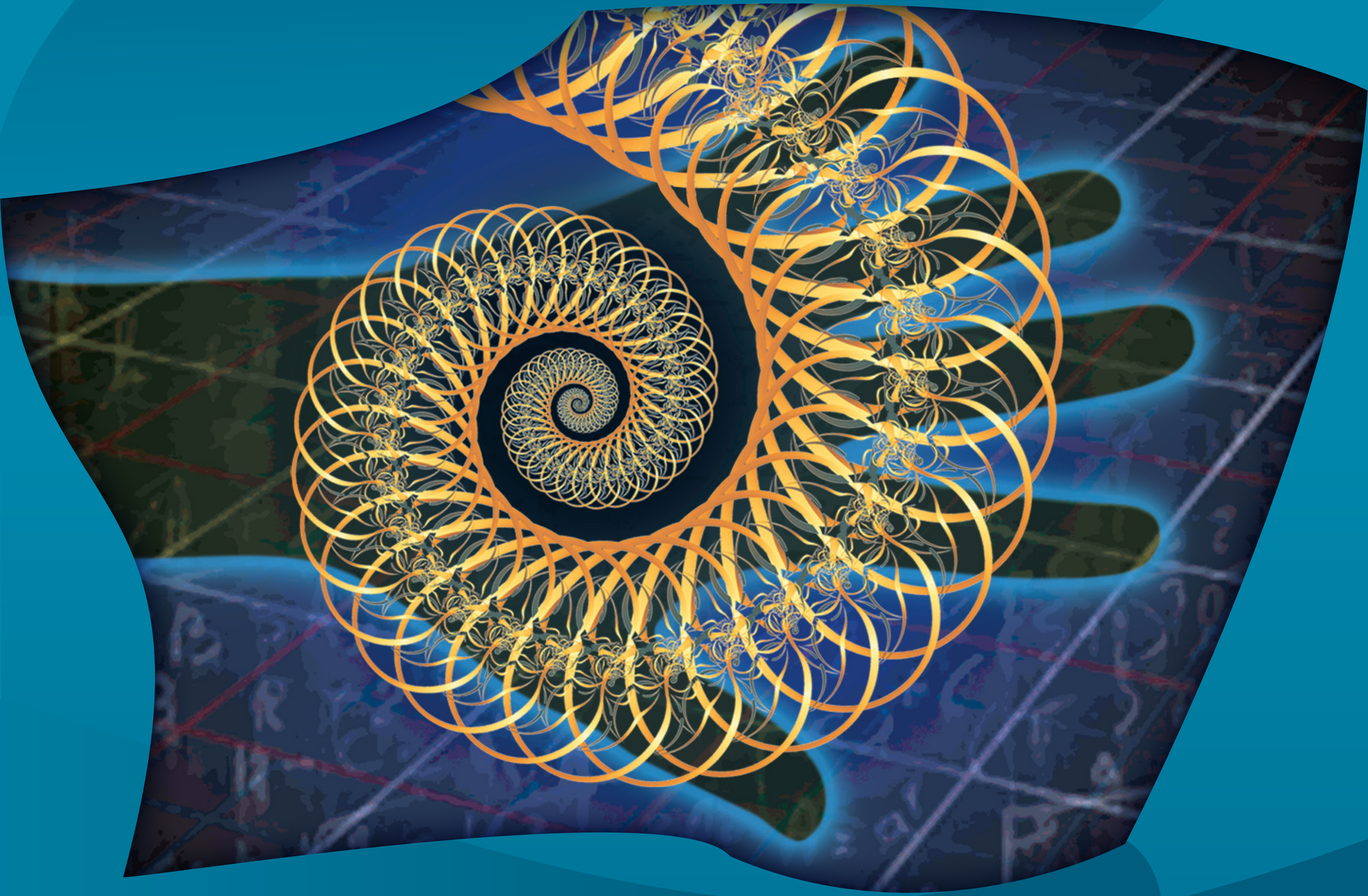
TRENDS IN INTERNATIONAL MATHEMATICS AND SCIENCE STUDY

TIMSS



TIMSS 2011 Assessment Frameworks

Ina V.S. Mullis, Michael O. Martin, Graham J. Ruddock, Christine Y. O'Sullivan, and Corinna Preuschoff

TIMSS & PIRLS International Study Center
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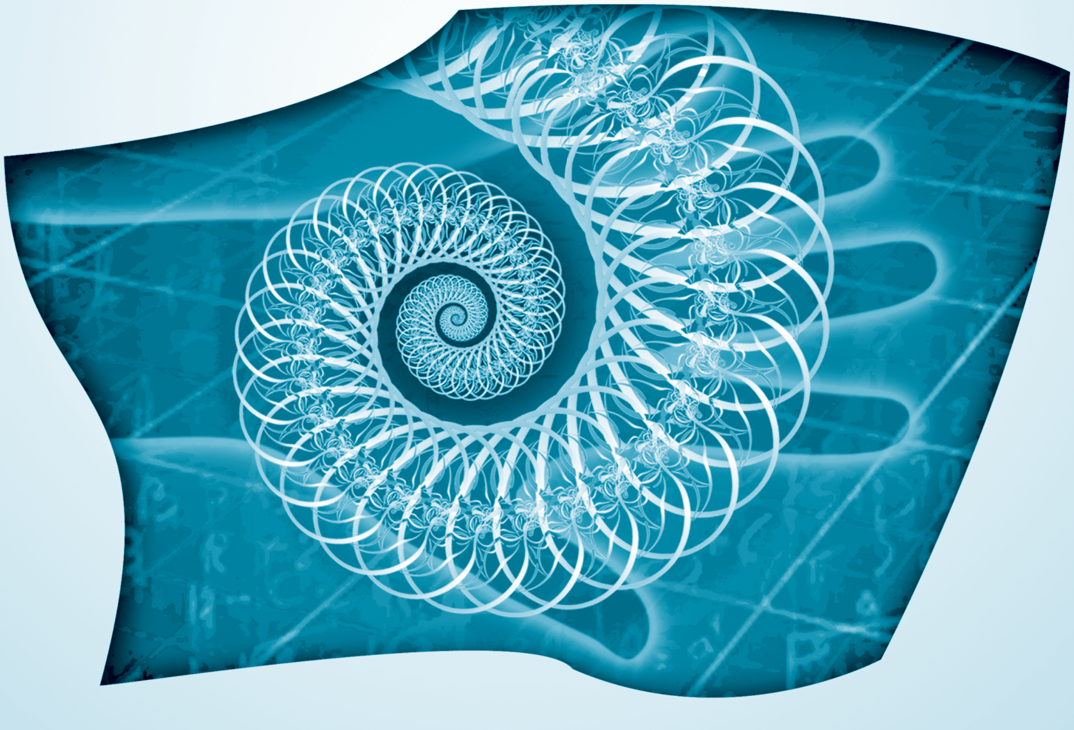

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TIMSS & PIRLS
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Foreword

TIMSS (the Trends in International Mathematics and Science Study) is a truly global, cooperative enterprise involving more than 60 countries from all around the world. There is enormous diversity among the TIMSS countries—in terms of economic development, geographical location, and population size. However, all have a common desire to improve the mathematics and science education of their students, and the conviction that comparing education systems in terms of their organization, curricula, instructional practices and corresponding student achievement is an effective policy analysis tool.

TIMSS 2011 is the fifth in the series of TIMSS assessments. Since first being conducted in 1995, TIMSS has reported every four years on the achievement of fourth and eighth grade students in countries all around the world. Countries that have participated in successive waves of TIMSS (1995, 1999, 2003, 2007, and now 2011) have access to unparalleled information about the improvement or decline in the mathematics and science achievement of their students. Central to the success of TIMSS has been participating countries' expertise in the areas of curriculum, measurement, and education, and their willingness to work together in the interests of improving mathematics and science education.

TIMSS is a project of the International Association for the Evaluation of Educational Achievement (IEA), an independent, international cooperative of national educational research institutions and governmental research agencies dedicated to improving education. IEA's mission is to provide high quality information on student achievement outcomes and on the educational contexts in which students achieve. Fundamental to IEA's vision is the notion that the diversity of educational philosophies, models, and approaches that characterize the world's educational systems constitute a natural laboratory in which each country can learn from the experiences of the others. Founded in 1959 for the purpose of conducting comparative studies focusing on educational policies and practices in countries around the world, IEA's membership has since grown to include more than 60 countries. It has a Secretariat located in Amsterdam, the Netherlands, and a Data Processing and Research Center in Hamburg, Germany. IEA studies have reported on a wide range of topics and subject matters, each contributing to a deep understanding of educational processes within individual countries and within a broad international context.

The *TIMSS 2011 Assessment Frameworks* provides a template for IEA's work in the assessment of mathematics and science at fourth and eighth grades. Building on the widely-accepted frameworks prepared for the 2007 assessment, this document is the product of an extensive collaborative process involving many individuals and expert groups from around the world, most notably the TIMSS advisory groups in mathematics and science and the National Research Coordinators (NRCs) of the more than 60 participating countries. The iterative process of consultation, collaboration, and systematic review among representatives of the TIMSS countries, the mathematics and science research community and other experts ensures that the document reflects the latest advances in thinking about large scale comparative assessment of mathematics and science and embodies the interests of many individuals and countries around the world.

Funding for TIMSS was provided by the National Center for Education Statistics of the U.S. Department of Education and the participating countries, with support from Boston College and the U.K.'s National Foundation for Educational Research.

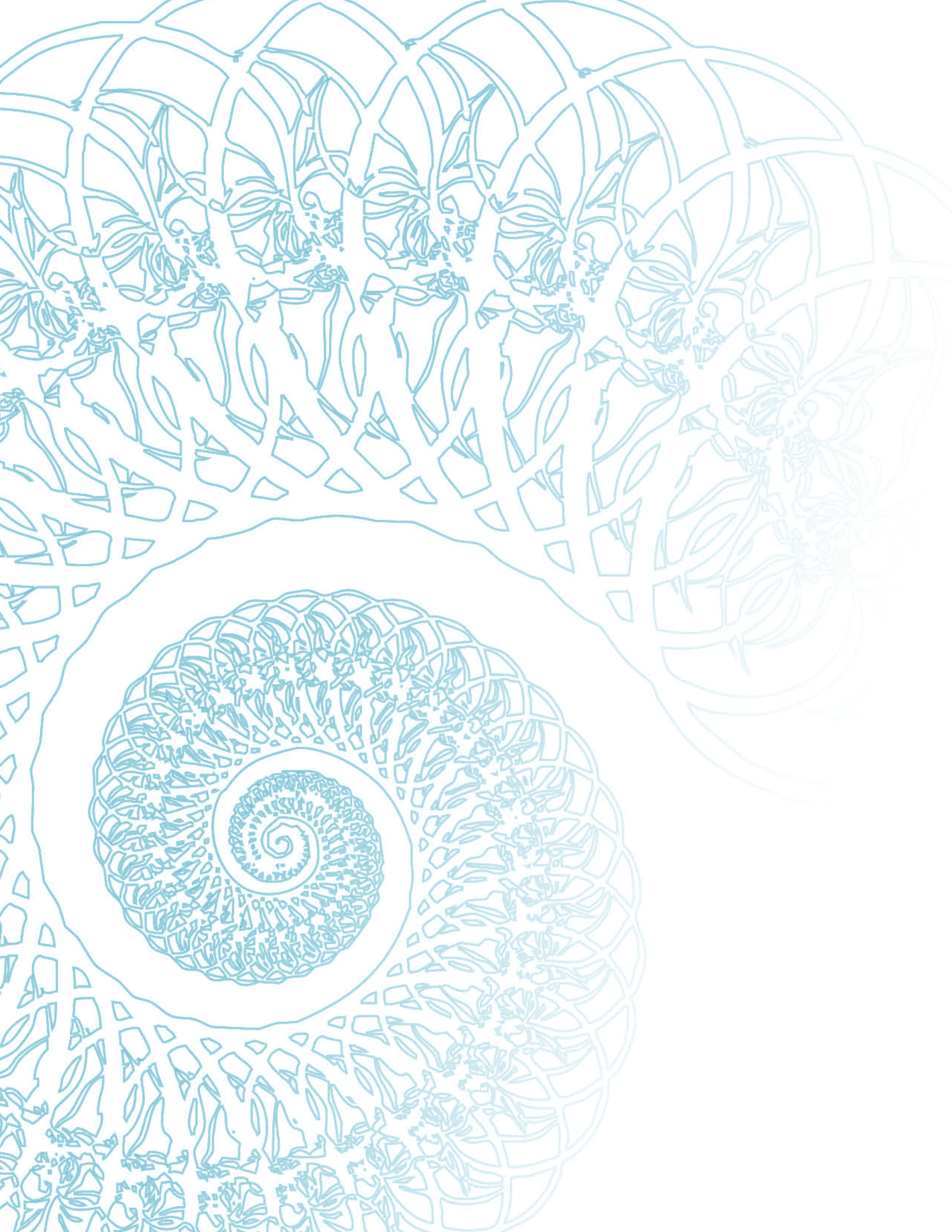
The work presented in this document represents the efforts of many individuals and groups. TIMSS is directed by IEA's

TIMSS & PIRLS International Study Center at Boston College, from which it derives the direction and leadership necessary to complete such a complex and ambitious project. Together with the committed and able staff from the consortium of organizations that work to implement TIMSS, including the IEA Data Processing and Research Center and Secretariat, Statistics Canada, and Educational Testing Service, the Center's dedicated staff and consultants have played a vital role in developing the assessment frameworks. Crucial also has been the work of the TIMSS advisory groups in mathematics and science, and in particular that of TIMSS Mathematics Coordinator Graham Ruddock and TIMSS Science Coordinator Christine O'Sullivan. Working closely with the mathematics and science coordinators, Corinna Preuschoff, Ebru Erberber, and Gabrielle Stanco each made major contributions to the frameworks document. All of the Boston College staff, and in particular the TIMSS Executive Directors, Ina V.S. Mullis and Michael O. Martin, have been central to the preparation of this document. To all of them I would like to express my sincere thanks.

