students, including the articulation of research questions or hypotheses, creating models and explanations, and effectively communicating results of investigations.[95]

TIMSS collects information about science inquiry emphasis and activities through the Teacher Questionnaire for the fourth and eighth grades. Science teachers indicate how often they ask students to carry out different types of investigations (e.g., open investigations of concepts, experiments with prescribed steps), as well as the degree to which they emphasize different aspects of the science inquiry process.

TIMSS Mathematics and Science Topics Taught

TIMSS collects information about teaching of the mathematics and science topics in the TIMSS 2023 assessment through the Teacher Questionnaire for fourth and eighth grade. Content exposure is an important component of students' opportunity to learn mathematics and science.[96,97] Teachers are asked to indicate whether specific topics or concepts have been covered in their own instruction, have been taught in previous years or schooling, or have not yet been taught.

Homework

Assignment of homework in mathematics and science varies both within and across countries, with some countries having policies that fourth grade students should not be assigned homework. The relationship between time spent on homework, types of homework assigned, and student achievement is not straightforward and may vary depending upon a particular country's context and policies.[98,99]

TIMSS collects information about homework through the Teacher Questionnaire for fourth and eighth grades, as well as the Student Questionnaire for eighth grade only. Teacher Questionnaire items ask how often homework is assigned and how homework is used in class, while the Student Questionnaire asks how often homework is assigned.

Classroom Assessment

Classroom assessment is an important component of teaching, serving both formative and summative functions.[100] Teachers have a number of ways to monitor student progress and achievement, including observing students as they work, asking students to answer questions during class, or administering written assessments. Results of these classroom assessments can help teachers engage with students and determine the best course of action during instruction. Clarifying or re-teaching concepts on the basis of a variety of ongoing classroom assessment strategies can improve student achievement.[101,102]

TIMSS gathers information about classroom assessment through the Teacher Questionnaire for the fourth and eighth grades. Teachers indicate the importance they place on various assessment strategies for gathering information about student learning, including observations, written assessments, and long-term projects.

Information Technology in the Classroom

Access to Digital Devices for Instruction

Access to digital devices is a necessary prerequisite for their use in instruction. Within and across countries, schools and classrooms vary in access to devices such as computers and tablets. TIMSS gathers information about access to digital devices during mathematics and science instruction through the Teacher Questionnaire for the fourth and eighth grades. Teachers indicate the type of access students have to digital devices, including school-owned devices shared among students and provisions for students to bring their own devices to school.

Uses of Digital Devices During Instruction

There are many ways that digital devices might be used in mathematics and science instruction. Teachers can utilize digital devices and other technologies to differentiate and personalize instruction for students, engage in classroom assessment, or promote exploration of concepts through games and activities.[103,104,105] Use of digital devices for instruction both within and outside of the classroom has also expanded considerably in response to the COVID-19 pandemic.

TIMSS obtains information about use of digital devices during mathematics and science instruction through the Teacher Questionnaire for the fourth and eighth grades. Teachers are asked to indicate how often they use digital devices for various instructional purposes, including simulated experiments and problem-solving activities.

Challenges Using Digital Devices During Instruction

TIMSS 2019 results highlighted integration of technology within mathematics and science instruction as a preferred area of professional development for teachers.[106] Research has shown that factors such as availability of professional development, on-site technological support, and teacher self-efficacy in working with technology can all impact use of digital devices in the classroom, and that the impacts of these factors varies internationally.[107,108,109] Using digital devices as part of effective instruction can depend on a number of factors beyond efficacy in using the devices. Teachers must meaningfully integrate digital devices in their lessons, as well as manage simultaneously both the devices and their instruction.

TIMSS obtains information about the challenges of integrating technology into mathematics and science instruction through the Teacher Questionnaire. Teachers indicate the extent to which lack of resources, difficulties in instructional management, or challenges meaningfully integrating devices into lessons limit their use of digital devices during instruction.

Classroom Climate

Classroom Management

Classroom management refers to noninstructional procedures that promote student learning and discourage disruptive behavior.[110] Although direct links between classroom management and student achievement are difficult to establish, some research suggests that effective classroom management has indirect, positive effects on student achievement.[111,112]

TIMSS obtains information on classroom management from fourth and eighth grade students. For students, this information is summarized in the *Disorderly Behavior During Mathematics or Science Lessons* scales. Eighth grade students enrolled in separate science subjects complete this scale for each subject in which they are enrolled.

Instruction Limited by Student Attributes

Attributes that students bring with them to the classroom can limit the impact of instruction. For example, research has shown that students lacking basic nutrition tend to have lower academic achievement.[113,114] Lack of sleep or prerequisite knowledge, as well as absences may negatively impact the effects of mathematics and science instruction.

TIMSS obtains information about these limiting factors through the Teacher and Student Questionnaires for the fourth and eighth grade. The Teacher Questionnaire contains items asking the extent to which teachers find their instruction limited by various student attributes and summarizes these responses in the *Classroom Teaching Limited by Students Not Ready for Instruction* scale. The Student Questionnaire asks students how often they feel tired or hungry when they are at school, as well as how often they are absent from school.

Student Attributes

Student Demographics

TIMSS collects basic student demographic information through the Student Questionnaire for both fourth and eighth grade. Students indicate their age, gender, and whether they were born in the country in which they are assessed.

Attitudes Toward Mathematics and Science

Liking Mathematics and Science

Students who enjoy mathematics and science find the subjects interesting and are likely to be more intrinsically motivated in mathematics and science classes. Intrinsic motivation influences behavior,[115] and students who like mathematics and science may have higher achievement and be more likely to choose courses in these subjects later in schooling.[116,117] These relationships can be reciprocal; students who do well in mathematics and science may be more likely to have positive attitudes towards the subjects.

TIMSS measures fourth and eighth grade students' liking of mathematics and science through the *Students Like Learning Mathematics* and *Students Like Learning Science* scales. For countries where eighth grade science is taught as separate subjects, students complete this scale for each of the science subjects in which they are enrolled.

Confidence in Mathematics and Science

Students tend to have distinct views of their abilities in different subjects, and their self-appraisal is often based on past experiences and how they see themselves compared with their peers.[118] Students who are confident in a particular subject persevere through challenging material because they believe they will ultimately succeed.[119] Additionally, anxiety or a lack of confidence in a subject is associated with lower achievement.[120,121]

TIMSS measures fourth and eighth grade students' confidence in mathematics and science through the *Students Confident in Mathematics* and *Students Confident in Science* scales. For countries where eighth grade science is taught as separate subjects, students complete this scale for each of the science subjects in which they are enrolled.

Valuing Mathematics and Science

Students who value mathematics and science are extrinsically motivated to learn these subjects because of future opportunities, such as entrance into desirable educational programs or a well-paying career. Some research has shown that such motivation is associated with choosing science courses later in schooling, particularly for students from disadvantaged backgrounds[122]. Additionally, students who articulate an interest in science careers in primary or early secondary school are more likely to actually pursue those careers.[123]

TIMSS measures students' valuing of mathematics and science for the eighth grade only using the *Students Value Mathematics* and *Students Value Science* scales.

Information Technology and Digital Devices

Use of Digital Devices

Students vary in their uses of digital devices, both at home and in school.[124] TIMSS collects this information through the Student Questionnaire for the eighth grade. Students indicate how often they use the internet for specific tasks, including accessing course materials, collaborating with classmates, or asking questions of teachers.

Digital Self-Efficacy

Although students participating in TIMSS 2023 have greater access to information technology and digital devices than past generations, it is a mistake to assume that they innately understand how they work.[125] Students vary in both their actual knowledge of digital devices, as well as their self-efficacy for using them.[126,127]

TIMSS collects information regarding fourth and eighth grade students' self-efficacy in the use of information technology through the *Digital Self-Efficacy* scale. Students indicate how well they can perform simple digital tasks, such as writing text, as well as more complex tasks, such as recognizing trustworthy websites and learning to use new apps or programs.

National Contexts

In every country, the educational system is embedded in a unique configuration of historical, economic, and language factors that combine to determine priorities in how the system is organized for teaching and learning. In addition to the more granular data described in the previous sections, TIMSS also gathers information on system-level characteristics that may contribute to students' learning of mathematics and science. Countries participating in TIMSS 2023 contribute information on many of these factors through chapters in the *TIMSS 2023 Encyclopedia*, along with information collected through the curriculum questionnaire. In particular, information collected on national contexts focuses on countries' organization of their education systems and their mathematics and science curricula. Specific curricular information is collected for both the fourth and eighth grades.

Organization of Education System

System for Preprimary Education

Even before they begin formal primary school, children receive considerable exposure to literacy, numeracy, and science as part of their preprimary educational experiences (e.g., preschool, kindergarten). Preprimary education is an area of investment for many countries. Research indicates that attending preprimary programs can have a positive impact on later academic outcomes.[128] The TIMSS curriculum questionnaire gathers information on the different types of early childhood and preprimary education available within countries.

Research has also shown that that the positive effects of preprimary education on later academic outcomes are dependent on the quality of the preprimary program.[129,130] TIMSS gathers information on any available curricular documents for early childhood and preprimary education, including provisions for socioemotional development as well as for the development of literacy and numeracy skills. This serves to contextualize the information on student participation in preprimary education that is collected through the Home Questionnaire.