Hans Wagemaker
Executive Director, IEA

TIMSS 2011 Assessment Frameworks

Introduction



Introduction

TIMSS 2011 Assessment Frameworks

Overview of TIMSS

Preparing students to excel in mathematics and science is one of the fundamental education goals in countries around the world. Studying mathematics and science during their early years of schooling prepares children to succeed in future educational endeavors and eventually in daily life and the workforce. Effective participation in society increasingly requires understanding of mathematics and science to make informed decisions about personal health and finance as well as about public policy concerning such issues as the environment and economy.

Because of the educational importance of mathematics and science, IEA's Trends in International Mathematics and Science Study, widely known as TIMSS, is dedicated to providing countries with information to improve teaching and learning in these curriculum areas. Conducted every four years on a regular cycle, TIMSS assesses achievement in mathematics and science at the fourth and eighth grades. The achievement data are collected together with extensive background information about the availability of school resources and the quality of curriculum and instruction. TIMSS provides countries with an unprecedented opportunity to measure progress in educational achievement in mathematics and science together with empirical information about the contexts for schooling.

As a project of the International Association for the Evaluation of Educational Achievement (IEA), TIMSS has the benefit of drawing on the cooperative expertise provided by representatives from countries all around the world. The IEA is an independent international cooperative of national research institutions and government agencies that has been conducting studies of cross-national achievement since 1959. As of 2009, IEA had 68 institutional members. TIMSS is directed by the TIMSS & PIRLS International Study Center at Boston College.

Monitoring Trends

TIMSS 2011 is the most recent in the TIMSS series, which began with the first assessment in 1995 and has continued with subsequent assessments in 1999, 2003, and 2007. For countries with data back to 1995, TIMSS 2011 will provide the fifth trend measure. Approximately 60 countries have TIMSS trend data, and new countries join TIMSS in each cycle. Nearly 70 countries are expected to participate in TIMSS 2011. Additionally, to provide each participating country with an extensive resource for interpreting its achievement results and to track changes in curriculum and instructional practices, TIMSS asks students, their teachers, and their school principals to complete questionnaires about the contexts for learning mathematics and science. TIMSS also collects detailed information about the mathematics and science curricula in each country. Trend data from these questionnaires provide a dynamic picture of changes in the implementation of educational policies and practices and help to raise new issues relevant to improvement efforts.

The results from the TIMSS 2007 mathematics and science assessments were reported in two companion volumes: the *TIMSS 2007 International Mathematics Report* (Mullis, Martin, & Foy, 2008) and the *TIMSS 2007 International Science Report* (Martin, Mullis, & Foy, 2008). These reports contain the results from the TIMSS 2007 mathematics and science assessments at the fourth and eighth grades, including trends over time in achievement and the educational contexts for mathematics and science instruction. Through the years, TIMSS data have had an enduring impact on reform and development efforts in mathematics and science education around the world, leading on one hand to continuing demand for trend data to monitor development and on the other hand to a need for more and better policy-relevant information to guide and evaluate new initiatives.

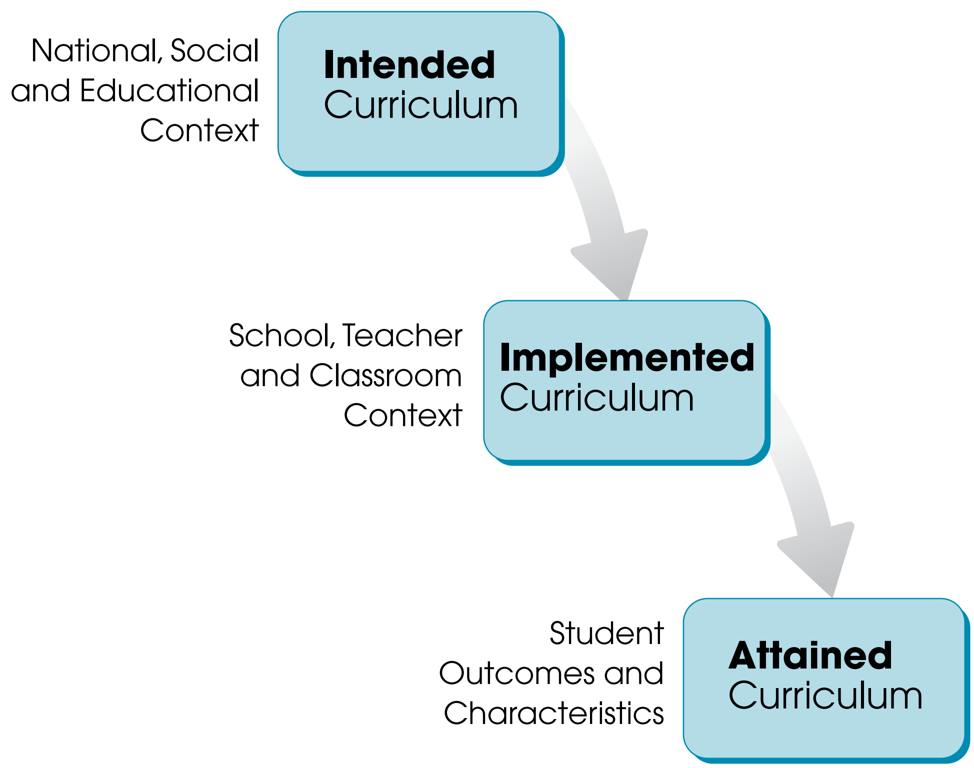
The TIMSS 2011 Assessment Frameworks

This publication, the *TIMSS 2011 Assessment Frameworks*, contains three frameworks and explains the assessment design that will serve as the basis for implementing TIMSS 2011. The *TIMSS 2011 Mathematics Framework* and the *TIMSS 2011 Science Framework* in Chapters 1 and 2, respectively, describe in some detail the major content and cognitive domains in mathematics and science to be tested at the fourth and eighth grades. The content domains (for example, algebra, geometry, etc. in mathematics, and biology, chemistry, etc. in science) and the topic areas within the domains are described separately for the fourth and eighth grades with each topic area elaborated with specific objectives. The cognitive domains describing the thinking students should be doing within the mathematics and science content domains are the same for mathematics and science and parallel across grades, but with different levels of emphasis. Chapter 3 contains the *TIMSS 2011 Contextual Framework* describing the types of situations and factors associated with students' learning in mathematics and science that will be investigated via the questionnaires. Finally, Chapter 4 provides an overview of the *TIMSS 2011 Assessment Design*, including general parameters for item development.

The TIMSS Curriculum Model

Building on earlier IEA studies of mathematics and science achievement, TIMSS uses the curriculum, broadly defined, as the major organizing concept in considering how educational opportunities are provided to students, and the factors that influence how students use these opportunities. The TIMSS curriculum model has three aspects: the intended curriculum, the implemented curriculum, and the achieved curriculum (see Exhibit 1). These represent, respectively, the mathematics and science that society intends for students to learn and how the education system should be organized to facilitate this learning; what is actually taught in classrooms, the characteristics of those teaching it, and how it is taught; and, finally, what it is that students have learned, and what they think about these subjects.

Exhibit 1: TIMSS Curriculum Model



Working from this model, TIMSS uses mathematics and science achievement tests to describe student learning in the participating countries, together with the TIMSS Encyclopedia and questionnaires, to provide extensive information about students' opportunity to learn. TIMSS asks countries to provide information about the level of mathematics and science students are expected to learn via the TIMSS Encyclopedia and the curriculum questionnaires. For example, the *TIMSS 2007 Encyclopedia* (Mullis, Martin, Olson, Berger, Milne, & Stanco, 2008) provided information from the countries participating in TIMSS 2007 about their national contexts for mathematics and science education as well as descriptions of their mathematics and science curricula. The more qualitative information provided in the *TIMSS 2007 Encyclopedia* complements both the *TIMSS 2007 International Mathematics Report* and the *TIMSS 2007 International Science Report*. The international reports contain extensive questionnaire data about the structure and rigor of the intended curriculum in mathematics and the efforts extended to help students actually learn the curriculum. For example, the questionnaire data include teachers' reports about their preparation, experience, and attitudes; the mathematics and science content actually taught to the students assessed for TIMSS; the instructional approaches used in teaching mathematics and science; and the resources available in classrooms and schools to support mathematics and science teaching and learning.

The Development Process for the TIMSS 2011 Assessment Frameworks

The TIMSS assessment frameworks for 2011 were updated from those used in the *TIMSS 2007 Assessment Frameworks* (Mullis, Martin, Ruddock, O'Sullivan, Arora, & Erberber, 2005). Updating the frameworks regularly provides participating countries greater opportunity to review and provide information about the frameworks and results in more coherence from assessment to assessment, permitting the frameworks, the instruments, and the procedures to evolve gradually into the future.

For TIMSS 2011, the frameworks were discussed by representatives of the participating countries at their first meeting. Each country identifies a TIMSS National Research Coordinator (NRC) to work with the international project staff to ensure that the study is responsive to the country's concerns. The NRCs are responsible for implementing the study in their countries in accordance with TIMSS methods and procedures. The NRCs also consulted with their national experts and responded to questionnaires about how best to update the content and cognitive domains for TIMSS 2011. The questionnaires attempted to garner each country's views about adding or deleting particular assessment topic areas and objectives.

Revised on the basis of input from the participating countries, the frameworks were reviewed in-depth by the TIMSS 2011 Science and Mathematics Item Review Committee (SMIRC). Using an iterative process, the frameworks as revised by SMIRC were once again reviewed by the NRCs and updated finally prior to publication. The *TIMSS 2011 Assessment Frameworks* document closely resembles that for TIMSS 2007. Since it is crucial to have continuity in a study designed to measure trends in educational achievement over time, this is very appropriate. However, there are some notable revisions.

In the discussions about updating the frameworks held by the NRCs and the SMIRC as well as by the IEA and TIMSS management and technical groups, the emphasis has been on improving the quality of measurement in the assessments for TIMSS 2011 and on increasing the utility of results for participating countries. This includes assessing content appropriate to the students and important to their future lives, ensuring adequate response time for students, increasing operational feasibility, and maximizing the potential to improve reporting achievement in the content and cognitive domains assessed.

TIMSS and PIRLS in 2011

To be particularly relevant to decision-making and implementing school policy, TIMSS assesses students at two important educational milestones—at the end of four years of formal schooling (end of primary school) and the end of eight years of formal schooling (end of lower-secondary education). Because TIMSS studies the effectiveness of curriculum and instruction in relation to student achievement, it is important for TIMSS to assess mathematics and science achievement at the same point in schooling across countries. That is, for fair comparisons, students should have had the opportunity to learn mathematics and science for an equivalent number of years of formal schooling.

TIMSS data complement IEA's Progress in International Reading Literacy Study (PIRLS) conducted at the fourth grade. By participating in TIMSS and PIRLS, countries can have information at regular intervals about how well their students read and what they know and can do in mathematics and science. 2011 presents a unique opportunity for international assessment at the fourth grade, because the four-year cycle of TIMSS will be in alignment with the five-year cycle of PIRLS. PIRLS is being conducted for the third time in 2011 after assessments in 2001 and 2006.

Because IEA's TIMSS and PIRLS international assessments both will be conducted in 2011, countries have the opportunity to conduct a comprehensive assessment of mathematics, science, and reading at the fourth grade. This will enable countries to profile students' relative strengths in mathematics, science, and reading in an international context. The assessments will include an extensive array of contextual background information for improving teaching and learning in these three basic curriculum areas. Since PIRLS has a questionnaire administered to students' parents or caregivers, participation in TIMSS together with PIRLS gives countries an opportunity to collect information from parents about early learning in mathematics and science as well as other characteristics of students' home environments.

What is the value of TIMSS?