Age of Entry and Retention Policies

Because TIMSS assesses students in the grades corresponding to the fourth and eighth years of formal schooling, policies about the age of entry into formal education (first year of primary school, ISCED Level 1) are important for understanding variation in achievement and students' ages within those grades across countries.[131] Countries' promotion and retention policies during different phases of schooling are also collected; research has shown that retention has negative relationships with student well-being and achievement, particularly in the short term.[132,133,134]

Number of Years of School

Although only fourth and eighth grade students participate in TIMSS, these grades are situated within a sequence of schooling that shapes the national context in which students learn. For this reason, TIMSS collects data on nationally mandated and provided years of education.

Language(s) of Instruction

Some countries have one commonly spoken language, while others are historically multilingual. Immigration has also increased the language diversity in many countries over time. TIMSS collects data on any official languages of instruction, as well as if mathematics and science instruction is typically presented to students in their native language.

Teacher and Principal Preparation

Information about the preparation of the teachers and principals whose students participate in TIMSS is collected through the Teacher and School Questionnaires; this is complemented by the information on the most typical preparation routes for teachers and principals within each country.

Mathematics and Science Curricula

Whether created at the national, provincial, community, or school level, curricular documents define and communicate the curriculum that specifies expectations for students in terms of the knowledge, skills, and attitudes to be developed or acquired through their formal mathematics and science education.

Mathematics and science curricula differ across countries and are constantly evolving, although there is some evidence of curricular convergence over time.[135] In mathematics, countries differ in the degree of emphasis placed on acquiring basic skills, memorizing rules, procedures, or facts, understanding mathematical concepts, applying mathematics to real life situations, and communicating or reasoning mathematically. In science, countries vary in the extent to which they focus on acquiring basic science facts, application of science concepts, formulating hypotheses and carrying out scientific investigations, and communicating scientific explanations. At the eighth grade, countries differ as to whether science is taught as a single subject or as separate science subjects (physics, chemistry, biology, and earth science).

TIMSS collects information on countries' coverage of the mathematics and science topics articulated in the *TIMSS 2023 Mathematics Framework* and *TIMSS 2023 Science Framework*, as well as any curricular specifications or mandates for incorporation of technology into instruction. Such information is essential for contextualizing the performance of each country's students on the TIMSS assessment.

References

1 Martin, M.O., Mullis, I.V.S., Foy, P., & Arora, A. (2012). Creating and interpreting the TIMSS and PIRLS 2011 context questionnaire scales. In M.O. Martin & I.V.S. Mullis (Eds.), *Methods and Procedures in TIMSS and PIRLS 2011* (pp. 1-11). Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

2 Muraki, E. (1992). A generalized partial credit model: Application of EM algorithm. *Applied Psychological Measurement, 16*, 159-176.

3 Dahl, G.B., & Lochner, L. (2012). The impact of family income on child achievement: Evidence from the earned income tax credit. *American Economic Review*, *102*(5), 1927–1956.

4 Davis-Kean, P.E. (2005). The influence of parent education and family income on child achievement: the indirect role of parental expectations and the home environment. *Journal of Family Psychology, 19*(2), 294-304.

5 Sirin, S.R. (2005). Socioeconomic status and academic achievement: A meta-analytic review of research. *Review of Educational Research, 75*(3), 417–453.

6 Chmielewski, A.K. (2019). The global increase in the socioeconomic achievement gap, 1964 to 2015. *American Sociological Review, 84*(3), 517-544.

7 Kim, S., Cho, H., & Kim. (2019). Socioeconomic status and academic outcomes in developing countries: a meta-analysis. *Review of Educational Research, 89*(6), 875-916.

8 Entorf, H., & Minoiu, N. (2005). What a difference immigration policy makes: A comparison of PISA scores in Europe and traditional countries of immigration. *German Economic Review*, 6(3), 355–376.

9 Robertson, S. & Graven, M. (2019). Language as an including or excluding factor in mathematics teaching and learning. *Mathematics Education Research Journal, 32*, 77-101.

10 Taylor, L.C., Clayton, J.D., & Rowley, S.J. (2004). Academic socialization: Understanding parental influences on children's school-related development in the early years. *Review of General Psychology*, *8*(3), 163–178.

11 Centurino, V.A.S. (2021). Using TIMSS to examine parental influences on fourth grade students' science achievement and attitudes toward learning and doing science [Unpublished doctoral dissertation]. Boston College.

12 Hill, N.E., & Tyson, D.F. (2009). Parental involvement in middle school: A meta-analytic assessment of the strategies that promote achievement. *Developmental Psychology, 45*(3), 740–763.

13 Hong, S., & Ho, H.–Z. (2005). Direct and indirect longitudinal effects of parental involvement on student achievement: Second-order latent growth modeling across ethnic groups. *Journal of Educational Psychology*, *97*(1), 32–42.

14 Pinquart, M. & Ebeling, M. (2020). Parental educational expectations and academic achievement in children and adolescents—a meta-analysis. *Educational Psychology Review, 32*, 463-480.

15 Gustafsson, J.-E., Hansen, K.Y., & Rosén, M. (2013). Effects of home background on student achievement in reading, mathematics, and science at the fourth grade. In M.O. Martin & I.V.S. Mullis (Eds.), *TIMSS and PIRLS 2011: Relationships among reading, mathematics, and science achievement at the fourth grade—Implications for early learning* (pp. 181–287). Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

16 Duncan, G.J., Dowsett, C.J., Claessens, A., Magnuson, K., Huston, A.C., Klebanov, P., Pagani, L.S., Feinstein, L., Engel, M., Brooks-Gunn, J., Sexton, H., Duckworth, K., & Japel, C. (2007). School readiness and later achievement. *Developmental Psychology, 43*(6), 1428-1446.

17 Hart, B., & Risley, T.R. (2003). The early catastrophe: The 30 million word gap by age 3. *American Educator, 27*(1), 4–9.

18 Sénéchal, M., & LeFevre, J. (2002). Parental involvement in the development of children's reading skill: A five-year longitudinal study. *Child Development, 73*(2), 445–460.

19 Zhu, J., & Chiu, M.M. (2019). Early home numeracy activities and later mathematics achievement: early numeracy, interest, and self-efficacy as mediators. *Educational Studies in Mathematics, 102,* 173-191.

20 Anders, Y., Rossbach, H.G., Weinert, S., Ebert, S., Kuger, S., Lehrl, S., & von Maurice, J. (2012). Home and preschool learning environments and their relations to the development of early numeracy skills. *Early Childhood Research Quarterly*, *27*(2), 231–244.

21 Claessens, A., & Engel, M. (2013). How important is where you start? Early mathematics knowledge and later school success. *Teachers College Record, 115*, 1–29.

22 Punter, A., Glas, C.A., & Meelissen, M.R.M. (2016). *Psychometric framework for modeling parental involvement and reading literacy.* Amsterdam, The Netherlands: IEA

23 Mullis, I.V.S., Martin, M.O., & Foy, P. (2013). The impact of reading ability on TIMSS mathematics and science achievement at the fourth grade: An analysis by item reading demands. In M.O. Martin & I.V.S. Mullis (Eds.), *TIMSS and PIRLS 2011: Relationships among reading, mathematics, and science achievement at the fourth grade—Implications for early learning* (pp. 67–108). Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

24 Duncan, G.J., & Magnuson, K. (2013). Investing in preschool programs. *Journal of Economic Perspectives*, *27*(2), 109–132.

25 McCoy, D.C., Yoshikawa, H., Ziol-Guest, K.M., Duncan, G.J., Schindler, H.S., Magnuson, K., Yang, R., Koepp, A., & Shonkoff, J.P. (2017). Impacts of early childhood education on medium- and long-term educational outcomes. *Educational Researcher, 46*(8), 474-487.

26 Bakken, L., Brown, N., & Downing, B. (2017). Early childhood education: the long-term benefits. *Journal of Research in Childhood Education, 31*(2), 255-269.

27 Duncan, G.J., & Sojourner, A.J. (2013). Can intensive early childhood intervention programs eliminate income-based cognitive and achievement gaps? *Journal of Human Resources*, *48*(4), 945–968.

28 Center for Disease Control and Prevention. (2009). *School connectedness: Strategies for increasing protective factors among youth*. Atlanta, GA: U.S. Department of Health and Human Services; 2009.

29 Hudson, S. & Hudson, P. (2019). "Please help me find teachers for my rural and remote school:" a model for teaching readiness. *Australian and International Journal of Rural Education, 29*(3).

30 Maranto, R. & Shuls, J.V. (2013). How do we get them on the farm? Efforts to improve rural teacher recruitment and retention in Arkansas. *The Rural Educator, 34*(1).

31 Greenough, R. & Nelson, S.R. (2015). Recognizing the variety of rural schools. *Peabody Journal of Education, 90*(2), 322-332.

32 Coleman, J.S., Campbell, E.Q., Hobson, C.J., McPartland, J., Mood, A.M., Weinfeld, F.D., & York, R.L. (1966). *Equality of educational opportunity*. Washington, DC: National Center for Educational Statistics, US Government Printing Office.

33 Martin, M.O., Foy, P., Mullis, I.V.S., & O'Dwyer, L.M. (2013). Effective schools in reading, mathematics, and science at the fourth grade. In M.O. Martin & I.V.S. Mullis (Eds.), *TIMSS and PIRLS 2011: Relationships among reading, mathematics, and science achievement at the fourth grade—Implications for early learning*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

34 Willms, J.D. (2006). *Learning divides: Ten policy questions about the performance and equity of schools and schooling systems*. Montreal, Canada: UNESCO Institute for Statistics.

35 Canales, A. & Webb, A. (2018). Educational achievement of indigenous students in Chile: school composition and peer effects. *Comparative Education Review, 62*(2), 231-273.

36 Chesters, J. & Daly, A. (2017). Do peer effects mediate the association between family socio-economic status and educational achievement? *Australian Journal of Social Issues, 52*, 63-77.

37 Sacerdote, B. (2011). Peer effects in education: How might they work, how big are they and how much do we know thus far? In E.A. Hanushek, S.J. Machin, & L. Wößmann, *Handbook of the economics of education* (pp. 249–277). San Diego, CA: Elsevier.

38 Akiba, M., LeTendre, G.K., & Scribner, J.P. (2007). Teacher quality, opportunity gap, and national achievement in 46 countries. *Educational Researcher, 36*(7), 369–387.

39 Goldhaber, D., Lavery, L., & Theobald, R. (2015). Uneven playing field? Assessing the teacher quality gap between advantaged and disadvantaged students. *Educational Researcher*, *44*(5), 293–307.

40 Cohen, J., McCabe, L., Michelli, N.M., & Pickeral, T. (2009). School climate: Research, policy, practice, and teacher education. *Teachers College Record, 111*(1), 190–213.

41 Glewwe, P.W., Hanushek, E.A., Humpage, S.D., & Ravina, R. (2011). School resources and educational outcomes in developing countries: A review of the literature from 1990 to 2010. In P. Glewwe (Ed.), *Education policy in developing countries* (pp. 13–64). Chicago: University of Chicago Press.

42 Hanushek, E.A., & Wößmann, L. (2017). School resources and student achievement: A review of cross-country economic research. In M. Rosén, K.Y. Hansen, & U. Wolff (Eds.), *Cognitive abilities and educational outcomes* (pp. 149–171). Methodology of Educational Measurement and Assessment. Switzerland: Springer International Publishing.

43 Hoy, W.K. (2012). School characteristics that make a difference for the achievement of all students: a 40-year odyssey. *Journal of Educational Administration, 50*(1), 76-97.

44 Martin, M.O., Foy, P., Mullis, I.V.S., & O'Dwyer, L.M. (2013). Effective schools in reading, mathematics, and science at the fourth grade. In M.O. Martin & I.V.S. Mullis (Eds.), *TIMSS and PIRLS 2011: Relationships among reading, mathematics, and science achievement at the fourth grade—Implications for early learning*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

45 Nilsen, T., & Gustafsson, J.-E. (2014). School emphasis on academic success: Exploring changes in science performance in Norway between 2007 and 2011 employing two-level SEM. *Educational Research and Evaluation, 20*(4), 308–327.

46 Hoy, W.K., Tarter, C.J., & Hoy, A.W. (2006). Academic optimism of schools: A force for student achievement. *American Educational Research Journal, 43*(3), 425–446.

47 Wu, J.H., Hoy, W.K., & Tarter, C.J. (2013). Enabling school structure, collective responsibility, and a culture of academic optimism: Toward a robust model of school performance in Taiwan. *Journal of Educational Administration, 51*(2), 176–193.

48 Johnson, S.M., Kraft, M.A., & Papay, J.P. (2012). How context matters in high-need schools: The effects of teachers' working conditions on their professional satisfaction and their students' achievement. *Teachers College Record*, *114*(10), 1–39.

49 Admiraal, W., Veldman, I., Mainhard, T. & van Tartwijk. (2019). A typology of veteran teachers' job satisfaction: their relationships with their students and the nature of their wok. *Social Psychology of Education, 22*, 337-355.

50 Kelly, S., & Northrop, L. (2015). Early career outcomes for the "best and the brightest": Selectivity, satisfaction, and attrition in the beginning teacher longitudinal survey. *American Educational Research Journal*, *52*(4), 624–656.

51 Skaalvik, E.M., & Skaalvik, S. (2011). Teacher job satisfaction and motivation to leave the teaching profession: Relations with school context, feeling of belonging, and emotional exhaustion. *Teaching and Teacher Education: An International Journal of Research and Studies*, *27*(6), 1029–1038.

52 Joyce, H.D., & Early, T.J. (2014). The impact of school connectedness and teacher support on depressive symptoms in adolescents: A multilevel analysis. *Children and Youth Services Review*, *39*, 101–107.

53 Korpershoek, H., Canrinus, E.T., Fokkens-Bruinsma, & de Boer, H. (2020). The relationship between school belonging and students' motivational, social-emotional, behavioural, and academic outcomes in secondary education: a meta-analytic review. *Research Papers in Education, 35*(6), 641-680.

54 Renshaw, T.L., Long, A.C.J., & Cook, C.R. (2015). Assessing adolescents' positive psychological functioning at school: Development and validation of the student subjective wellbeing questionnaire. *School Psychology Quarterly*, *30*(4), 534–552.

55 Cheng, A., & Peterson, P.E. (2017). How satisfied are parents with their children's schools? *Education Next*, *17*(2), 21–27.

56 Stacer, M.J., & Perrucci, R. (2013). Parental involvement with children at school, home, and community. *Journal of Family and Economic Issues*, *34*(3), 340–354.

57 Lacoe, J. (2020). Too scared to learn? The academic consequences of feeling unsafe in the classroom. *Urban Education, 55*(10), 1385-1418.

58 Martin, M.O., Foy, P., Mullis, I.V.S., & O'Dwyer, L.M. (2013). Effective schools in reading, mathematics, and science at the fourth grade. In M.O. Martin & I.V.S. Mullis (Eds.), *TIMSS and PIRLS 2011: Relationships among reading, mathematics, and science achievement at the fourth grade—Implications for early learning*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

59 Konishi, C., Hymel, S., Zumbo, B. D., & Li, Z. (2010). Do school bullying and student-teacher relationships matter for academic achievement? A multilevel analysis. *Canadian Journal of School Psychology, 25*(1), 19–39.

60 Kutsyuruba, B., Klinger, D.A., & Hussain, A. (2015). Relationships among school climate, school safety, and student achievement and well-being: A review of the literature. *Review of Education*, *3*(2), 103–135.

61 Gottfredson, G.D., Gottfredson, D.C., Payne, A.A., & Gottfredson, N.C. (2005). School climate predictors of school disorder: Results from a national study of delinquency prevention in schools. *Journal of Research in Crime and Delinquency, 42*(4), 412–444.

62 O'Neill, B. & Dinh, T. (2015). Mobile technologies and the incidence of cyberbullying in seven European countries: Findings from net children go mobile. *Societies, 5*, 384-398.

63 Dalla Pozza, V., Di Pietro, A., Morel, S., & Psaila, E. (2016). *Cyberbullying among young people*. European Parliament Policy Department C – Citizens' Rights and Constitutional Affairs.

64 Center for Disease Control and Prevention. (2018). *Youth risk behavior surveillance—United States, 2017.* MMWR Surveillance Summaries 2018, 67(8).

65 Konishi, C., Hymel, S., Zumbo, B. D., & Li, Z. (2010). Do school bullying and student-teacher relationships matter for academic achievement? A multilevel analysis. *Canadian Journal of School Psychology, 25*(1), 19–39.

66 Kowalski, R.M., & Limber, S.P. (2013). Psychological, physical, and academic correlates of cyberbullying and traditional bullying. *Journal of Adolescent Health*, *53*, S13-S20.

67 Tokunaga, R.S. (2010). Following you home from school: A critical review and synthesis of research on cyberbullying victimization. *Computers in Human Behavior, 26*(3), 277–287.

68 Goddard, R., Goddard, Y., Kim, S.E., & Miller, R. (2015). A theoretical and empirical analysis of the roles of instructional leadership, teacher collaboration, and collective efficacy beliefs in support of student learning. *American Journal of Education*, *121*(4), 501–530.

69 Tschannen-Moran, M., & Gareis, C. (2015). Faculty trust in the principal: An essential ingredient in high-performing schools. *Journal of Educational Administration, 53*(1), 66–92.

70 Azaiez, H., & Slate, J.R. (2017). Student achievement differences as a function of principal longevity. *Journal of Advances in Education Research*, *2*(3), 157-162.

71 Miller, A. (2013). Principal turnover and student achievement. *Economics of Education Review*, *36*(3), 60–72.

72 Darling-Hammond, L. (2000). How teacher education matters. *Journal of Teacher Education, 51*(3), 166–173.

73 Hill, H.C., Rowan, B., & Ball, D.L. (2005). Effects of teachers' mathematical knowledge for teaching on student achievement. *American Educational Research Journal, 42*(2), 371–406.

74 Harris, D.N., & Sass, T.R. (2011). Teacher training, teacher quality and student achievement. *Journal of Public Economics, 95*(7–8), 798–812.

75 Ladd, H.F., & Sorensen, L.C. (2017). Returns to teacher experience: Student achievement and motivation in middle school. *Education Finance and Policy*, *12*(2), 241–279.

76 Papay, J.P., & Kraft, M. (2015). Productivity returns to experience in the teacher labor market: Methodological challenges and new evidence on long-term career improvement. *Journal of Public Economics*, *130*, 105–119.

77 Yang, R., Porter, A.C., Massey, C.M., Merlino, J.F., & Desimone, L.M. (2019). Curriculum-based teacher professional development in middle school science: a comparison of training focused on cognitive science principles versus content knowledge. *Journal of Research on Science Teaching, 57*(4), 536-566.

78 Capps, D.K., Crawford, B.A., & Constas, M.A. (2012). A review of empirical literature on inquiry professional development: Alignment with best practices and a critique of the findings. *Journal of Science Teacher Education, 23*(3), 291–318.