TIMSS provides valuable information that helps countries monitor and evaluate their mathematics and science teaching across time and across grades. More information about TIMSS can be found on the website: http://timssandpirls.bc.edu

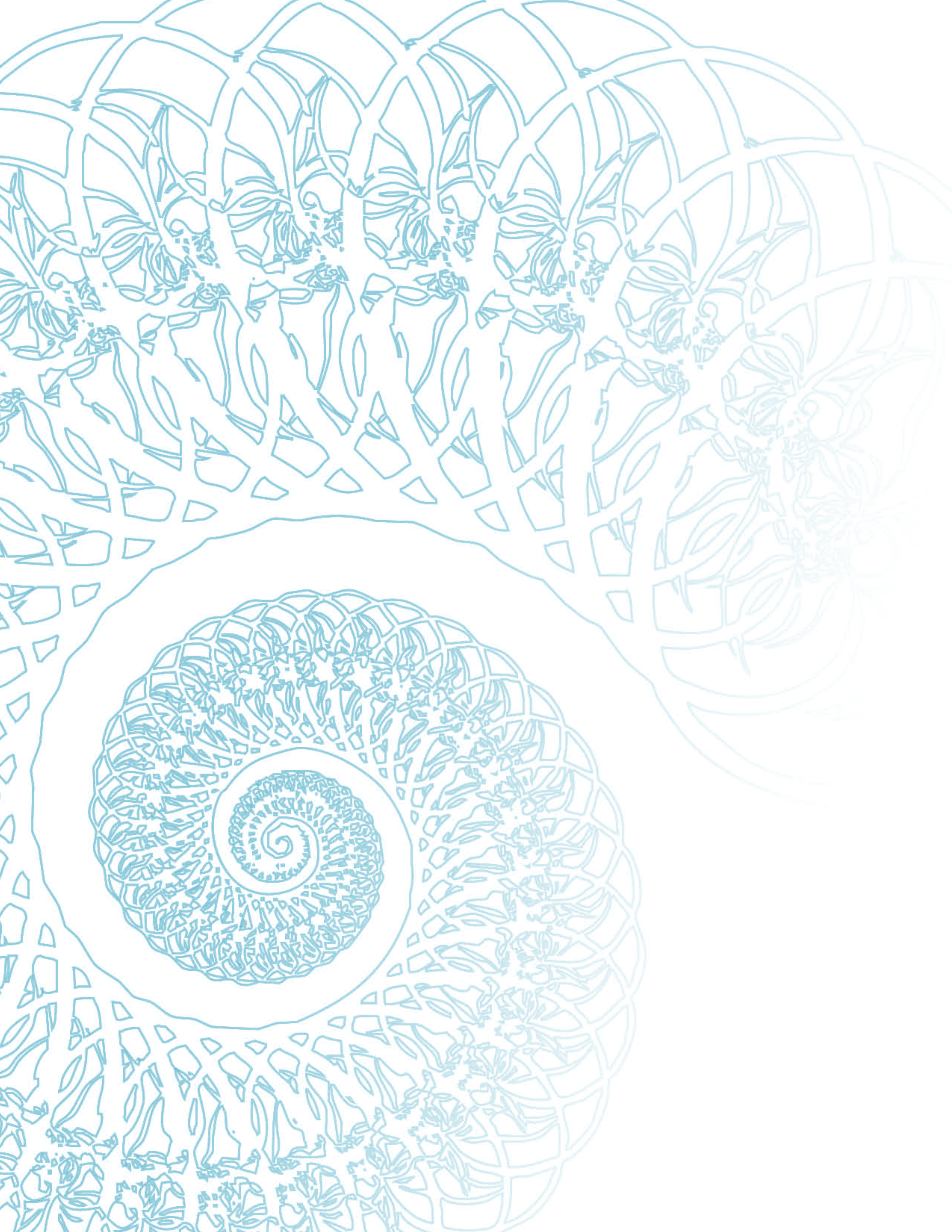
By participating in TIMSS, countries can:

- Have comprehensive and internationally comparable data about what mathematics and science concepts, processes, and attitudes students have learned by the fourth and eighth grades.
- Assess progress internationally in mathematics and science learning across time for students at the fourth grade and for students at the eighth grade.
- Identify aspects of growth in mathematical and scientific knowledge and skills from fourth grade to eighth grade.
- Monitor the relative effectiveness of teaching and learning at the fourth as compared to the eighth grade, since the cohort of fourth-grade students is assessed again as eighth graders.

- Understand the contexts in which students learn best. TIMSS enables international comparisons among the key policy variables in curriculum, instruction, and resources that result in higher levels of student achievement.
- Use TIMSS to address internal policy issues. Within countries, for example, TIMSS provides an opportunity to examine the performance of population subgroups and address equity concerns. It is efficient for countries to add questions of national importance (national options) as part of their data collection effort.

TIMSS 2011 Mathematics Framework

Chapter 1



Chapter 1

TIMSS 2011 Mathematics Framework

Overview

Students should be educated to recognize mathematics as an immense achievement of humanity, and to appreciate its nature. Nevertheless, learning mathematics for its own sake is probably not the most compelling reason for universal inclusion of mathematics in school curricula. Prime reasons for having mathematics as a fundamental part of schooling include the increasing awareness that effectiveness as a citizen and success in a workplace are greatly enhanced by knowing and, more important, being able to use mathematics. The number of vocations that demand a high level of proficiency in the use of mathematics, or mathematical modes of thinking, has burgeoned with the advance of technology, and with modern management methods.

This chapter contains the framework for the TIMSS 2011 mathematics assessments at the fourth and eighth grades. The *TIMSS 2011 Mathematics Framework* is very similar to that used in TIMSS 2007 with only minor updates to particular topics. Updates were based on the information in the *TIMSS 2007 Encyclopedia* and the *TIMSS 2007 International Mathematics Report* as well as recommendations made during the reviews conducted by the mathematics experts and countries participating in TIMSS 2011.[1] At each grade, the mathematics assessment framework for TIMSS 2011 is organized around two dimensions, a content dimension specifying the domains or subject matter to be assessed within mathematics (for example, number, algebra, geometry, and data and chance at the

1 Special attention was paid during the reviews to reflect current research concerning mathematics education and assessment such as that documented in *The Final Report of the National Mathematics Advisory Panel* published in 2008 by the U.S. Department of Education, including *Curriculum Focal Points for Prekindergarten through Grade 8 Mathematics* (NCTM, 2006) extending the work published in the *Principles and Standards for School Mathematics* (NCTM, 2000).

eighth grade) and a cognitive dimension specifying the domains or thinking processes to be assessed (that is, knowing, applying, and reasoning). The cognitive domains describe the sets of behaviors expected of students as they engage with the mathematics content.

Exhibit 2 shows the target percentages of testing time devoted to each content and cognitive domain for the TIMSS 2011 fourth- and eighth-grade assessments.

Exhibit 2: Target Percentages of the TIMSS 2011 Mathematics Assessment Devoted to Content and Cognitive Domains at Fourth and Eighth Grades

Fourth Grade

Content Domains	Percentages
Number	50%
Geometric Shapes and Measures	35%
Data Display	15%

Eighth Grade

Content Domains	Percentages
Number	30%
Algebra	30%
Geometry	20%
Data and Chance	20%

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

The content and cognitive domains are the foundation of the TIMSS 2011 fourth- and eighth-grade assessments. The content domains differ for the fourth and eighth grades, reflecting the nature and difficulty of the mathematics widely taught at each grade. There is more emphasis on number at the fourth grade than at the eighth grade. At the eighth grade, two of the four content domains are algebra and geometry, but since algebra and geometry generally are not taught as formal subjects in primary school, the introductory algebra concepts assessed at the fourth grade are included as part of number and the geometric domain focuses on geometric shapes and measures. At the fourth grade, the domain pertaining to data focuses on reading and displaying data whereas at the eighth grade it includes more emphasis on interpretation of data and the fundamentals of probability (called "chance").

The cognitive domains are the same for both grades, encompassing a range of cognitive processes involved in working mathematically and solving problems right through the primary and middle school years.

The content and cognitive domains for the mathematics assessment are discussed in detail in the following sections. The content domains for the fourth grade are presented first, followed by those for the eighth grade. Each content domain has several topic areas (i.e., number at eighth grade is further categorized by whole numbers; fractions and decimals; integers; and ratio, proportion, and percent). Each topic area is presented as a list of objectives covered in many participating countries, at either fourth grade or eighth grade as appropriate. The cognitive domains, applicable to both grades, then follow. Example mathematics items and tasks are presented in Appendix B.

Mathematics Content Domains – Fourth Grade

The content domains described in the *TIMSS 2011 Mathematics Framework* for the fourth grade and the target percentages of testing time devoted to each are shown below in Exhibit 3.

Exhibit 3: Target Percentages of the TIMSS 2011 Mathematics Assessment Devoted to Content Domains at Fourth Grade

Fourth-Grade Content Domains	Percentages
Number	50%
Geometric Shapes and Measures	35%
Data Display	15%

The content domains define the specific mathematics subject matter covered by the TIMSS 2011 assessment at fourth grade. Each content domain has several topic areas; each one is presented as a list of objectives covered in the mathematics curriculum in the majority of participating countries. These grade specific objectives are written in terms of student understandings or abilities that items aligned with these objectives are designed to elicit. The following sections describe each of the mathematics content domains at fourth grade.

Number

The number content domain for the fourth grade includes understanding of place value, ways of representing numbers, and the relationships between numbers. At the fourth grade, students should have developed number sense and computational fluency, understand the meanings of operations and how they relate to one another, and be able to use numbers and operations (i.e., add, subtract, multiply, and divide) to solve problems. They should be familiar with a range of number patterns, exploring the relationships between the numbers which are in the pattern or are used to derive it.

The number content domain consists of understandings and skills related to four topic areas:

- Whole number
- Fractions and decimals
- Number sentences with whole numbers
- Patterns and relationships

Since whole numbers provide the easiest introduction to operations with numbers that are basic to the development of mathematics, working with whole numbers is the foundation of mathematics in the primary school. The TIMSS 2011 content framework reflects this. Most children learn to count at a young age and can solve simple addition, subtraction, multiplication, and division problems during the first few years of school. Fourth-grade students should be able to compute with whole numbers of reasonable size; estimate sums, differences, products, and quotients; and use computation to solve problems.

Students also should be using their grasp of number to understand the relationships between units of measurement and to convert from one unit to another. Such relationships should include the multiples of 10 found in the metric system of measurement and other familiar ones such as the relationships between seconds, minutes, hours, and days.

At the fourth grade, pre-algebraic concepts and skills are also part of the TIMSS assessment. The focus is on the type of understanding, which is built upon later to develop more formal, algebraic thinking. Understandings related to simple equations—in the form of number sentences—and to number patterns are included.

Students should be working with number sentences and finding missing numbers in them, working towards the idea of finding a value for an unknown, and using number sentences to model simple situations involving one of the four operations. They should be exploring well-defined number patterns, investigating the relationships between their terms, and finding or using the rules that generate them.

In the area of common fractions and decimal fractions, the emphasis is on representation of fractions and understanding what quantities the symbols represent. At the fourth grade, students should be able to compare familiar fractions and decimals.

Number: Whole Numbers

1. Demonstrate knowledge of place value, including recognizing and writing numbers in expanded form and representing whole numbers using words, diagrams, or symbols.
2. Compare and order whole numbers.
3. Compute with whole numbers (+, −, ×, ÷) and estimate such computations by approximating the numbers involved.
4. Recognize multiples and factors of numbers.
5. Solve problems, including those set in real life contexts and those involving measurements, money, and simple proportions.

Number: Fractions and Decimals

1. Show understanding of fractions by recognizing fractions as parts of unit wholes, parts of a collection, locations on number lines, and by representing fractions using words, numbers, or models.
2. Identify equivalent simple fractions; compare and order simple fractions.
3. Add and subtract simple fractions.
4. Show understanding of decimal place value including representing decimals using words, numbers, or models.
5. Add and subtract decimals.
6. Solve problems involving simple fractions or decimals.

Note: Fourth-grade fractions items will involve denominators of 2, 3, 4, 5, 6, 8, 10, 12, or 100.
Fourth-grade decimals items will involve decimals to tenths and/or hundredths.

Number: Number Sentences with Whole Numbers

1. Find the missing number or operation in a number sentence (e.g., 17 + ■ = 29).
2. Model simple situations involving unknowns with expressions or number sentences.

Number: Patterns and Relationships

1. Extend or find missing terms in a well-defined pattern, describe relationships between adjacent terms in a sequence and between the sequence number of the term and the term.
2. Write or select a rule for a relationship given some pairs of whole numbers satisfying the relationship, and generate pairs of whole numbers following a given rule (e.g., multiply the first number by 3 and add 2 to get the second number).

Geometric Shapes and Measures

The geometric shapes and measures domain includes properties of geometrical figures such as lengths of sides, sizes of angles, areas, and volumes. Students should be able to identify and analyze the properties and characteristics of lines, angles, and a variety of geometric figures, including two- and three-dimensional shapes, and to provide explanations based on geometric relationships. This domain includes understanding informal coordinate systems and using spatial visualization skills to relate between two- and three-dimensional representations of the same shape.

The two topic areas in geometric shapes and measures are:

- Points, lines, and angles
- Two- and three-dimensional shapes

Spatial sense is integral to the study and assessment of geometry. At the fourth grade, students will be asked to describe, visualize, and draw a variety of geometric figures, including angles, lines, triangles, quadrilaterals, and other polygons. Students should be able to make and decompose compound shapes of common geometric figures. They should be able to recognize line symmetry, draw symmetrical figures, and describe rotations.

At the fourth grade, appropriate performances expected of students include the use of instruments and tools to measure physical attributes, including length, area, volume, and angle. Knowledge about which units to use in particular contexts should underlie their measurement skills. Students at this grade are also expected to use approximation and estimation and simple formulas to calculate areas and perimeters of squares and rectangles.

Geometric Shapes and Measures: Points, Lines, and Angles

1. Measure and estimate lengths.
2. Identify and draw parallel and perpendicular lines.
3. Compare angles by size and draw angles (e.g., a right angle, angles larger or smaller than a right angle).
4. Use informal coordinate systems to locate points in a plane.

Geometric Shapes and Measures: Two- and Three-dimensional Shapes

1. Identify, classify and compare common geometric figures (e.g., classify or compare by shape, size, or properties).
2. Recall, describe, and use elementary properties of geometric figures, including line and rotational symmetry.
3. Recognize relationships between three-dimensional shapes and their two-dimensional representations.
4. Calculate areas and perimeters of squares and rectangles; determine and estimate areas and volumes of geometric figures (e.g., by covering with a given shape or by filling with cubes).