79 Darling-Hammond, L., & McLaughlin, M.W. (2011). Policies that support professional development in an era of reform. *Phi Delta Kappan Magazine, 92*(6), 81–92.

80 Hanushek, E.A., & Wößmann, L. (2017). School resources and student achievement: A review of cross-country economic research. In M. Rosén, K.Y. Hansen, & U. Wolff (Eds.), *Cognitive Abilities and Educational Outcomes* (pp. 149–171). Methodology of Educational Measurement and Assessment. Switzerland: Springer International Publishing.

81 Mullis, I.V.S., Martin, M.O., & Loveless, T. (2016). *20 years of TIMSS: International trends in mathematics and science achievement, curriculum, and instruction*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

82 Kim, Y. (2018). Revisiting classroom practices in East Asian countries: examination of within-country variations and effects of classroom instruction. *Teachers College Record, 120*(7), 1-42.

83 Lehtinen, E., Hannula-Sormunen, M., McMullen, J., & Gruber, H. (2017). Cultivating mathematical skills: from drill-and-practice to deliberate practice. *ZDM Mathematics Education, 49*, 625-636.

84 Rittle-Johnson, B., Loehr, A.M., & Durkin, K. (2017). Promoting self-explanation to improve mathematics learning: a meta-analysis and instructional design principles. *ZDM Mathematics Education, 49*, 599-611.

85 Arnold, J.C., Kremer, K., & Mayer, J. (2014). Understanding students' experiments—what kind of support do they need in inquiry tasks? *International Journal of Science Education, 36*(16), 2719-2749.

86 Kirschner, P.A., Sweller, J., & Clark, R.E. (2006). Why minimal guidance during instruction does not work: an analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 41*(2). 75-86.

87 Nilsen, T., Gustafsson, J.-E., & Blömeke, S. (2016). Conceptual framework and methodology of this report. In T. Nilsen & J.-E. Gustafsson (Eds.), *Teacher quality, instructional quality, student outcomes* (pp. 1–19). Amsterdam, The Netherlands: IEA.

88 Ferguson, R.F. (2012). Can student surveys measure teaching quality? *Phi Delta Kappan*, *94*(3), 24–28.

89 Lipowsky, F., Rakoczy, K., Pauli, C., Drollinger-Vetter, B., Klieme, E., & Reusser, K. (2009). Quality of geometry instruction and its short-term impact on students' understanding of the Pythagorean Theorem. *Learning and Instruction*, *19*, 527–537.

90 McLaughlin, M., McGrath, D.J., Burian-Fitzgerald, M.A., Lanahan, L., Scotchmer, M., Enyeart, C., & Salganik, L. (2005, April). Student content engagement as a construct for the measurement of effective classroom instruction and teacher knowledge. Paper presented at the annual meeting of the American Educational Researchers Association, Montreal, Canada.

91 Nilsen, T., Gustafsson, J.-E., & Blömeke, S. (2016). Conceptual framework and methodology of this report. In T. Nilsen & J.-E. Gustafsson (Eds.), *Teacher quality, instructional quality, student outcomes* (pp. 1–19). Amsterdam, The Netherlands: IEA.

92 Bergem, O.K., Nilsen, T., & Scherer, R. (2016). Undervisningskvalitet i matematikk. In O.K. Bergem, H. Kaarstein, & T. Nilsen, *Vi kan lykkes i realfag. Resultater og analyser fra TIMSS 2015* (pp.120–136). Retrieved from https://www.idunn.no/vi-kan-lykkes-i-realfag#/contents

93 Furtak, E.M., Seidel, T., Iverson, H., & Briggs, D.C. (2012). Experimental and quasi-experimental studies of inquiry-base science teaching: a meta-analysis. *Review of Educational Research, 82*(3), 300-329.

94 Teig, N., Scerer, R., & Nilsen, T. (2018). More isn't always better: the curvilinear relationship between inquiry-based teaching and student achievement in science. *Learning and Instruction, 56*, 20-29.

95 Rönnebeck, S. Bernholt, S., & Rophol, M. (2016). Searching for common ground—a literature review of empirical research in scientific inquiry activities. *Studies in Science Education, 52(*2), 161-197.

96 Carroll, J.B. (1963). A model of school learning. *Teachers College Record, 64,* 723-733.

97 Schmidt, W.H., Burroughs, N.A., & Houang, R.T. (2015). The role of schooling in perpetuating educational inequality: an international perspective. *Educational Researcher, 44,* 371-386.

98 Fan, H., Xu, J., Cai, Z., He., & Fan, X. (2017). Homework and students' achievement in math and science: a 30-year meta-analysis, 1986-2015. *Educational Research Review, 20*, 35-54.

99 Fernández-Alonso, R., Álvarez-Diaz, M., Suárez-Álvarez, J., & Muñiz, J. (2017). Students' achievement and homework assignment strategies. *Frontiers in Psychology, 8*, 1-11.

100 Black, P. & Wiliam, D. (2018). Classroom assessment and pedagogy. *Assessment in Education: Principles, Policy & Practice, 25*(6), 551-575.

101 Shepard, L.A. (2000). The role of assessment in a learning culture. *Educational Researcher, 29*(7), 4-14.

102 Veldhuis, M. & van den Heuvel-Panhuizen, M. (2020). Supporting primary school teachers' classroom assessment in mathematics education: effects on student achievement. *Mathematics Education Research Journal, 32*, 449-471.

103 Faber, J.M., Luyten, H., & Visscher, A.J. (2017). The effects of a digital formative assessment tool on mathematics achievement and student motivation: results of a randomized experiment. *Computers & Education, 106*, 83-96.

104 Fishman, B., Riconscente, M., Snider, R., Tsai, T., & Plass, J. (2014). *Empowering educators: Supporting student progress in the classroom with digital games*. Ann Arbor: University of Michigan. Retrieved from gamesandlearning.umich.edu/agames

105 McKnight, K., O'Malley, K., Ruzic, R., Horsley, M.K., Franey., J.J., & Bassett, K. (2016). Teaching in a digital age: How educators use technology to improve student learning. *Journal of Research on Technology in Education, 48*(3), 194–211.

106 Mullis, I.V.S., Martin, M.O., Foy, P., Kelly, D.L., & Fishbein, B. (2020). *TIMSS 2019 international results in mathematics and science*. Retrieved from Boston College, TIMSS & PIRLS International Study Center website: https://timssandpirls.bc.edu/timss2019/international-results/

107 Ertmer, P.A., & Ottenbreit-Leftwich, A.T. (2010). Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. *Journal of Research on Technology in Education, 42*(3), 255–284.

108 Gerick, J., Eickelmann, B., & Bos, W. (2017). School-level predictors for the use of ICT in schools and students' CIL in international comparison. *Large Scale Assessments in Education, 5*(5), 1-13.

109 Hatlevik, O.E. (2017). Examining the relationship between teachers' self-efficacy, their digital competence, strategies to evaluate information, and use of ICT at school. *Scandinavian Journal of Educational Research, 61*(5), 555-567.

110 Oliver, R.M., Wehby, J.H., & Reschly, D.J. (2011). Teacher classroom management practices: effects on disruptive or aggressive student behavior. *Campbell Systematic Reviews, 7*, 1-55.

111 Herman, K.C., Reinke, W.M., Dong, N., & Bradshaw, C.P. (2020). Can effective classroom behavior management increase student achievement in middle school? Findings from a group randomized trial. *Journal of Educational Psychology.* Advance online publication. http://dx.doi.org/10.1037/edu0000641

112 Van Dijk, W., Gage, N.A., & Grasley-Boy, N. (2019). The relation between classroom management and mathematics achievement: a multilevel structural equation model. *Psychology in the Schools, 56*, 1173-1186.

113 Faught, E.L., Williams, P.L., Willows, N.D., Asbridge, M., & Veugelers, P.J. (2017). The association between food insecurity and academic achievement in Canadian school-aged children. *Public Health Nutrition, 20*(15), 2778-2785.

114 Taras, H. (2005). Nutrition and performance at school. *Journal of School Health, 75*(6), 199-213.

115 Deci, E.L., & Ryan, R.M. (1985). *Intrinsic motivation and self-determination in human behavior*. New York: Plenum Press.

116 Kennedy, J., Quinn, F., & Lyons, T. (2020). The keys to STEM: Australian year 7 students' attitudes and intentions towards science, mathematics and technology courses. *Research in Science Education, 50*, 1805-1832.

117 Raccanello, D., Brondino, M., Moé, A., Stupnisky, R., & Lichtenfeld, S. (2019). Enjoyment, boredom, anxiety in elementary schools in two domains: relations with achievement. *The Journal of Experimental Education, 87*(3), 449-469.

118 Marsh, H.W., & Craven, R.G. (2006). Reciprocal effects of self-concept and performance from a multidimensional perspective: Beyond seductive pleasure and unidimensional perspectives. *Perspectives on Psychological Science, 1*(2), 133–163.

119 Bandura, A. (1997). *Self-efficacy: The exercise of control.* New York: W.H. Freeman and Company.

120 Namkung, J.M., Peng, P., & Lin, X. (2019). The relation between mathematics anxiety and mathematics performance among school-aged students: a meta-analysis. *Review of Educational Research, 89*(3), 459-496.

121 Raccanello, D., Brondino, M., Moé, A., Stupnisky, R., & Lichtenfeld, S. (2019). Enjoyment, boredom, anxiety in elementary schools in two domains: relations with achievement. *The Journal of Experimental Education, 87*(3), 449-469.

122 Mujtaba, T., Sheldrake, R., Reiss, M.J., & Simon, S. (2018). Students' science attitudes, beliefs, and context: associations with science and chemistry aspirations. *International Journal of Science Education, 40*(6), 644-667.

123 Tai, R.H., Liu, C.Q., Maltese, A.V., & Fan, X. (2006). Planning early for careers in science. *Science, 312*, 1143-1144.

124 Fraillon, J., Ainley, J., Schulz, W., Friedman, T., & Duckworth, D. (2020). *Preparing for life in a digital world. IEA International Computer and Information Literacy Study 2018 international report.* Cham, Switzerland: Spring.

125 Kirscher, P.A., & De Bruyckere, P. (2017). The myths of the digital native and the multitasker. (2017). *Teaching and Teacher Education, 67*, 135-142.

126 Hatlevik, O. E., Throndsen, I., Loi, M., & Guðmundsdóttir, G.B. (2015). Students' ICT self-efficacy and computer and information literacy: Determinants and relationships. *Computers & Education*, *118*, 107–119.

127 Rohatgi, A., Scherer, R. & Hatlevik, O. (2016). The role of ICT self-efficacy for students' ICT use and their achievement in a computer and information literacy test. *Computers & Education*, *102*, 103–116.

128 Duncan, G.J. & Magnuson, K. (2013). Investing in preschool programs. *Journal of Economic Perspectives, 27*(2), 109-132.

129 Broekhuizen, M.L., Mokrova, I.L., Burchinal, M.R., & Garrett-Peters, P.T. (2016). Classroom quality at pre-kindergarten and kindergarten and children's social skills and behavior problems. *Early Childhood Research Quarterly*, *36*, 212–222.

130 Mashburn, A.J., Pianta, R.C., Hamre, B.K., Downer, J.T., Barbarin, O.A., Bryant, D., Burchinal M., Early D.M., & Howes, C. (2008). Measures of classroom quality in prekindergarten and children' s development of academic, language, and social skills. *Child Development, 79*(3), 732–749.

131 Martin, M.O., Mullis, I.V.S., & Foy, P. (2011). Age distribution and reading achievement configurations among fourth-grade students in PIRLS 2006. *IERI Monograph Series: Issues and Methodologies in Large-scale Assessments, 4*, 9–33.

132 García-Pérez, J., Hidalgo-Hidalgo, M., & Robles-Zurita, J.A. (2014). Does grade retention affect students' achievement? Some evidence from Spain. *Applied Economics*, *46*(12), 1372–1392.

133 Kretschmann, J., Vock, M., Lüdtke, O., Jansen, M., & Gronostaj, A. (2019). Effects of grade retention on students' motivation: A longitudinal study over 3 years of secondary school. *Journal of Educational Psychology, 111*(8), 1432-1446.

134 Mathys, C., Véronneau, M., & Lecocq, A. (2019). Grade retention at the transition to secondary school: using propensity score matching to identify consequences on psychosocial adjustment. *Journal of Early Adolescence, 39*(1), 97-133.

135 Stacey, O., De Lazzari, G., Grayson, H., Griffin, H., Jones, E., Taylor, A., & Thomas, D. (2018). The globalization of science curricula. *IEA Research for Education (A Series of In-depth Analyses Based on Data of the International Association for the Evaluation of Educational Achievement (IEA)), Volume 3*. Springer, Cham.

CHAPTER 4

TIMSS 2023 Assessment Design

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Overview

TIMSS is designed to provide countries with information about their students' mathematics and science achievement that can be used to inform evidence-based decisions for improving educational policy and practice. Conducted every four years since 1995, with each assessment linked to the one that preceded it, TIMSS provides regular and timely data for educators and policymakers on trends in students' mathematics and science achievement.

Central to TIMSS's mission is the measurement of student achievement in mathematics and science in a way that does justice to the breadth and richness of these subjects as they are taught in the participating countries, and that monitors countries' improvements or declines by tracking trends in student performance from one assessment cycle to the next. This requires an assessment that is wide ranging in its coverage and difficulties of mathematics and science and innovative in its measurement approach. With a diverse set of countries participating in TIMSS, with varying curricula and ability levels, this has always been a challenge. In the past, TIMSS has offered less difficult versions of mathematics that countries participating at the fourth grade could choose to administer, starting with TIMSS Numeracy in 2015[1] and following up with the TIMSS less difficult mathematics assessment in 2019.[2] These efforts were successful in expanding the TIMSS coverage of students at the lower end of the mathematics ability distribution. However, the linked parallel assessments were complex both conceptually and operationally. Most importantly, they did not address the need for more challenging mathematics material for higher achieving students or science.

TIMSS continues its tradition of innovation in each assessment cycle. TIMSS 2019 began the transition from paper-and-pencil to digital format, with about half of the countries choosing digital format and half keeping paper format as in previous TIMSS assessments. For TIMSS 2023, the vast majority of countries have transitioned, or are transitioning, to a digital assessment. Moreover, TIMSS 2023 is adopting a single unified assessment based on a new group adaptive assessment design to address the need for a broader range of assessment difficulty and better targeting of student ability. The group adaptive design was introduced in the PIRLS 2021 assessment and its rationale can be found in Appendix A of the PIRLS 2021 Assessment Design chapter.[3]

Since the majority of TIMSS 2023 countries have transitioned to a digital administration, the group adaptive assessment for TIMSS 2023 is available in digital format only. For the new or trend countries not ready for digital format, a paper assessment for TIMSS 2023 is provided and described in a later section.

The group adaptive design for TIMSS 2023 adopts the main aspects of the group adaptive design introduced in PIRLS 2021[4] while maintaining the customary 14-block TIMSS design in order to minimize its impact on item and block development, and booklet assembly. The TIMSS 2023 group adaptive design has three levels of item block difficulty—difficult, medium, and easy—that are combined into two levels of booklet difficulty. Each country administers the entire assessment, but the balance of more difficult and less difficult booklets varies with the mathematics and science achievement level of the students in the country. TIMSS 2023 aims to improve the match between assessment difficulty and student ability in each country's population by having a greater proportion of more difficult booklets in countries with relatively high achievement and a greater proportion of less difficult booklets in countries with relatively low achievement. Accordingly, the new design maximizes the information obtained from the assessment while limiting changes to the TIMSS assessment design.

Student Population Assessed

TIMSS assesses the mathematics and science achievement of students in their fourth and eighth years of formal schooling. Participating countries may choose to assess one or both populations, according to their policy priorities and resource availability. Because in TIMSS the number of years of formal schooling (four or eight) is the basis for comparison among participating countries, the TIMSS assessment is targeted at the grade levels that correspond to these. TIMSS defines the fourth year and eighth year of formal schooling according to the International Standard Classification of Education (ISCED) developed by the UNESCO Institute for Statistics[5]. The ISCED classification provides an international standard for describing levels of schooling across countries, and covers the full range of schooling, from early childhood education (Level 0) to doctoral or equivalent level study (Level 8). The target populations for TIMSS are defined as follows:

- At the fourth grade, the TIMSS target grade should be the grade that represents four years of schooling, counting from the first year of ISCED Level 1.
- At the eighth grade, the TIMSS target grade should be the grade that represents eight years of schooling, counting from the first year of ISCED Level 1.

ISCED Level 1 corresponds to primary education, or the first stage of basic education, and is considered to be the first stage of formal schooling. The target grade for the fourth grade TIMSS assessment typically is the fourth grade in most countries. Similarly, the target grade for eighth grade TIMSS is the eighth grade in most countries and usually corresponds to ISCED Level 2 or lower secondary education. However, given the cognitive demands of the assessments, TIMSS aims to avoid assessing very young students. Thus, TIMSS recommends that countries assess the next higher grade (i.e., fifth grade for fourth grade TIMSS, and ninth grade for eighth grade TIMSS) if, for fourth grade students, the average age at the time of testing would be less than 9.5 years, and, for eighth grade students, less than 13.5 years.

Reporting Student Achievement

The TIMSS assessment is designed to provide a comprehensive picture of the mathematics and science achievement of fourth and eighth grade students in each participating country. This includes achievement in each of the content and cognitive domains (as defined in Chapters 1 and 2) as well as overall mathematics and science achievement.

A major consequence of TIMSS's ambitious reporting goals is that many more questions are required for the assessment than can be answered by any one student in the amount of testing time available. Accordingly, TIMSS uses a matrix sampling approach that involves packaging the entire assessment pool of mathematics and science items at each grade level into a set of booklets, or virtual eBooklets (booklets for short) in the digital version. Each item appears in two booklets, providing a mechanism for linking together the student responses from the various booklets when data from all booklets are taken together. To facilitate the process of creating the student achievement booklets, TIMSS groups the assessment items into a series of item blocks, with approximately 10 to 14 items in each block at the fourth grade and 12 to 18 at the eighth grade. As much as possible, the distribution of items across content and cognitive domains within each block matches the distribution across the item pool overall, as described in the *TIMSS 2023 Mathematics and Science Assessment Frameworks*.

To keep the assessment burden on any one student to a minimum, each student is presented with only one booklet which contains a sample of the items, as described in the next section. Following data collection, student responses to the items in each assessment are aggregated and converted to the TIMSS mathematics and science scale metrics at each grade level to provide a comprehensive picture of the assessment results for each country.