Data Display

The data display content domain includes reading and interpreting displays of data. It also includes understanding how to organize data and how to display it in graphs and charts that will be useful in answering the questions that prompted the data collection. Students should be able to compare characteristics of data and to draw conclusions based on data displays.

The data content domain consists of the following major topic areas:

- Reading and interpreting
- Organizing and representing

At the fourth grade, students should be able to read various data displays. Students also can engage in simple data-gathering plans or work with data that have been gathered by others. They should be developing skills in representing data and recognizing a variety of forms of data display.

Data Display: Reading and Interpreting

1. Read scales and data from tables, pictographs, bar graphs, and pie charts.
2. Compare information from related data sets (e.g., given data or representations of data on the favorite flavors of ice cream in four or more classes, identify the class with chocolate as the most popular flavor).
3. Use information from data displays to answer questions that go beyond directly reading the data displayed (e.g., combine data, perform computations based on the data, make inferences, and draw conclusions).

Data Display: Organizing and Representing

1. Compare and match different representations of the same data.
2. Organize and display data using tables, pictographs, and bar graphs.

Mathematics Content Domains – Eighth Grade

The content domains described in the *TIMSS 2011 Mathematics Framework* for the eighth grade and the target percentages of testing time devoted to each are shown below in Exhibit 4.

Exhibit 4: Target Percentages of the TIMSS 2011 Mathematics Assessment Devoted to Content Domains at Eighth Grade

Eighth-Grade Content Domains	Percentages
Number	30%
Algebra	30%
Geometry	20%
Data and Chance	20%

The content domains define the specific mathematics subject matter covered by the TIMSS 2011 assessment at eighth grade. Each content domain has several topic areas; each one is presented as a list of objectives covered in the mathematics curriculum in the majority of participating countries. These grade specific objectives are written in terms of student understandings or abilities that items aligned with these objectives are designed to elicit. Sometimes the wording of objectives is similar or identical for fourth and eighth grades. In these instances, the progression in learning between the two grades is established by the difficulty of the items used. The following sections describe each of the mathematics content domains at eighth grade.

Number

The number content domain includes understanding of numbers, ways of representing numbers, relationships among numbers, and number systems. At the eighth grade, students should have developed number sense and computational fluency, understand the meanings of operations and how they relate to one another, and be able to use numbers and operations to solve problems.

The number content domain consists of understandings and skills related to:

- Whole numbers
- Fractions and decimals
- Integers
- Ratio, proportion, and percent

The emphasis within computation is on fractions and decimals rather than on whole numbers. Within fractions and decimals, the emphasis is on representation and translation between forms, understanding what quantities the symbols represent, computation, and problem solving. By the eighth grade, students should be able to move flexibly among equivalent fractions, decimals, and percents using a range of strategies.

Eighth-grade students should have extended their mathematical understanding from whole numbers to integers, including order and magnitude as well as operations with integers. Students should also be able to work with percents and proportions and use proportional reasoning to solve problems.

The problems students will be asked to solve include both the routine and the non-routine, those set in everyday contexts and those where mathematics itself is the context. Some problems involve computation with a range of measures and units of measurement.

Number: Whole Numbers

1. Demonstrate understanding of the principles of whole numbers and operations with them (e.g., knowledge of the four operations, place value, commutativity, associativity, and distributivity).
2. Find and use multiples or factors of numbers, identify prime numbers, and evaluate powers of numbers and square roots of perfect squares to 144.
3. Solve problems by computing, estimating, or approximating with whole numbers.

Number: Fractions and Decimals

1. Compare and order fractions; recognize and write equivalent fractions.
2. Demonstrate understanding of place value for finite decimals (e.g., by comparing or ordering them).
3. Represent fractions and decimals and operations with fractions and decimals using models (e.g., number lines); identify and use such representations.
4. Convert between fractions and decimals.
5. Compute with fractions and decimals and solve problems involving them.

Number: Integers

1. Represent, compare, order, and compute with integers and solve problems using them.

Number: Ratio, Proportion, and Percent

1. Identify and find equivalent ratios; model a given situation by using a ratio and divide a quantity in a given ratio.
2. Convert between percents and fractions or decimals.
3. Solve problems involving percents and proportions.

Algebra

While functional relationships and their uses for modeling and problem solving are of prime interest, it is also important to assess how well the supporting knowledge and skills have been learned. The algebra content domain includes recognizing and extending patterns, using algebraic symbols to represent mathematical situations, and developing fluency in producing equivalent expressions and solving linear equations.

The major topic areas in algebra are:

- Patterns
- Algebraic expressions
- Equations/formulas and functions

Algebraic concepts are relatively formalized by this grade, and students should have developed an understanding of linear relationships and the concept of variable. Students at this level are expected to use and simplify algebraic formulas, solve linear equations, inequalities, pairs of simultaneous equations involving two variables, and use a range of functions. They should be able to solve real-world problems using algebraic models and to explain relationships involving algebraic concepts.

Algebra: Patterns

1. Extend well-defined numeric, algebraic, and geometric patterns or sequences using numbers, words, symbols, or diagrams; find missing terms.
2. Generalize pattern relationships in a sequence, or between adjacent terms, or between the sequence number of the term and the term, using numbers, words, or algebraic expressions.

Algebra: Algebraic Expressions

1. Find sums, products, and powers of expressions containing variables.
2. Evaluate expressions for given numeric values of the variable(s).
3. Simplify or compare algebraic expressions to determine if they are equal.
4. Model situations using expressions.

Algebra: Equations/Formulas and Functions

1. Evaluate equations/formulas given values of the variables.
2. Indicate whether a value (or values) satisfies a given equation/formula.
3. Solve linear equations and linear inequalities, and simultaneous (two variables) linear equations.
4. Recognize and write equations, inequalities, simultaneous equations, or functions that model given situations.
5. Recognize and generate representations of functions in the form of tables, graphs, or words.
6. Solve problems using equations/formulas and functions.

Geometry

Eighth-grade students should be able to analyze the properties and characteristics of a variety of two and three-dimensional geometric figures, including lengths of sides and sizes of angles, and to provide explanations based on geometric relationships. They should be able to apply the Pythagorean Theorem to solve problems. The focus should be on using geometric properties and their relationships.

Alongside their appreciation of geometric properties and relationships, students also should be competent in geometric measurement, using measuring instruments accurately, estimating where appropriate, and selecting and using formulas for perimeters, areas, and volumes. The geometry content area also includes understanding coordinate representations and using spatial visualization skills to move between two- and three-dimensional shapes and their representations. Students should be able to use symmetry and apply transformation to analyze mathematical situations.

The three topic areas in geometry are:

- Geometric shapes
- Geometric measurement
- Location and movement

Spatial sense is integral to the study and assessment of geometry. The cognitive range extends from making drawings and constructions to mathematical reasoning about combinations of shapes and transformations. Students will be asked to describe, visualize, draw, and construct a variety of geometric figures, including angles, lines, triangles, quadrilaterals, and other polygons. Students should be able to combine, decompose, and analyze compound shapes. By this grade, they should be able to interpret or create top or side views of objects and use their understanding of similarity and congruence to solve problems.

Students should be able to use the Cartesian plane to locate points and lines. They should be able to recognize line symmetry and draw symmetrical figures. They should understand and be able to describe rotations, translations, and reflections in mathematical terms (e.g., center, direction, and angle).

As students progress through school, using proportional thinking in geometric contexts is important, as is making some initial links between geometry and algebra. Students should be able to solve problems using geometric models and explain relationships involving geometric concepts.

Geometry: Geometric Shapes

1. Identify different types of angles and know and use the relationships between angles on lines and in geometric figures.
2. Recognize geometric properties of common two- and three-dimensional shapes, including line and rotational symmetry.
3. Identify congruent triangles and quadrilaterals and their corresponding measures; identify similar triangles and recall and use their properties.
4. Recognize relationships between three-dimensional shapes and their two-dimensional representations (e.g., nets or two-dimensional views of three-dimensional objects).
5. Apply geometric properties, including the Pythagorean Theorem, to solve problems.

Note: Eighth-grade geometric shapes items will involve circles, the following triangles—scalene, isosceles, equilateral, and right-angled; the following quadrilaterals—scalene, trapezoid, parallelogram, rectangle, rhombus, and square; as well as other polygons including pentagon, hexagon, octagon, and decagon.

Geometry: Geometric Measurement

1. Draw given angles and lines; measure and estimate the size of given angles, line segments, perimeters, areas, and volumes.
2. Select and use appropriate measurement formulas for perimeters, circumferences, areas, surface areas, and volumes; find measures of compound areas.

Geometry: Location and Movement

1. Locate points in the Cartesian plane, and solve problems including such points.
2. Recognize and use geometric transformations (translation, reflection, and rotation) of two-dimensional shapes.

Data and Chance

The data and chance content domain includes knowing how to organize data that have been collected by oneself or others and how to display data in graphs and charts that will be useful in answering questions that prompted the data collection. This content domain includes understanding issues related to misinterpretation of data.

The data and chance content domain consists of the following three major topic areas:

- Data organization and representation
- Data interpretation
- Chance

Students can engage in simple data-gathering plans or work with data that have been gathered by others or generated by simulations. They should understand what various numbers, symbols, and points mean in data displays. For example, they should recognize that some numbers represent the values of the data and others represent the frequency with which those values occur. Students should develop skill in representing their data using bar graphs, tables, or line graphs. They should be able to recognize and compare the relative merits of various types of displays.

Students should be able to describe and compare characteristics of data (shape, spread, and central tendency), and draw conclusions based on data displays. Students should be able to identify trends in data, make predictions based on data, and evaluate the reasonableness of interpretations.

Eighth-grade students' appreciation of chance (elementary probability) should include being able to designate the occurrence of familiar events as certain; as having greater, equal, or less likelihood; or as impossible, and should extend to using data from experiments or knowledge of equally likely outcomes to predict the chance of a given outcome.

Data and Chance: Data Organization and Representation

1. Read scales and data from tables, pictographs, bar graphs, pie charts, and line graphs.
2. Organize and display data using tables, pictographs, bar graphs, pie charts, and line graphs.
3. Compare and match different representations of the same data.

Data and Chance: Data Interpretation

1. Identify, calculate and compare characteristics of data sets, including mean, median, mode, range, and shape of distribution (in general terms).
2. Use and interpret data sets to answer questions and solve problems (e.g., make inferences, draw conclusions, and estimate values between and beyond given data points).
3. Recognize and describe approaches to organizing and displaying data that could lead to misinterpretation (e.g., inappropriate grouping and misleading or distorted scales).

Data and Chance: Chance

1. Judge the chance of an outcome as certain, more likely, equally likely, less likely, or impossible.
2. Use data to estimate the chances of future outcomes; use the chances of a particular outcome to solve problems; determine the chances of possible outcomes.

Guidelines for Calculator Use

Although technology in the form of calculators and computers can help students learn mathematics, it should not be used to replace basic understanding and competencies. Like any teaching tool, calculators need to be used appropriately, and policies for their use differ across the TIMSS countries. Also, the availability of calculators varies widely. It would not be equitable to require calculator use when students in some countries may never have used them. Similarly, however, it is not equitable to deprive students of the use of a familiar tool.

After considerable debate on the issue, TIMSS 2003 introduced calculator use in the eighth-grade mathematics assessment. For newly developed items, calculators were not required, but were permitted if participating countries wanted to allow their students to use them. Based on a study conducted as part of TIMSS 2003 where the same items were given before the break when calculators were not permitted and in the session after the break when calculators were allowed, it was found that even without specifically planning nearly all the TIMSS mathematics items could be answered just as easily without the use of a calculator. That is, performance was not significantly different with or without a calculator for all except five items. Also, of the students who had calculators (63 percent), the vast majority (47 percent) reported that although they had calculators, they used them very little or not at all.

Based on the experience in TIMSS 2003, in TIMSS 2007 eighth-grade students were permitted to use calculators for the entire assessment and this will be continued in TIMSS 2011. As with previous TIMSS assessments, fourth-grade students will not be permitted to use calculators.

The aim of the TIMSS guidelines for calculator use is to give students the best opportunity to operate in settings that mirror their classroom experience. Thus, if students are used to having calculators for their classroom activities, then the country should encourage students to use them during the assessment. On the other hand, if students are not used to having calculators or are not permitted to use them in their daily mathematics lessons, then the country need not permit their use. In developing the new assessment materials, every effort will be made to ensure that the test questions do not advantage or disadvantage students either way—with or without calculators.

Mathematics Cognitive Domains – Fourth and Eighth Grades

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. Describing these skills plays a crucial role in the development of an assessment like TIMSS 2011, since they are vital in 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 to solve problems or answer questions. The third domain, reasoning, goes beyond the solution of routine problems to encompass unfamiliar situations, complex contexts, and multi-step problems.

These three cognitive domains are used for both grades, but the balance of testing time differs, reflecting the difference in age and experience of students in the two grades. For fourth and eighth grades, each content domain will include 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 5 shows the target percentages of testing time devoted to each cognitive domain for both the fourth- and eighth-grade assessments.

Exhibit 5: Target Percentages of the TIMSS 2011 Mathematics Assessment Devoted to Cognitive Domains at Fourth and Eighth Grades

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

Knowing

Facility in using mathematics, or reasoning about mathematical situations, depends on mathematical knowledge and familiarity with mathematical concepts. The more relevant knowledge a student is able to recall and the wider the range of concepts he or she has understood, the greater the potential for engaging in a wide range of problem-solving situations and for developing mathematical understanding.