One of the major strengths of TIMSS is its measurement of trends over time in mathematics and science achievement. The TIMSS achievement scales provide established metrics on which countries can compare students' progress in mathematics and science from assessment to assessment at the fourth and eighth grades. The TIMSS mathematics and science achievement scales were created with the first TIMSS assessment in 1995, separately for each subject and each grade. The scale units were established so that 100 points on the scale was equivalent to one standard deviation of the distribution of achievement across all of the countries that participated in TIMSS 1995, and the scale midpoint of 500 was located at the mean of this international achievement distribution.

Using items that were administered in both 1995 and 1999 assessments as a basis for linking the two sets of assessment results, the TIMSS 1999 data also were placed on the scales so that countries could gauge changes in students' mathematics and science achievement since 1995. This was done separately for mathematics and science and for fourth and eighth grades. Using similar procedures, the data from TIMSS 2003, TIMSS 2007, TIMSS 2011, TIMSS 2015, and TIMSS 2019 were placed on the TIMSS scales[6], as will be the data from TIMSS 2023. This will enable TIMSS 2023 countries that have participated in

TIMSS since its inception to have comparable achievement data from 1995, 1999, 2003, 2007, 2011, 2015, 2019, and 2023, and to plot changes in performance over this 28-year period.

In addition to the overall achievement scales for mathematics and science, TIMSS 2023 will construct scales for reporting relative student performance in each of the mathematics and science content and cognitive domains defined in the TIMSS 2023 Mathematics and Science Assessment Frameworks. Reporting scales will be constructed for each content and cognitive domain in mathematics and science at each grade level.

Because the TIMSS 2023 paper booklets are limited to trend blocks from the 2019 assessment, the TIMSS 2023 paper administration will provide only overall mathematics and science achievement results.

TIMSS 2023 Group Adaptive Design

The group adaptive testing design for TIMSS 2023 is modeled after the PIRLS 2021 group adaptive design. Consistent with the goal of comprehensive subject coverage, the TIMSS 2023 design preserves those main aspects of the PIRLS group adaptive design while maintaining the conventional 14-block design. The complete TIMSS 2023 group adaptive assessment has a total of 28 blocks at each grade, 14 consisting of mathematics items and 14 consisting of science items. Implementing the group adaptive design in TIMSS 2023 required grouping the item blocks into three levels of difficulty—easy, medium, and difficult—with five easy, four medium, and five difficult item blocks per subject and grade. Of the 14 item blocks by subject and grade needed for the design, eight were administered previously in TIMSS 2019 and available to support the measurement of trends and six were developed and field tested for first time use in TIMSS 2023. Exhibits 4.1 and 4.2 show how the existing trend item blocks fit into the subject-by-difficulty level scheme at the fourth grade and eighth grade, respectively, and also where the new item blocks belong.

Exhibit 4.1: Subject and Difficulty Level for TIMSS 2023 Fourth Grade Item Blocks

Subject	Difficulty Level	TIMSS 2023 Item Block Label	TIMSS 2019 Trend Block Label*
Mathematics	Difficult	MD1	ME08 (19)
		MD2	ME09 (15)
		MD3	New item block for 2023
		MD4	MI01 (19)
		MD5	New item block for 2023
	Medium	MM1	New item block for 2023
		MM2	ME04 (19)
		MM3	ME10 (19)
		MM4	ME14 (19)
	Easy	ME1	New item block for 2023
		ME2	ME11 (15)
		ME3	New item block for 2023
		ME4	ME13 (15)
		ME5	New item block for 2023
Science	Difficult	SD1	SE10 (19)
		SD2	SE13 (15)
		SD3	New item block for 2023
		SD4	SI02 (19)
		SD5	New item block for 2023
	Medium	SM1	New item block for 2023
		SM2	SE09 (15)
		SM3	SE12 (19)
		SM4	SE08 (19)
	Easy	SE1	New item block for 2023
		SE2	SE14 (19)
		SE3	New item block for 2023
		SE4	SE04 (19)
		SE5	New item block for 2023

* The number in parentheses is the assessment year in which the item block was first introduced.

Exhibit 4.2: Subject and Difficulty Level for TIMSS 2023 Eighth Grade Item Blocks

Subject	Difficulty Level	TIMSS 2023 Item Block Label	TIMSS 2019 Trend Block Label*
Mathematics	Difficult	MD1	ME08 (19)
		MD2	ME12 (19)
		MD3	New item block for 2023
		MD4	MI02 (19)
		MD5	New item block for 2023
	Medium	MM1	New item block for 2023
		MM2	ME04 (19)
		MM3	ME14 (19)
		MM4	ME10 (19)
	Easy	ME1	New item block for 2023
		ME2	ME11 (15)
		ME3	New item block for 2023
		ME4	ME13 (15)
		ME5	New item block for 2023
Science	Difficult	SD1	SE04 (19)
		SD2	SE09 (15)
		SD3	New item block for 2023
		SD4	SI01 (19)
		SD5	New item block for 2023
	Medium	SM1	New item block for 2023
		SM2	SE11 (15)
		SM3	SE10 (19)
		SM4	SE14 (19)
	Easy	SE1	New item block for 2023
		SE2	SE12 (19)
		SE3	New item block for 2023
		SE4	SE13 (15)
		SE5	New item block for 2023

* The number in parentheses is the assessment year in which the item block was first introduced.

In 2019, the TIMSS computer-based assessments included Problem Solving and Inquiry (PSI) tasks—two item blocks for mathematics and two item blocks for science at each grade—arranged in two separate assessment booklets. Half of the PSI item blocks—one per subject and grade—were secured for use as trend blocks in TIMSS 2023. Also, the TIMSS fourth grade assessment was accompanied by a less difficult mathematics assessment consisting of the same science item blocks, and with 10 of the 14 mathematics item blocks designed specifically with easier material, six of which were secured for future use. Since relatively few countries were exposed to these less difficult mathematics item blocks in 2019, they were considered as suitable candidates for the new easy fourth grade mathematics item blocks required for the TIMSS 2023 group adaptive design. Taking all of these materials together, there were eight regular TIMSS trend item blocks and one PSI trend item block available at each subject and grade for 2023, as well as six less difficult mathematics item blocks available as new easy item blocks for fourth grade mathematics. Five of the six available TIMSS 2019 less difficult mathematics item blocks were included in the TIMSS 2023 field test, with the intent of including the three more suitable candidates for inclusion as new easy item blocks.

Of the six new item blocks per subject and grade, three will be easy item blocks, one will be medium, and two will be difficult. However, for the three new fourth grade easy item blocks, three item blocks from the TIMSS 2019 less difficult mathematics assessment will be used. The exhibits also include an item block label for each item block to facilitate the assignment of item blocks to booklets. The item block labels begin with either as ME or MI for mathematics, SE or SI for science.

Item Block Difficulty Level

For the group adaptive design to be effective, it is necessary that there be distinctive differences in the average difficulties of the item blocks across the difficulty groups (difficult, medium, easy). Reasonable difficulty goals in terms of average percent correct across student populations would be 40% for the difficult group, 55% for the medium group, and 70% for the easy group. New item blocks developed for TIMSS 2023 will aim for these difficulty levels, but there is less flexibility with the existing trend item blocks, which make up about 60% of the assessments.

As shown in Exhibit 4.3, the difficulties of the existing trend blocks are not well differentiated across the three difficulty groups at both grades and subjects. In particular, the existing trend blocks designated as easy are far more difficult than the long-term goal of 70% for this group. However, by combining the existing item blocks with new blocks developed to be closer to the target difficulties, it will be possible to make progress toward the long-term goals in each of the three difficulty groups.

Exhibit 4.3: Average Difficulties of Existing Trend Blocks from 2019 and Target Difficulties for 2023 (Average Percent Correct)

Subject	Item Block Level	Difficulty of Trend Blocks from 2019	Target Difficulty for 2023
Fourth Grade Mathematics	Difficult	46%	44%
	Medium	49%	50%
	Easy	51%	64%
Fourth Grade Science	Difficult	47%	44%
	Medium	54%	55%
	Easy	57%	65%
Eighth Grade Mathematics	Difficult	37%	38%
	Medium	42%	46%
	Easy	45%	60%
Eighth Grade Science	Difficult	44%	42%
	Medium	48%	50%
	Easy	51%	63%

Booklet Design

In TIMSS, each student is randomly assigned a test booklet (or booklet equivalent in the context of computer-based assessments) consisting of two mathematics item blocks and two science item blocks. In TIMSS 2023, the 14 mathematics and 14 science item blocks at each grade are arranged into 14 booklets with two mathematics and two science blocks each, with each item block appearing in two booklets and paired with different item blocks each time. Exhibit 4.4 summarizes the item block pairings among the mathematics and science item blocks that make up each booklet. The pairing pattern is identical at both grades. The direction of the arrows indicates which item block comes first in the booklet. For example, an arrow points from block ME1, an easy block, to MM1, a medium block, indicating these two blocks share a booklet, with ME1 preceding MM1. Note that when blocks of different difficulties are paired in the same booklet, the easier of the two always comes first. Because each booklet consists of two mathematics and two science item blocks, the matching pairs of mathematics and science blocks appear in the same booklet. For example, ME1 & MM1 appear in the same booklet as their science counterparts SE1 and SM1.