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 factual knowledge that provides the basic language of mathematics, and the essential mathematical facts and properties that form the foundation for mathematical thought.

Procedures form a bridge between more basic knowledge and the use of mathematics for solving routine 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. They need to see that particular procedures can be used to solve entire classes of problems, not just individual problems.

Knowledge of concepts enables students to make connections between elements of knowledge that, at best, would otherwise be retained as isolated facts. It allows them to make extensions beyond their existing knowledge, judge the validity of mathematical statements and methods, and create mathematical representations.

1	**Recall**	Recall definitions; terminology; number properties; geometric properties; and notation (e.g., $a \times b = ab$, $a + a + a = 3a$).
2	**Recognize**	Recognize mathematical objects, e.g., shapes, numbers, expressions, and quantities. Recognize mathematical entities that are mathematically equivalent (e.g., equivalent familiar fractions, decimals and percents; different orientations of simple geometric figures).
3	**Compute**	Carry out algorithmic procedures for $+$, $-$, $\times$, $\div$, or a combination of these with whole numbers, fractions, decimals and integers. Approximate numbers to estimate computations. Carry out routine algebraic procedures.
4	**Retrieve**	Retrieve information from graphs, tables, or other sources; read simple scales.
5	**Measure**	Use measuring instruments; choose appropriate units of measurement.
6	**Classify/Order**	Classify/group objects, shapes, numbers, and expressions according to common properties; make correct decisions about class membership; and order numbers and objects by attributes.

Applying

The applying domain involves the application of mathematical tools in a range of contexts. The facts, concepts, and procedures will often be very familiar to the student, with the problems being routine ones. In some items aligned with this domain, 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 equivalent representations is fundamental to success in the subject.

Problem solving is central to the applying domain, but the problem settings are more routine than those aligned with the reasoning domain, being rooted firmly in the implemented curriculum. The routine problems will typically have been standard in classroom exercises designed to provide practice in particular methods or techniques. Some of these problems will have been in words that set the problem situation in a quasi-real context. Though they range in difficulty, each of these types of "textbook" problems is expected to be sufficiently familiar to students that they will essentially involve selecting and applying learned facts, concepts, and procedures.

Problems may be set in real-life situations, or may be concerned with purely mathematical questions involving, for example, numeric or algebraic expressions, functions, equations, geometric figures, or statistical data sets. Therefore, problem solving is included not only in the applying domain, with emphasis on the more familiar and routine tasks, but also in the reasoning domain.

1	**Select**	Select an efficient/appropriate operation, method, or strategy for solving problems where there is a known procedure, algorithm, or method of solution.
2	**Represent**	Display mathematical information and data in diagrams, tables, charts, or graphs, and generate equivalent representations for a given mathematical entity or relationship.
3	**Model**	Generate an appropriate model, such as an equation, geometric figure, or diagram for solving a routine problem.
4	**Implement**	Implement a set of mathematical instructions (e.g., draw shapes and diagrams to given specifications).
5	**Solve Routine Problems**	Solve standard problems similar to those encountered in class. The problems can be in familiar contexts or purely mathematical.

Reasoning

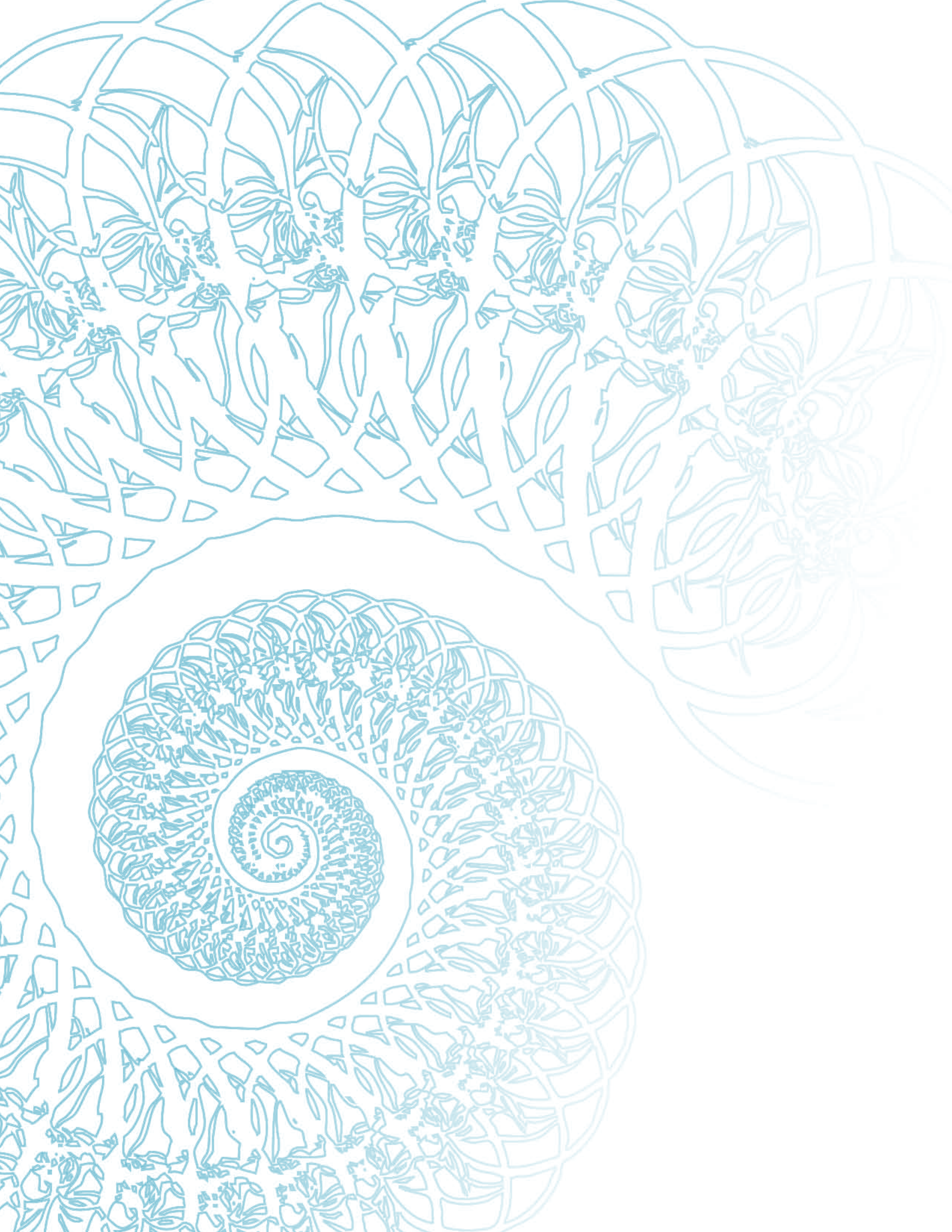
Reasoning mathematically involves the capacity for logical, systematic thinking. It includes intuitive and inductive reasoning based on patterns and regularities that can be used to arrive at solutions to non-routine problems. Non-routine problems are problems that are very likely to be unfamiliar to students. They make cognitive demands over and above those needed for solution of routine problems, even when the knowledge and skills required for their solution have been learned. Non-routine problems may be purely mathematical or may have real-life settings. Both types of items involve transfer of knowledge and skills to new situations, and interactions among reasoning skills are usually a feature. Problems requiring reasoning may do so in different ways, because of the novelty of the context or the complexity of the situation, or because any solution to the problem must involve several steps, perhaps drawing on knowledge and understanding from different areas of mathematics.

Even though of the many behaviors listed within the reasoning domain are those that may be drawn on in thinking about and solving novel or 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.

1	**Analyze**	Determine, describe, or use relationships between variables or objects in mathematical situations, and make valid inferences from given information.
2	**Generalize/ Specialize**	Extend the domain to which the result of mathematical thinking and problem solving is applicable by restating results in more general and more widely applicable terms.
3	**Integrate/ Synthesize**	Make connections between different elements of knowledge and related representations, and make linkages between related mathematical ideas. Combine mathematical facts, concepts, and procedures to establish results, and combine results to produce a further result.
4	**Justify**	Provide a justification by reference to known mathematical results or properties.
5	**Solve Non-routine Problems**	Solve problems set in mathematical or real life contexts where students are unlikely to have encountered closely similar items, and apply mathematical facts, concepts, and procedures in unfamiliar or complex contexts.

TIMSS 2011 Science Framework

Chapter 2



Chapter 2

TIMSS 2011 Science Framework

Overview

In today's world, some understanding of science is imperative if citizens are to make informed decisions about themselves and the world in which they live. Every day they are faced with a barrage of information, and sifting fact from fiction is possible only if they have the tools to accomplish this. It is important, therefore, to make certain that students leaving high school are equipped with a fundamental understanding of science such that the decisions they make are informed decisions. Students in the early grades have a natural curiosity about the world and their place in it, thus it is appropriate for them to start to learn the basics of science at a young age. This knowledge and understanding should be built upon throughout their schooling so that when as adults they are faced with making decisions that relate to such diverse issues as the treatment of diseases, global warming, and applications of technology, they are able to do so from a sound scientific basis.

The science assessment framework for TIMSS 2011 consists of a content dimension specifying the subject matter domains to be assessed within science (for example, biology, chemistry, physics, and earth science at the eighth grade) and a cognitive dimension specifying the cognitive domains or skills and behaviors (that is, knowing, applying, and reasoning) expected of students as they engage with the science content. 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 on 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 cognitive framework, however, is the same for both grades, encompassing a range of cognitive processes involved in learning science concepts and engaging in scientific inquiry right through the primary and middle school years. Exhibit 6 shows the target percentages of testing time devoted to each science content and cognitive domain for the fourth- and eighth-grade assessments.

Exhibit 6: Target Percentages of the TIMSS 2011 Science Assessment Devoted to Content and Cognitive Domains at 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%

One of the ways in which students have been encouraged to build upon their knowledge and understanding of science is through the process of scientific inquiry and considerable emphasis has been placed in the contemporary science curricula of many countries on engaging students in this process. Recognizing the importance of scientific inquiry in the teaching and learning process, the *TIMSS 2011 Science Framework* takes the position that the understandings and abilities required to engage in this process should not be assessed in isolation. Rather, scientific inquiry should be assessed in the context of one or other of the TIMSS science content domains and drawing upon the full range of skills and behaviors specified in the cognitive domains. Accordingly, assessment items addressing aspects of scientific inquiry are included within the two dimensions of the assessment framework—the content dimension that covers all the fields of science and the cognitive dimension that includes skills-based components.

The content and cognitive domains for the science assessment as well as the TIMSS perspective on scientific inquiry are discussed in detail in the following sections. The content domains for the fourth grade are presented first, followed by those for the eighth grade. The cognitive domains, applicable to both grades, are next, followed by scientific inquiry.

Science Content Domains – Fourth Grade

While TIMSS recognizes that the organization of science curricula differs across countries, for the purposes of the TIMSS 2011 assessment at the fourth grade, three major domains covering most of the topics in the various countries' curricula were chosen to define the science content—life science, physical science, and earth science. It should be noted that the topics included in these content domains may be taught in some countries in other subject areas, such as geography.

The content domains are shown in Exhibit 7 together with the target percentage devoted to each domain.

Exhibit 7: Target Percentages of the TIMSS 2011 Science Assessment Devoted to Content Domains at Fourth Grade

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

Each content domain has several main topic areas, presented as a list of objectives covered in the science curriculum in the majority of participating countries. The sections below describe each science content domain, give an overview of the topic areas to be covered in each domain, and provide a set of assessment objectives for each topic area. These objectives are written in terms of behaviors to be elicited by items that exemplify the understandings and abilities expected of students at fourth grade.

Life Science

Life science includes understandings of the characteristics and life processes of living things, the relationships between them, and their interaction with the environment. The topic areas for life science are as follows:

- Characteristics and life processes of living things
- Life cycles, reproduction, and heredity
- Interaction with the environment
- Ecosystems
- Human health

Knowledge of the characteristics and life processes of living things is fundamental to the study of life science. As such, students at fourth grade are expected to be able to describe differences between living and nonliving things, compare and contrast physical and behavioral characteristics of major groups of organisms, and relate structures of such organisms to their function.

Students are expected to know and be able to compare the life cycles of plants, such as a tree and a bean, and animals, such as a housefly and a frog. In the areas of reproduction and heredity, knowledge is restricted to a very basic understanding that organisms of the same kind reproduce and that offspring closely resemble their parents. They should also be able to relate the production of multiple seeds or eggs to survival of different kinds of plants and animals.

Students are expected to be able to associate physical features and patterns of behavior of plants and animals with the environment in which they live and to provide examples of physical and behavioral characteristics that make some plants and animals better suited to particular environments. Students also should be able to demonstrate a rudimentary knowledge of bodily responses to outside conditions.

The study of ecosystems is essential to understanding the interdependence of living organisms and their relationship to the physical environment. Basic concepts related to ecosystems, including energy flow and the interaction of biotic and abiotic factors, are expected to be introduced in the primary school science curriculum. Students' understandings may be demonstrated through descriptions of specific relationships between plants and animals in common ecosystems. Some understanding of the ways in which human behavior can affect the environment also is expected of fourth-grade students, especially in relation to pollution.

Finally, fourth-grade students are expected to have a rudimentary knowledge of human health, nutrition, and disease. They should demonstrate familiarity with common communicable diseases and also be able to relate diet and personal habits to their effect on health.

Life Science: Characteristics and Life Processes of Living Things

1. Describe differences between living and nonliving things; identify common characteristics of living things (e.g., reproduction, growth, basic needs for air, food, water).
2. Compare and contrast physical and behavioral characteristics of major groups of living things (e.g., insects, birds, mammals, flowering plants); identify or provide examples of animals and plants belonging to these groups.
3. Relate major structures in animals to their functions (e.g., stomach – digests food, teeth – break down food, bones - support the body, lungs - take in air).
4. Relate major structures in plants to their functions (e.g., roots - absorb water, leaves - make food).

Life Science: Life Cycles, Reproduction, and Heredity

1. Trace the general steps in the life cycle of plants (germination, growth and development, reproduction, seed dispersal) and animals (birth, growth and development, reproduction, death); recognize and compare life cycles of familiar plants (e.g., trees, beans) and animals (e.g., humans, houseflies, frogs).
2. Recognize that plants and animals reproduce with their own kind to produce offspring with features that closely resemble those of the parents; describe simple relationships between reproduction and survival of different kinds of plants and animals (e.g., a plant producing many seeds, a fish producing many eggs).

Life Science: Interactions with the Environment

1. Associate physical features of plants and animals with the environments in which they live; identify or describe examples of certain physical or behavioral characteristics of plants and animals that help them survive in particular environments and explain why (e.g., type of root, type of leaf, fur thickness, hibernation, migration).
2. Describe bodily responses in animals to outside conditions (e.g., heat, cold, danger) and to activities (e.g., exercise).

Life Science: Ecosystems

1. Explain that plants need the Sun to make their food, while animals eat plants or other animals; recognize that all plants and animals need food to provide energy for activity and raw material for growth and repair.
2. Describe relationships in a given community (e.g., forest, tide pool, desert) based on simple food chains, using common plants and animals and predator-prey relationships.
3. Explain ways in which human behavior can have positive or negative effects on the environment; provide general descriptions and examples of the effects of pollution on humans, plants, animals, and their environments, and of ways of preventing or reducing pollution.

Life Science: Human Health

1. Recognize ways that common communicable diseases (e.g., colds, influenza) are transmitted; identify signs of health or illness and some methods of preventing and treating illness.
2. Describe ways of staying healthy including eating a balanced diet and regular exercise; identify common food sources (e.g., fruits, vegetables, grains).

Physical Science

Physical science includes concepts related to matter and energy, and covers topics in the areas of both chemistry and physics. Since students in fourth grade have only a beginning knowledge of chemistry, the framework places more emphasis on physics concepts. The topic areas for physical science are listed below:

- Classification and properties of matter
- Sources and effects of energy
- Forces and motion

In the area of classification and properties of matter, fourth-grade students are expected to have a beginning understanding of physical states and changes in matter from one form to another—solid, liquid, and gas. While general knowledge about changes of state is not expected, students should know that water can exist in all three forms and can change from one form to another by being heated or cooled. They should be able to compare or classify objects and materials on the basis of physical properties and relate these properties to their uses. Students are expected to have a beginning practical knowledge of the formation of mixtures and water solutions. They also are expected to identify some changes in familiar materials that produce other materials with different properties, but are not expected to know how these changes are related to chemical transformations.

Concepts related to sources and effects of energy encompass heat, temperature, light, electricity, and magnetism. Students should be able to identify common energy sources and have some understanding of hot objects being able to heat up cold objects. Their understanding of light will be assessed through identifying common light sources and relating familiar physical phenomena to the behavior of light. In the area of electricity and magnetism, students should have some notion of a complete electrical circuit and some practical knowledge of magnets and their uses.

Students should have an intuitive grasp of the idea of forces as they relate to movement, such as gravity acting on falling objects and push/pull forces. They should also be able to compare the effects of greater or lesser forces on an object. Knowledge about determining the relative weight of objects using a balance may also be assessed.

Physical Science: Classification and Properties of Matter

1. Name three states of matter (solid, liquid, gas) and describe characteristic differences in shape and volume of each state; recognize that matter can be changed from one state to another by heating or cooling and describe these changes in terms of melting, freezing, boiling, evaporation, or condensation.
2. Compare and sort objects and materials on the basis of physical properties (e.g., weight/mass, volume, magnetic attraction); identify properties of metals and relate them to their use; identify properties and common uses of water in its solid, liquid, and gas state (e.g., coolant, solvent, heat source).
3. Describe examples of mixtures and explain how they can be separated; give examples of materials that dissolve in water and those that do not; explain ways of increasing how much and how quickly materials dissolve.
4. Identify observable changes in materials caused by decaying, burning, rusting, cooking that make new materials with different properties.

Physical Science: Energy — Sources and Effects

1. Identify sources of energy (e.g., the Sun, electricity, water, wind, vibrations); describe practical uses of this energy.
2. Recognize that hot objects can heat up cold objects; explain that heating up means an increase in temperature; identify examples of common materials that easily conduct heat.
3. Identify common light sources (e.g., bulb, flame, the Sun); relate familiar physical phenomena to the behavior of light (e.g., reflections, rainbows, shadows).
4. Explain the need for a complete (unbroken) electrical pathway for simple electrical systems (e.g., flashlight, batteries in appliances) to work; recognize objects and materials that conduct electricity.
5. Recognize that magnets have north and south poles, that like poles repel and opposite poles attract, and that magnets can be used to attract some other materials or objects.

Physical Science: Forces and Motion

1. Identify familiar forces that cause objects to move (e.g., gravity on falling objects, push/pull forces); compare effects of greater or lesser forces on an object; describe how the relative weight of objects can be determined using a balance.

Earth Science

Earth science is concerned with the study of Earth and its place in the solar system. While there is no single picture of what constitutes an earth science curriculum that applies to all countries, the *TIMSS 2011 Science Framework* identifies the following topic areas that are universally considered to be important for students at the fourth grade to understand about the planet on which they live and its place in the solar system:

- Earth's structure, physical characteristics, and resources
- Earth's processes, cycles, and history
- Earth in the solar system

Fourth-grade students are expected to have some general knowledge about the structure and physical characteristics of Earth. They should recognize that most of Earth's surface is covered by water and be able to describe where fresh and salt water are found. At this level, assessment of students' understandings of the atmosphere is limited to evidence for the existence of air and the presence of water in the air. Students are also expected to know common features of Earth's landscape and have some understanding of the uses and conservation of Earth's resources.

In the area of Earth's processes, cycles, and history, fourth-grade students are expected to be able to describe some of Earth's processes in terms of observable changes, including the movement of water, cloud formation, and changes in daily or seasonal weather conditions.

Assessing the understanding of Earth's history is fairly limited at the fourth grade. However, students at this level should know that fossils found in rocks are the remains of plants and animals that lived a long time ago and be able to make simple deductions about changes in Earth's surface from the position and arrangement of these fossils.

Fourth-grade students are expected to demonstrate some understandings about Earth's place in the solar system based on observations of changes in Earth and sky. In particular, they should be familiar with the motions of Earth, and relate daily changes on Earth to its rotation on its axis and relationship to the Sun. They also should be able to recognize that the moon has different phases.

Earth Science: Earth's Structure, Physical Characteristics, and Resources

1. Identify substances that make up Earth's surface. Recognize that most of Earth's surface is covered with water; describe where fresh or salt water are found; provide evidence for the existence of air; recognize common events such as cloud formation, dewdrops, evaporation of puddles, and drying of wet clothes, as evidence that air contains water.
2. Describe features of Earth's landscape (e.g., mountains, plains, deserts, rivers, lakes, seas) and relate them to human use (e.g., farming, irrigation, land development); identify some of Earth's resources that are used in everyday life (e.g., water, soil, wood, minerals, air); explain the importance of using these resources responsibly.

Earth Science: Earth's Processes, Cycles, and History

1. Describe the movement of water on Earth's surface (e.g., flowing in rivers or streams from mountains to oceans or lakes); relate the formation of clouds and rain or snow to a change of state of water; describe changes in weather conditions from day to day or over the seasons in terms of temperature, precipitation (rain or snow), clouds, and wind.
2. Recognize that some remains (fossils) of animals and plants that lived on Earth a long time ago are found in rocks; make simple deductions about changes in Earth's surface from the location of these remains (fossils).

Earth Science: Earth in the Solar System

1. Describe the solar system as a group of planets (including Earth) each revolving around the Sun; recognize that the moon revolves around Earth and looks different in different times of the month; identify the Sun as the source of heat and light for the solar system.
2. Relate daily patterns observed on Earth to Earth's rotation on its axis and its relationship to the Sun (e.g., day and night, appearance of shadows).

Science Content Domains – Eighth Grade

Four major content domains—biology, chemistry, physics, and earth science—define the science content covered in the eighth-grade assessment. It is important to note, however, that in an international assessment such as TIMSS the organization of science topics into these domains does not correspond to the structure of science instruction in all countries. In many countries, for example, science is taught as general science or integrated science whereas in others, science is taught as separate subjects such as biology, physics, and chemistry.

Additionally, some of the topics included in the *TIMSS 2011 Science Framework* may in some countries be taught in other courses, such as health education, social studies, or geography. The content domains are shown in Exhibit 8 together with the target percentage devoted to each domain.

Exhibit 8: Target Percentages of the TIMSS 2011 Science Assessment Devoted to Content Domains at Eighth Grade

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

Each content domain has several main topic areas; each of which is presented as a list of objectives covered in the science curriculum in the majority of participating countries. The sections below describe each of the science content domains, give an overview of the topic areas to be covered in each domain, and provide a set of assessment objectives for each topic area. These objectives are written in terms of behaviors to be elicited by items that exemplify the understandings and abilities expected of students at eighth grade.

Biology

Biology includes students' understandings of the structure, life processes, diversity, and interdependence of living organisms.

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

Eighth-grade students are expected to be able to state the defining characteristics of major taxonomic groups and classify organisms according to these characteristics. They should also be able to locate major organs in the human body and relate the structure and function of organs and organ systems to basic biological processes.

Students should have a beginning understanding of cells and their function, as evidenced by their ability to describe cellular make up and to identify cell structures and relate them to their function. They also should be able to explain how certain biological processes such as photosynthesis and respiration are necessary to sustain life.

Students are expected to be able to distinguish between growth and development in different organisms. They also should be able to compare sexual and asexual reproduction in terms of biological processes at the cellular level, including ideas about heredity that involve the passing of genetic material from parent(s) to offspring.

Some understanding of diversity, adaptation, and natural selection among organisms is expected of eighth-grade students. They should have an appreciation of modern species in terms of similarity of characteristics and reproduction capabilities in a population of related organisms. They also should be able to relate diversity of characteristics to the survival or extinction of species in changing environments. Students are expected to start considering evidence for the history and changes in Earth's life forms over time by the comparison of living species and fossil records.

The study of ecosystems is essential to understanding the interdependence of living organisms and their relationship to the physical environment. At the eighth grade, students are expected to show introductory level understanding of the interdependence between populations of organisms that maintains balance in an ecosystem. They are expected to represent the flow of energy in an ecosystem, recognize the role of organisms in the cycling of materials, and predict the effects of changes in ecosystems. The effect of human activity on ecosystems is an important aspect of understanding the interdependence of living organisms and the environment.

Eighth-grade students are expected to demonstrate knowledge of human health, nutrition, and disease. They should know some causes of disease, communicate knowledge about the mechanisms of infection and transmission, and know the importance of the immune system. They also should be able to describe the role of specific nutrients in the functioning of the human body.

Biology: Characteristics, Classification, and Life Processes of Organisms

1. State the defining characteristics that differentiate among the major taxonomic groups and organisms within these groups; classify organisms on the basis of a variety of physical characteristics.
2. Locate major organs in the human body; identify the components of organ systems; explain the role of organs and organ systems in sustaining life (e.g., circulatory, respiratory); compare and contrast organs and organ systems in humans and other organisms.
3. Explain how biological actions in response to external and internal changes work to maintain stable bodily conditions (e.g., sweating in heat, shivering in cold, increased heart rate during exercise).

Biology: Cells and Their Functions

1. Explain that living things are made of cells that carry out life functions and undergo cell division, and that tissues, organs, and organ systems are formed from groups of cells with specialized structures and functions; identify cell structures and some functions of cell organelles (e.g., cell wall, cell membrane, nucleus, chloroplast, vacuole); compare plant and animal cells.
2. Describe the processes of photosynthesis (the need for light, carbon dioxide, water, and chlorophyll; production of food; and release of oxygen) and cellular respiration (the need for oxygen, breaking down of food to produce energy, and release of carbon dioxide).

Biology: Life Cycles, Reproduction, and Heredity

1. Compare and contrast how different organisms (e.g., humans, plants, birds, insects) grow and develop.
2. Compare and contrast asexual and sexual reproduction in general terms (e.g., asexual reproduction producing identical offspring versus sexual reproduction—egg and sperm—producing offspring that are similar but not identical to either parent).
3. Relate the inheritance of traits to organisms passing on genetic material to their offspring; distinguish inherited characteristics from acquired or learned characteristics.

Biology: Diversity, Adaptation, and Natural Selection

1. Relate the survival or extinction of species to variation in physical/behavioral characteristics in a population and reproductive success in a changing environment.
2. Recognize that fossils provide evidence for the relative length of time major groups of organisms have existed on Earth (e.g., humans, reptiles, fish, plants); describe how similarities and differences among living species and fossils provide evidence of the changes that occur in living things over time.