Exhibit 4.4: Item Block Pairings for Each Assessment Booklet

Subject	Difficult Item Blocks	Medium Item Blocks	Easy Item Blocks
Mathematics	MD1	MM1	ME1
	MD2	MM2	ME2
	MD3	MM3	ME3
	MD4	MM4	ME4
	MD5	—	ME5
Science	SD1	SM1	SE1
	SD2	SM2	SE2
	SD3	SM3	SE3
	SD4	SM4	SE4
	SD5	—	SE5

The 14 assessment booklets at each grade are divided into two levels of difficulty, as follows:

- More difficult booklets (7) composed of either two difficult item blocks or one medium and one difficult item block for each subject;
- Less difficult booklets (7) composed of either two easy item blocks or one easy and one medium item block for each subject.

Exhibit 4.5 shows the item block assignments for the 14 TIMSS booklets, with booklets 1-7 being the more difficult booklets and booklets 8-14 the less difficult ones. The assignments are identical for both grades.

Exhibit 4.5: Assessment Booklets with Item Block Assignments

Student Assessment Booklets		Part 1		Part 2	
More Difficult Booklets	Booklet 1	SM1	SD1	MM1	MD1
	Booklet 2	MD2	MD3	SD2	SD3
	Booklet 3	SM2	SD2	MM2	MD2
	Booklet 4	MD5	MD1	SD5	SD1
	Booklet 5	SM3	SD3	MM3	MD3
	Booklet 6	MM4	MD4	SM4	SD4
	Booklet 7	SD4	SD5	MD4	MD5
Less Difficult Booklets	Booklet 8	ME1	MM1	SE1	SM1
	Booklet 9	SE1	SE2	ME1	ME2
	Booklet 10	ME2	MM2	SE2	SM2
	Booklet 11	SE3	SE5	ME3	ME5
	Booklet 12	ME3	MM3	SE3	SM3
	Booklet 13	SE4	SM4	ME4	MM4
	Booklet 14	ME5	ME4	SE5	SE4

Exhibits 4.6 and 4.7 also present the item block assignments for each booklet, this time showing where the existing trend blocks belong and where the new item blocks developed for 2023, including the fourth grade less difficult mathematics blocks, will go. Exhibit 4.6 shows the fourth grade booklets, Exhibit 4.7 shows the eighth grade booklets.

Exhibit 4.6: Fourth Grade Assessment Booklets with Trend and New Block Assignments

Student Assessment Booklets		Part 1		Part 2	
More Difficult Booklets	Booklet 1	New SM1 (23)	SE10 (19)	New MM1 (23)	ME08 (19)
	Booklet 2	ME09 (15)	New MD3 (23)	SE13 (15)	New SD3 (23)
	Booklet 3	SE09 (15)	SE13 (15)	ME04 (19)	ME09 (15)
	Booklet 4	New MD5 (23)	ME08 (19)	New SD5 (23)	SE10 (19)
	Booklet 5	SE12 (19)	New SD3 (23)	ME10 (19)	New MD3 (23)
	Booklet 6	ME14 (19)	MI01 (19)	SE08 (19)	SI02 (19)
	Booklet 7	SI02 (19)	New SD5 (23)	MI01 (19)	New MD5 (23)
Less Difficult Booklets	Booklet 8	New ME1(23)	New MM1 (23)	New SE1 (23)	New SM1 (23)
	Booklet 9	New SE1 (23)	SE14 (19)	New ME1 (23)	ME11 (15)
	Booklet 10	ME11 (15)	ME04 (19)	SE14 (19)	SE09 (15)
	Booklet 11	New SE3 (23)	New SE5 (23)	New ME3 (23)	New ME5 (23)
	Booklet 12	New ME3 (23)	ME10 (19)	New SE3 (23)	SE12 (19)
	Booklet 13	SE04 (19)	SE08 (19)	ME13 (15)	ME14 (19)
	Booklet 14	New ME5(23)	ME13 (15)	New SE5 (23)	SE04 (19)

Exhibit 4.7: Eighth Grade Assessment Booklets with Trend and New Block Assignments

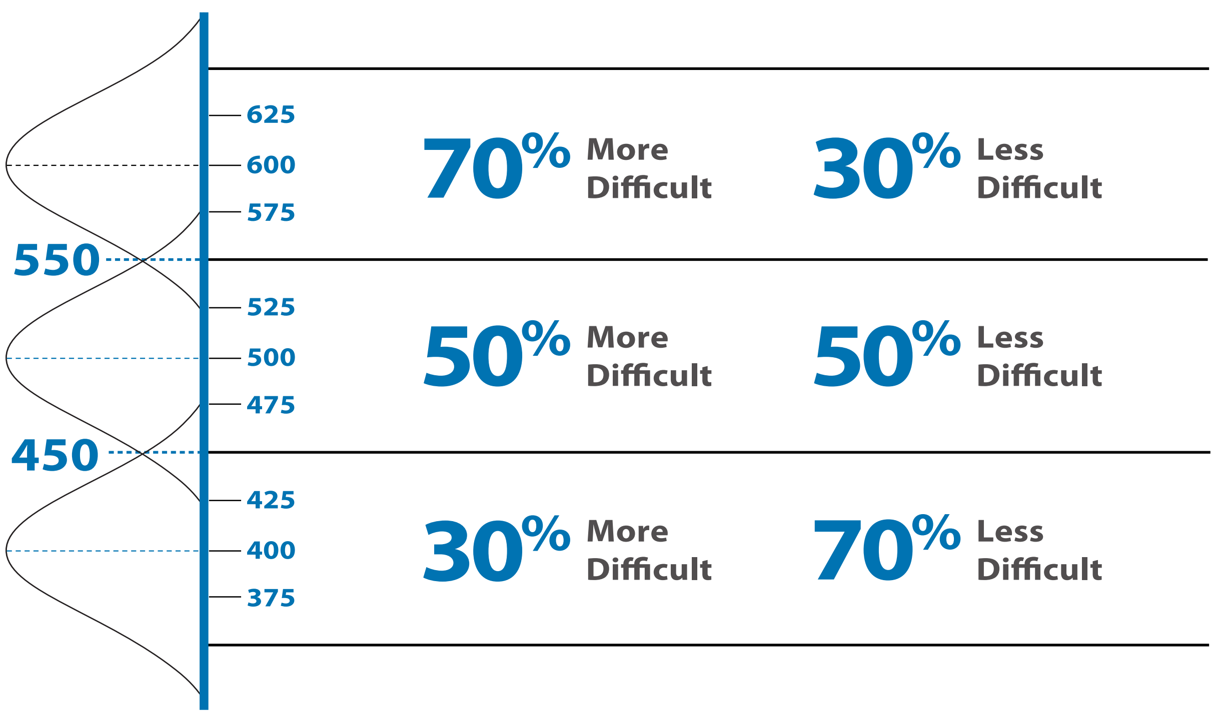
Student Assessment Booklets		Part 1		Part 2	
More Difficult Booklets	Booklet 1	New SM1 (23)	SE04 (19)	New MM1 (23)	ME08 (19)
	Booklet 2	ME12 (19)	New MD3 (23)	SE09 (15)	New SD3 (23)
	Booklet 3	SE11 (15)	SE09 (15)	ME04 (19)	ME12 (19)
	Booklet 4	New MD5 (23)	ME08 (19)	New SD5 (23)	SE04 (19)
	Booklet 5	SE10 (19)	New SD3 (23)	ME14 (19)	New MD3 (23)
	Booklet 6	ME10 (19)	MI02 (19)	SE14 (19)	SI01 (19)
	Booklet 7	SI01 (19)	New SD5 (23)	MI02 (19)	New MD5 (23)
Less Difficult Booklets	Booklet 8	New ME1(23)	New MM1 (23)	New SE1 (23)	New SM1 (23)
	Booklet 9	New SE1 (23)	SE12 (19)	New ME1 (23)	ME11 (15)
	Booklet 10	ME11 (15)	ME04 (19)	SE12 (19)	SE11 (15)
	Booklet 11	New SE3 (23)	New SE5 (23)	New ME3 (23)	New ME5 (23)
	Booklet 12	New ME3 (23)	ME14 (19)	New SE3 (23)	SE10 (19)
	Booklet 13	SE13 (15)	SE14 (19)	ME13 (15)	ME10 (19)
	Booklet 14	New ME5(23)	ME13 (15)	New SE5 (23)	SE13 (15)

Booklet Assignment within Countries

To ensure that the same assessment is conducted in every country, all 14 booklets in the TIMSS 2023 group adaptive design are distributed in every country, but with varying proportions of the more and less difficult booklets depending on the average mathematics and science abilities of the student population. This is estimated based on performance in prior TIMSS assessments, or in the field test for countries participating for the first time. Higher performing countries assign proportionally more of the more difficult booklets while lower performing countries assign proportionally more of the less difficult booklets, with the goal of a better match between assessment difficulty and student ability in each country.

Exhibit 4.8 illustrates the differential booklet assignment plan for higher, middle, and lower performing countries. As a general objective, countries with higher average performance (above 550 on the TIMSS mathematics and science achievement scales) would randomly assign proportionally more of the more difficult booklets (70%), and fewer of the less difficult booklets (30%). Countries with performance between 450 and 550 would assign equal proportions of the more and less difficult booklets. Countries with lower average performance (below 450 on the TIMSS mathematics and science achievement scales) would assign proportionally fewer of the more difficult booklets (30%) and more of the less difficult booklets (70%).

Exhibit 4.8: Booklet Assignment Plan for Higher, Middle, and Lower Performing Countries



While TIMSS 2023 is a transition cycle towards meeting the long-term goals of the group adaptive design, as shown by the 2023 target difficulty levels in Exhibit 4.3, the objective for 2023 is to have the group adaptive design impact fewer countries during this transition cycle. To that end, most countries participating in TIMSS 2023 will assign equal proportions of the more and less difficult booklets, while countries with achievement above 565 will assign more of the more difficult booklets, and countries with achievement below 435 will assign more of the less difficult booklets.

Although the TIMSS 2023 group adaptive design was developed to provide a better match between assessment difficulty and student ability at the country level, it is possible to apply the group adaptive approach for subgroups within a country, provided the country has clearly defined subpopulations that differ substantially in student achievement. In addition, the implementation of the TIMSS 2023 group adaptive design can vary by grade, but not by subject.

TIMSS 2023 Paper Assessments

The TIMSS 2023 group adaptive design is devised specifically for countries that have transitioned or are transitioning to computer-based administration in 2023. Although the vast majority of TIMSS 2023 countries will implement the digital assessments, a few countries will not be ready for digital administration in 2023. The TIMSS 2023 paper assessments provide a limited paper-based administration for those countries, with eight assessment booklets at each grade consisting solely of trend items from the TIMSS 2019 paper-based assessments. For countries that are transitioning to digital administration in 2023, the administration of these paper booklets paired with the administration of the digital TIMSS 2023 group adaptive assessments will allow them to examine mode differences between the two modes of administration based on trend items. Finally, TIMSS 2023 also provides an alternate set of eight paper booklets at the fourth grade based on the secured trend item blocks from the TIMSS 2019 fourth grade less difficult mathematics assessment for lower performing countries not yet transitioning to a digital administration.

The TIMSS 2023 paper assessments utilize the eight secured regular trend item blocks from each subject from the TIMSS 2019 paper-based assessments to form eight booklets at each grade. Exhibit 4.9 illustrates the TIMSS 2023 paper booklet design, showing the trend item block labels from TIMSS 2019. The booklet design is identical at both grades. Six of the eight booklets—booklets 2 through 7—are identical to booklets that were administered in TIMSS 2019. Booklets 1 and 8 are made up to complete the rotation of trend blocks. As usual, each item block appears in two booklets in different positions and each booklet contains two mathematics and two science item blocks.

Exhibit 4.9: TIMSS 2023 Paper Booklets with Trend Item Blocks – Fourth and Eighth Grades

TIMSS 2023 Paper Booklets	Part 1		Part 2	
Booklet 1	MP04	MP08	SP04	SP08
Booklet 2	SP08	SP09	MP08	MP09
Booklet 3	MP09	MP10	SP09	SP10
Booklet 4	SP10	SP11	MP10	MP11
Booklet 5	MP11	MP12	SP11	SP12
Booklet 6	SP12	SP13	MP12	MP13
Booklet 7	MP13	MP14	SP13	SP14
Booklet 8	SP14	SP04	MP14	MP04

An alternate set of paper booklets is available for lower performing countries administering the TIMSS 2023 paper assessment at the fourth grade. It is based on the TIMSS 2019 less difficult mathematics assessment and also consists of trend item blocks. Exhibit 4.10 presents the eight paper booklets and item blocks from the TIMSS 2019 fourth grade less difficult mathematics assessment. Six of the eight mathematics trend item blocks are unique to the TIMSS 2019 less difficult assessment and identifiable by the letters "MN" in the item block labels. The other two mathematics item blocks—MP08 and MP13, as well as all science item blocks are identical with the regular TIMSS 2023 paper assessment shown in Exhibit 4.9.

Exhibit 4.10: TIMSS 2023 Paper Booklets with Item Blocks from Fourth Grade Less Difficult Mathematics

TIMSS 2023 Paper Booklets	Part 1		Part 2	
Booklet 1	MN04	MP08	SP04	SP08
Booklet 2	SP08	SP09	MP08	MN09
Booklet 3	MN09	MP13	SP09	SP10
Booklet 4	SP10	SP11	MP13	MN11
Booklet 5	MN11	MN12	SP11	SP12
Booklet 6	SP12	SP13	MN12	MN13
Booklet 7	MN13	MN14	SP13	SP14
Booklet 8	SP14	SP04	MN14	MN04

The design of TIMSS 2023 paper booklets at both grades, including the less difficult mathematics version, follow the same administration procedures as in the past. The trend item blocks being from 2019 means they are all of roughly the same difficulty level at each subject and grade. Consequently, the group adaptive design is not present in their implementation. The less difficult paper assessment allows some measure of adaptability for lower performing countries with respect to fourth grade mathematics.

The TIMSS 2023 paper assessments will provide countries with overall scores in mathematics and science linked to the TIMSS reporting metrics. However, because the TIMSS 2019 trend item blocks represent about 60% of the entire TIMSS assessment frameworks in terms of items, achievement scores for the content or cognitive domains will not be available. This is true for countries administering the paper assessments instead of the computer-based assessments, as well as digital countries administering the paper booklets for performing mode comparison studies.

Student Testing Time

As summarized in Exhibit 4.11, each student completes one student achievement booklet consisting of two parts, followed by a student questionnaire. The individual student response time for the TIMSS 2023 assessment, including non-digital paper assessment, is the same as it has been since TIMSS 2007. That is, the TIMSS administration consists of two 36-minute sessions, one for each part, separated by a short break, and then followed by a 30-minute session for the student questionnaire at fourth grade. At the eighth grade, the administration consists of two 45-minute sessions, followed by a 30-minute session for the student questionnaire.

Exhibit 4.11: TIMSS 2023 Student Testing Time – Fourth and Eighth Grades

Activity	Fourth Grade	Eighth Grade
Student Achievement Booklet – Part 1	36 minutes	45 minutes
Break		
Student Achievement Booklet – Part 2	36 minutes	45minutes
Break		
Student Questionnaire	30 minutes	30 minutes

References

1 Martin, M. O., Mullis, I.V.S., & Foy, P. (2013). TIMSS 2015 sssessment design. In Mullis, I.V.S. & Martin, M.O. (Eds.), *TIMSS 2015 Assessment Frameworks*. Retrieved from Boston College, TIMSS & PIRLS International Study Center website: https://timssandpirls.bc.edu/timss2015/downloads/T15_FW_Chap4.pdf

2 Martin, M. O., Mullis, I.V.S., & Foy, P. (2017). TIMSS 2019 sssessment design. In Mullis, I.V.S., & Martin, M. O. (Eds.), *TIMSS 2019 Assessment Frameworks*. Retrieved from Boston College, TIMSS & PIRLS International Study Center website: https://timss2019.org/wp-content/uploads/frameworks/T19-Assessment-Frameworks-Chapter-4.pdf

3 Martin, M. O., von Davier, M., Foy, P., & Mullis, I.V.S. (2019). PIRLS 2021 sssessment design. In I.V.S. Mullis, & M. O. Martin (Eds.), *PIRLS 2021 Assessment Frameworks*. Retrieved from Boston College, TIMSS & PIRLS International Study Center website: http://pirls2021.org/frameworks/wp-content/uploads/sites/2/2019/04/P21_FW_Ch3_AssessDesign.pdf

4 Martin, M. O., von Davier, M., Foy, P., & Mullis, I.V.S. (2019). PIRLS 2021 sssessment design. In I.V.S. Mullis, & M. O. Martin (Eds.), *PIRLS 2021 Assessment Frameworks*. Retrieved from Boston College, TIMSS & PIRLS International Study Center website: http://pirls2021.org/frameworks/wp-content/uploads/sites/2/2019/04/P21_FW_Ch3_AssessDesign.pdf

5 UNESCO. (2012). *International standard classification of education ISCED 2011*. Retrieved from http://uis.unesco.org/sites/default/files/documents/international-standard-classification-of-education-isced-2011-en.pdf

6 Foy, P., Fishbein, B., von Davier, M., & Yin, L. (2020). Implementing the TIMSS 2019 scaling methodology. In M. O. Martin, M. von Davier, & I.V.S. Mullis (Eds.), *Methods and Procedures: TIMSS 2019 Technical Report* (pp. 12.1–12.146). Retrieved from Boston College, TIMSS & PIRLS International Study Center website: https://timssandpirls.bc.edu/timss2019/methods/chapter-12.html

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With each new assessment cycle of a study, one of the most important tasks is to update the assessment frameworks. Updating the TIMSS assessment frameworks for 2023 began in September of 2020, and has involved extensive input and reviews by individuals at the TIMSS & PIRLS International Study Center, IEA, the TIMSS 2023 National Research Coordinators, and the two TIMSS expert committees—the TIMSS 2023 Science and Mathematics Item Review Committee and the TIMSS 2023 Questionnaire Item Review Committee. Of all the individuals around the world that it takes to make TIMSS a success, the intention here is to specifically acknowledge some of the many persons who had particular responsibility and involvement in developing and producing the *TIMSS 2023 Assessment Frameworks*.

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TIMSS 2023 Science and Mathematics Item Review Committee

The Science and Mathematics Item Review Committee (SMIRC), comprised of internationally recognized mathematics and science experts, reviewed and recommended updates for the *TIMSS 2023 Mathematics and Science Frameworks*. The SMIRC also reviews the TIMSS 2023 items at key points in the development process.

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The TIMSS 2023 Questionnaire Item Review Committee (QIRC) is comprised of educational policy analysis experts and TIMSS 2023 National Research Coordinators who have a special responsibility for participating in the development of the *TIMSS 2023 Context Questionnaire Framework* and context questionnaires for TIMSS 2023.

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The TIMSS 2023 National Research Coordinators (NRCs) are responsible for implementing the study in their countries, and participated in a series of reviews of the updated frameworks

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