Biology: Ecosystems

1. Describe the flow of energy in an ecosystem; identify different organisms as producers, consumers, and decomposers; draw or interpret food pyramids or food web diagrams.
2. Describe the role of living things in the cycling of elements and compounds (e.g., oxygen, carbon, water) through Earth's surface and the environment.
3. Explain the interdependence of populations of organisms in an ecosystem in terms of the effects of competition and predation.
4. Identify factors that can limit population size (e.g., disease, predators, food resources, drought); predict effects of changes in an ecosystem (e.g., climate, water supply, population changes, migration) on the available resources and the balance among populations.
5. Recognize that the world's human population is growing and identify reasons why (e.g., advances in medicine, sanitation); discuss the effects of population growth on the environment.

Biology: Human Health

1. Describe causes of common diseases (e.g., influenza, measles, strep throat, malaria, HIV), methods of infection or transmission, prevention, and the importance of the body's resistance (immunity) and healing capabilities.
2. Explain the importance of diet, exercise, and lifestyle in maintaining health and preventing illness (e.g., heart disease, high blood pressure, diabetes, skin cancer, lung cancer); identify the dietary sources and role of nutrients in a healthy diet (vitamins, minerals, proteins, carbohydrates, fats).

Chemistry

In the area of chemistry, students will be assessed on their understanding of concepts related to the following topic areas:

- Classification and composition of matter
- Properties of matter
- Chemical change

At the eighth grade, students should be able to classify substances on the basis of characteristic physical properties and recognize that substances can be grouped according to similar chemical and physical properties. They are expected to differentiate between elements, compounds, and mixtures in terms of their composition. They also are expected to have a beginning understanding of the particulate structure of matter in terms of atoms and molecules.

Students should have a clear understanding of the properties of matter. They should describe methods of separating mixtures based on their physical properties, define solutions, and recognize the factors that affect the rate at which materials dissolve. Students also are expected to demonstrate knowledge of some properties and uses of metals and water, and be able to compare properties of acids and bases.

In the area of chemical change, students are expected to recognize the differences between physical and chemical changes and demonstrate basic knowledge of conservation of matter during these changes. In addition, they should be able to identify common reactions that release or absorb heat. Students also are expected to recognize the need for oxygen in rusting, tarnishing, and burning and the relative tendency of familiar substances to undergo these types of reactions.

Chemistry: Classification and Composition of Matter

1. Classify or compare substances on the basis of characteristic physical properties that can be demonstrated or measured (e.g., density, thermal or electrical conductivity, solubility, melting or boiling point, magnetic properties).
2. Recognize that substances may be grouped according to similar chemical and physical properties; describe properties of metals that distinguish them from nonmetals.
3. Differentiate between pure substances (elements and compounds) and mixtures (homogeneous and heterogeneous) on the basis of their formation and composition, and provide or identify examples of each (may be solid, liquid, or gas).
4. Describe the structure of matter in terms of particles, including molecules as combinations of atoms (e.g., H_2O, O_2, CO_2) and atoms as composed of subatomic particles (electrons surrounding a nucleus containing protons and neutrons).

Chemistry: Properties of Matter

1. Select or describe physical methods for separating mixtures into their components (e.g., filtration, distillation, dissolution); define solutions in terms of substance(s) (solid, liquid, or gas solutes) dissolved in a solvent; relate concentration to the amounts of solute or solvent; explain the effect of factors such as temperature, stirring, and particle size on the rate at which materials dissolve.

2. Relate the behavior and uses of water to its physical properties (e.g., melting point and boiling point, ability to dissolve many substances, thermal properties, expansion upon freezing).
3. Compare the properties of common acids and bases (acids have a sour taste and react with metals; bases usually have a bitter taste and slippery feel; strong acids and bases are corrosive; both acids and bases dissolve in water and react with indicators to produce different color changes; acids and bases neutralize each other).

Chemistry: Chemical Change

1. Differentiate chemical from physical changes in terms of the transformation (reaction) of one or more pure substances (reactants) into different pure substances (products); provide evidence that a chemical change has taken place based on common examples (e.g., temperature change, gas production, color change, light emission).
2. Recognize that mass is conserved during chemical change; recognize that some chemical reactions release energy (e.g., heat, light) while others absorb it; classify familiar chemical changes as either releasing or absorbing heat (e.g., burning, neutralization, cooking).
3. Recognize that oxygen is needed in common oxidation reactions (combustion, rusting, tarnishing); relate its importance to fire safety and preservation of metal objects (coins, cars, cookware, statues); order familiar substances by how readily they burn, rust, or tarnish.

Physics

In physics, students' understandings of concepts related to physical processes and energy will be assessed in the following topic areas:

- Physical states and changes in matter
- Energy transformations, heat, and temperature
- Light and sound
- Electricity and magnetism
- Forces and motion

Eighth-grade students should be able to describe processes involved in changes of state and begin to relate the states of matter to the distance and movement among particles. They also should be able to demonstrate understanding that mass is conserved during physical changes. Concepts related to energy transformations, heat, and temperature also are assessed at the eighth-grade level. Students are expected to be able to identify different forms of energy, describe simple energy transformations, and apply the principle of conservation of total energy in practical situations. Students also are expected to relate heating to transfer of energy, and to relate temperature changes to changes in the speed of particles.

Students at the eighth grade are expected to know some basic properties of light and its interaction with matter; to use simple geometrical optics to solve practical problems; and to relate the appearance and color of objects to light properties. Students also are expected to recognize the characteristics of sound and some of its properties. In the area of electricity and magnetism, assessment of students' understandings of electricity includes current flow in complete circuits, simple circuit diagrams, and the relationship between current and voltage in circuits. They also are expected to be able to describe properties, forces, and uses of permanent magnets and electromagnets.

Students are expected to be able to describe general types of forces, and predict changes in the motion of an object based on the forces acting upon it. They also should demonstrate common sense understanding of density and pressure as they relate to familiar physical phenomena, although more formalized knowledge is not expected. Students also are expected to have a basic knowledge of work and simple machines.

Physics: Physical States and Changes in Matter

1. Apply knowledge about the movement of and distance between particles to explain the physical properties of solids, liquids, and gases (volume, shape, density, compressibility).
2. Describe melting, freezing, boiling, evaporation, and condensation as changes of state resulting from heating and cooling; relate the rate or extent of these processes to physical factors (e.g., surface area, dissolved substances, temperature); recognize that temperature remains constant during changes of state; explain that mass remains constant during physical changes (e.g., change of state, dissolving solids, thermal expansion).

Physics: Energy Transformations, Heat, and Temperature

1. Identify different forms of energy (e.g., mechanical, light, sound, electrical, thermal, chemical); describe simple energy transformations (e.g., combustion in an engine to move a car, electrical energy to power a lamp, light energy to chemical energy in photosynthesis, hydroelectric power, changes between potential and kinetic energy); and apply knowledge of the concept of conservation of total energy.
2. Relate heating to the transfer of energy from an object at a higher temperature to one at a lower temperature; compare the relative thermal conductivity of different materials; compare and contrast methods of heat transfer (conduction, convection, and radiation).
3. Relate temperature changes to changes in volume and/or pressure and to changes in the speed of particles.

Physics: Light and Sound

1. Describe or identify basic properties of light (e.g., transmission through different media; speed of light; reflection, refraction, absorption; splitting of white light into its component colors); relate the appearance or color of objects to the properties of reflected or absorbed light; 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 and locate reflected or projected images using lenses.
2. Recognize the characteristics of sound (loudness, pitch, amplitude, frequency); describe or identify some basic properties of sound (need for a medium for transmission, reflection and absorption by surfaces, and relative speed through different media).

Physics: Electricity and Magnetism

1. Describe the flow of current in an electrical circuit; draw or identify diagrams representing complete circuits (series and parallel); classify materials as electrical conductors or insulators; describe factors that affect currents in circuits; recognize that there is a relationship between current and voltage in a circuit.
2. Describe the properties of permanent magnets and electromagnets and the effects of magnetic force; describe uses of permanent magnets and electromagnets in everyday life (e.g., doorbell, recycling factories).

Physics: Forces and Motion

1. Describe the motion (uniform and non-uniform) of an object in terms of its position, direction, and speed; describe general types of forces (e.g., weight as a force due to gravity, contact force, buoyant force, friction); predict changes in motion (if any) of an object based on the forces acting on it.
2. Explain observable physical phenomena in terms of density differences (e.g., floating or sinking objects, rising balloons).
3. Demonstrate basic knowledge of work and the function of simple machines (e.g., levers and ramps) using common examples.
4. Explain pressure in terms of force and area; describe effects related to pressure (e.g., atmospheric pressure as a function of altitude, ocean pressure as a function of depth, evidence of gas pressure in balloons, fluid levels).

Earth Science

Earth science is concerned with the study of Earth and its place in the solar system and the universe. 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, physics, and chemistry. 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.

While there is no single picture of what constitutes an earth science curriculum that applies to all countries, the *TIMSS 2011 Science Framework* identifies the following topic areas that are universally considered to be important for students at the eighth grade to understand 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. They are expected to demonstrate knowledge of the structure and physical characteristics of Earth's crust, mantle, and core, and to describe the distribution of water on Earth, including its physical state, composition, and movement. Students are expected to be familiar with the relative abundance of the main components of air, and with changes in atmospheric conditions in relation to altitude.

In the area of Earth's processes, cycles, and history, students should provide descriptions based on the concept of cycles and patterns. In particular, they should be able to describe in words or diagrams the rock and water cycle. Students are expected to have a sense of the magnitude of time scales, and to describe some physical processes and geological events that have taken place on Earth over billions of years. Students also are expected to interpret and use data or maps relating global and local factors to weather patterns, and to differentiate between daily weather changes and general climate in various regions of the world.

Students should be able to demonstrate knowledge of Earth's resources and their use and conservation by providing examples of renewable and nonrenewable resources, describing methods of conservation and recycling, relating common methods of agriculture and land use to land resources, and discussing the factors related to the supply and demand of fresh water.

Eighth-grade students are expected to have some knowledge of the solar system in terms of the relative distances, sizes, and motions of the Sun, the planets, and their moons, and of how phenomena on Earth relate to the motion of bodies in the solar system. Students also are expected to compare the physical features of Earth, the moon, and the other planets with respect to their ability to support life.

Earth Science: Earth's Structure and Physical Features

1. Describe the structure and physical characteristics of Earth's crust, mantle, and core as provided by observable phenomena (e.g., earthquakes, volcanoes); describe the characteristics and uses of rocks, minerals, and soils; describe the formation of soils.
2. Compare the physical state, movement, composition and relative distribution of water on Earth.
3. Recognize that Earth's atmosphere is a mixture of gases, and identify the relative abundance of its main components; relate changes in atmospheric conditions to altitude.

Earth Science: Earth's Processes, Cycles, and History

1. Describe the general processes involved in the rock cycle; identify or describe physical processes and major geological events that have occurred over millions of years (e.g., erosion, volcanic activity, mountain building, plate movement); explain the formation of fossils and fossil fuels.
2. Diagram or describe the processes in Earth's water cycle, referencing the Sun as the source of energy; and the role of cloud movement and water flow in the circulation and renewal of fresh water on Earth's surface.
3. Compare seasonal climates in relation to latitude, altitude and geography; identify or describe causes of long- and short-term climatic changes (e.g., ice ages, global warming, volcanic eruptions, changes in ocean currents); interpret weather data/maps, and relate changing weather patterns to global and local factors in terms of such factors as temperature, pressure, precipitation, and wind speed and direction.

Earth Science: Earth's Resources, Their Use and Conservation

1. Provide examples of renewable and nonrenewable resources; discuss advantages and disadvantages of different energy sources; describe methods of conservation of resources and methods of waste management (e.g., recycling); relate some environmental concerns to their possible causes and effects (e.g., pollution, global warming, deforestation, desertification); present ways in which science, technology, and human behavior can be used to address these concerns.
2. Explain how common methods of agriculture and land use (e.g., farming, tree harvesting, mining) can affect land resources; describe how fresh water is obtained (e.g., purification, desalination, irrigation); explain the importance of water conservation.

Earth Science: Earth in the Solar System and the Universe

1. Explain phenomena on Earth (day and night, year, seasons in the northern and southern hemisphere, tides, phases of the moon, eclipses, appearance of the Sun, moon, planets, and constellations) in terms of the relative movements, distances, and sizes of Earth, the moon, and other bodies in and outside the solar system.
2. Compare and contrast the physical features of Earth with the moon and other planets (e.g., atmosphere, temperature, water, distance from the Sun, period of revolution and rotation, ability to support life); recognize the role of gravity in the solar system (e.g., tides, keeping the planets and moons in orbit, pulling us to Earth's surface).

Science Cognitive Domains – Fourth and Eighth Grades

To respond correctly to TIMSS test items, students need to be familiar with the science content being assessed, but they also need to draw on a range of cognitive skills. Describing these skills plays a crucial role in the development of an assessment like TIMSS 2011, since they are vital in ensuring that the survey covers the appropriate range of cognitive skills across the content domains already outlined.

This section outlines the skills and abilities associated with the cognitive dimension.

The cognitive dimension is divided into three domains based on what students have to know and do when confronting the various items developed for the TIMSS 2011 assessment. The first domain, knowing, covers science facts, procedures, and concepts students need to know, while the second domain, applying, focuses on the ability of the student to apply knowledge and conceptual understanding to a science problem. The third domain, reasoning, goes beyond the solution of routine science problems to encompass unfamiliar situations, complex contexts, and multi-step problems.

These three cognitive domains are used at both grades, however the percentages vary between fourth and eighth grade in accordance with the increased cognitive ability, maturity, instruction, experience, and breadth and depth of understanding of students at the higher grade level (see Exhibit 9). Thus the percentage of items that involve knowing is higher at the fourth grade while the percentage of items that ask students to engage in reasoning is higher at the eighth grade. For fourth and eighth grades, each content domain will include items developed to address each of the three cognitive domains. For example, the life science content domain will include knowing, applying, and reasoning items, as will the other content domains.

Exhibit 9: Target Percentages of the TIMSS 2011 Science Assessment Devoted to Cognitive Domains at Fourth and Eighth Grades

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

While some hierarchy is imposed in the division of behaviors into the three cognitive domains, a range of difficulty levels is expected for items developed for each of the cognitive domains. The following sections further describe the student skills and abilities defining the cognitive domains. The general descriptions are followed by lists of specific behaviors to be elicited by items that are aligned with each domain.

Knowing

Knowing refers to students' knowledge base of science facts, information, concepts, and tools. Accurate and broad-based factual knowledge enables students to engage successfully in the more complex cognitive activities essential to the scientific enterprise. Students are expected to recall or recognize accurate science statements; possess knowledge of vocabulary, facts, information, symbols, and units; and select appropriate apparatus, equipment, measurement devices, and experimental operations to use in conducting investigations. This cognitive domain also includes the selection of illustrative examples in support of statements of facts or concepts.

1	**Recall/ Recognize**	Make or identify accurate statements about science facts, relationships, processes, and concepts; identify the characteristics or properties of specific organisms, materials, and processes.
2	**Define**	Provide or identify definitions of scientific terms; recognize and use scientific vocabulary, symbols, abbreviations, units, and scales in relevant contexts.
3	**Describe**	Describe organisms, physical materials, and science processes that demonstrate knowledge of properties, structure, function, and relationships.
4	**Illustrate with Examples**	Support or clarify statements of facts or concepts with appropriate examples; identify or provide specific examples to illustrate knowledge of general concepts.
5	**Demonstrate Knowledge of Scientific Instruments**	Demonstrate knowledge of how to use science apparatus, equipment, tools, measurement devices, and scales.

Applying

The questions in this cognitive domain are designed to involve the direct application of knowledge and understanding of science in straightforward situations. To measure applying, TIMSS 2011 will include items that require students to compare, contrast, and classify; to interpret scientific information in light of a science concept or principle; and to use and apply their understanding of science concepts and principles to find a solution or develop an explanation. Items aligned with this cognitive domain may also involve the direct application or demonstration of relationships, equations, and formulas in contexts likely to be familiar in the teaching and learning of science concepts. Both quantitative problems requiring a numerical solution and qualitative problems requiring a written descriptive response are included. In providing explanations, students should be able to use diagrams or models to illustrate structures and relationships and demonstrate knowledge of scientific concepts.

1	**Compare/ Contrast/ Classify**	Identify or describe similarities and differences between groups of organisms, materials, or processes; distinguish, classify, or order individual objects, materials, organisms, and processes based on given characteristics and properties.
2	**Use Models**	Use a diagram or model to demonstrate understanding of a science concept, structure, relationship, process, or biological or physical system or cycle (e.g., food web, electrical circuit, water cycle, solar system, atomic structure).
3	**Relate**	Relate knowledge of an underlying biological or physical concept to an observed or inferred property, behavior, or use of objects, organisms, or materials.
4	**Interpret Information**	Interpret relevant textual, tabular, or graphical information in light of a science concept or principle.

5	**Find Solutions**	Identify or use a science relationship, equation, or formula to find a qualitative or quantitative solution involving the direct application/demonstration of a concept.
6	**Explain**	Provide or identify an explanation for an observation or natural phenomenon, demonstrating understanding of the underlying science concept, principle, law, or theory.

Reasoning

Reasoning is involved in the more complex tasks related to science. A major purpose of science education is to prepare students to engage in scientific reasoning to solve problems, develop explanations, draw conclusions, make decisions, and extend their knowledge to new situations. In addition to the more direct applications of science concepts exemplified in the applying domain, some problem-solving situations involve unfamiliar or more complicated contexts that require students to reason from scientific principles to provide an answer. Solutions may involve breaking down a problem into component parts, each involving the application of a science concept or relationship. Students may be required to analyze a problem to determine what underlying principles are involved; devise and explain strategies for problem solving; select and apply appropriate equations, formulas, relationships, or analytical techniques; and evaluate their solutions. Correct solutions to such problems may stem from a variety of approaches or strategies, and developing the ability to consider alternative strategies is an important educational goal in the teaching and learning of science.

Students may be required to draw conclusions from scientific data and facts, providing evidence of both inductive and deductive reasoning and of an understanding of the investigation of cause and effect. They are expected to evaluate and make decisions, weigh advantages and disadvantages of alternative materials and processes, consider the impact of different scientific endeavors, and evaluate solutions to problems. By the eighth grade, in particular, students should consider and evaluate alternative explanations, extend conclusions to new situations, and justify explanations based on evidence and scientific understanding. Considerable scientific reasoning also is involved in developing hypotheses and designing scientific investigations to test them, and in analyzing and interpreting data. Abilities in this area are introduced at a very basic level in primary school and then further developed throughout students' science education in middle and secondary school.

Some items in this cognitive domain may focus on unified concepts and major conceptual themes, requiring students to bring together knowledge and understanding from different areas and apply it to new situations. As such, they may involve the integration of mathematics and science and/or the integration and synthesis of concepts across the domains of science.

1	**Analyze**	Analyze problems to determine the relevant relationships, concepts, and problem-solving steps; develop and explain problem-solving strategies.
2	**Integrate/ Synthesize**	Provide solutions to problems that require consideration of a number of different factors or related concepts; make associations or connections between concepts in different areas of science; demonstrate understanding of unified concepts and themes across the domains of science; integrate mathematical concepts or procedures in the solutions to science problems.

3	**Hypothesize/ Predict**	Combine knowledge of science concepts with information from experience or observation to formulate questions that can be answered by investigation; formulate hypotheses as testable assumptions using knowledge from observation and/or analysis of scientific information and conceptual understanding; make predictions about the effects of changes in biological or physical conditions in light of evidence and scientific understanding.
4	**Design**	Design or plan investigations 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; make decisions about measurements or procedures to use in conducting investigations.
5	**Draw Conclusions**	Detect patterns in data, describe or summarize data trends, and interpolate or extrapolate from data or given information; make valid inferences on the basis of evidence and/or understanding of science concepts; draw appropriate conclusions that address questions or hypotheses, and demonstrate understanding of cause and effect.

6	**Generalize**	Make general conclusions that go beyond the experimental or given conditions, and apply conclusions to new situations; determine general formulas for expressing physical relationships.
7	**Evaluate**	Weigh advantages and disadvantages to make decisions about alternative processes, materials, and sources; consider scientific and social factors to evaluate the impact of science and technology on biological and physical systems; evaluate alternative explanations and problem-solving strategies and solutions; evaluate results of investigations with respect to sufficiency of data to support conclusions.
8	**Justify**	Use evidence and scientific understanding to justify explanations and problem solutions; construct arguments to support the reasonableness of solutions to problems, conclusions from investigations, or scientific explanations.

Scientific Inquiry in TIMSS 2011

In the *TIMSS 2011 Science Framework*, the processes of scientific inquiry are accepted as fundamental aspects of scientific knowledge inherent in all fields of science and having both content- and skills-based components. Items and tasks assessing these processes require students to demonstrate knowledge of the tools and methods necessary to do science, to apply this knowledge to engage in scientific investigations, and to use scientific understanding to propose explanations based on evidence. In TIMSS, such items are not considered to be context-free, but always are situated in the context of content objectives (biology, chemistry, etc.) and draw from the full range of skills and behaviors specified in the cognitive domains.

It is expected that students at both grade levels will possess some general knowledge of the nature of science and scientific inquiry, including the fact that scientific knowledge is subject to change, the importance of using different types of scientific investigations in verifying scientific knowledge, the use of basic "scientific methods", communication of results, and the interaction of science, mathematics, and technology. In addition to this general knowledge, students are expected to demonstrate the skills and abilities involved in five major aspects of the scientific inquiry process:

- Formulating questions and hypotheses
- Designing investigations
- Representing data
- Analyzing and interpreting data
- Drawing conclusions and developing explanations

These aspects of scientific inquiry are appropriate for both fourth- and eighth-grade students, but the understandings and abilities to be demonstrated increase in complexity across grades, reflecting the cognitive development of students.

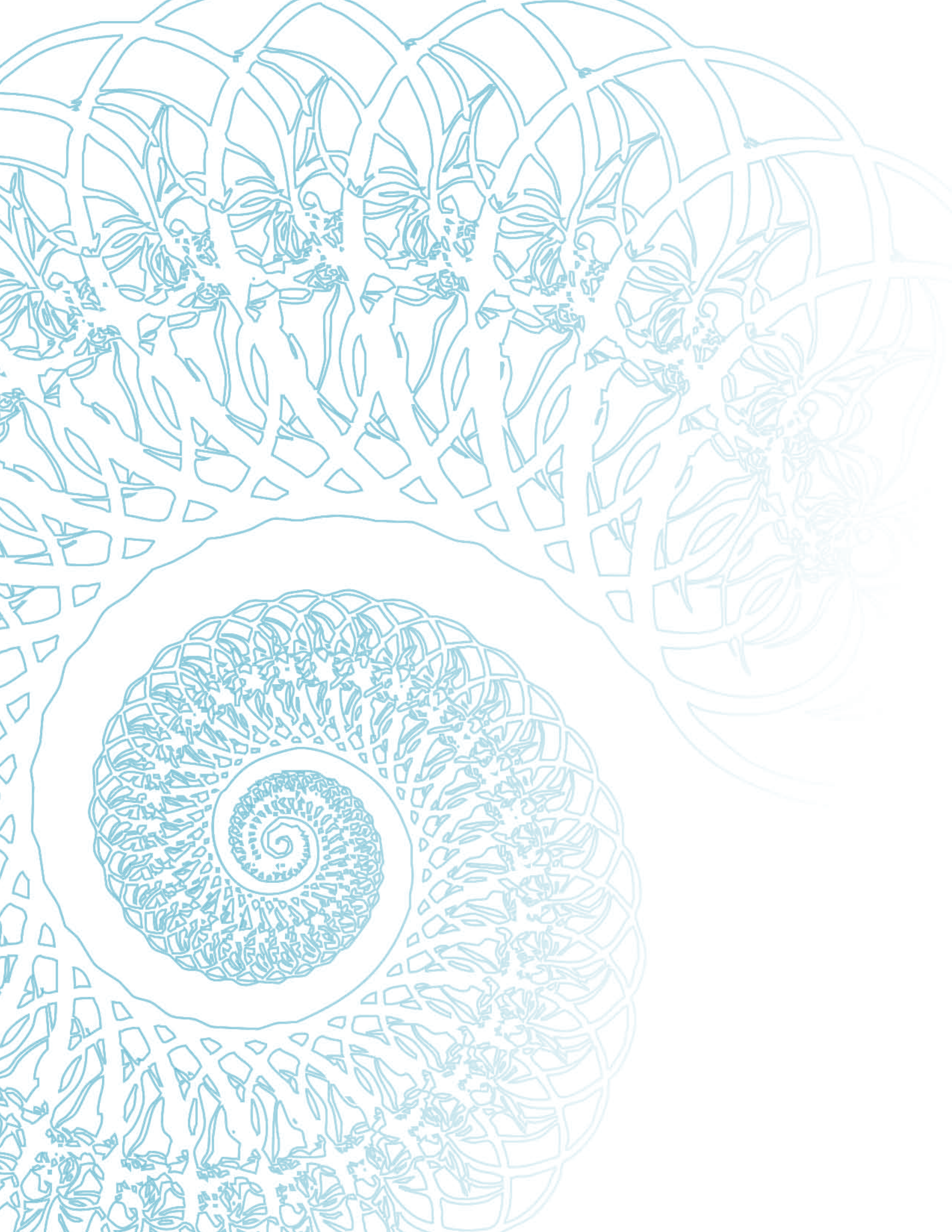
The learning of science in the fourth grade is focused on observing and describing and students at this level are expected to be able to formulate questions that can be answered based on observations or information obtained about the natural world. To obtain evidence to answer these questions, they should demonstrate a grasp of what constitutes a "fair test", and be able to describe and conduct an investigation based on making systematic observations or measurements using simple tools, equipment, and procedures. They also are expected to represent their findings using simple charts and diagrams, identify simple relationships, and briefly describe the results of their investigations. Conclusions drawn from investigations at the fourth grade are expected to be written as an answer to a specific question.

By the eighth grade, students should demonstrate a more formalized approach to scientific investigation that involves more evaluation and decision-making. They are expected to be able to formulate a hypothesis or prediction based on observation or scientific knowledge that can be tested by investigation. They are expected to demonstrate an understanding of cause and effect and the importance of specifying variables to be controlled and varied in well-designed investigations. They may also be required to make more decisions about the measurements to be made and the equipment and procedures to use. In addition, students at this level are expected to use appropriate terminology, units, precision, format, and scales. They should also demonstrate more advanced data analysis skills in selecting and applying appropriate mathematical techniques and describing patterns in data. Eighth-grade students may be expected to evaluate the results of their investigation with respect to the sufficiency of their data for supporting conclusions that address the question or hypothesis under investigation.

The assessment of both fourth- and eighth-grade students' ability to provide explanations based on evidence from scientific investigations provides another measure of their understanding and application of related science concepts. By the eighth grade, it is expected that students will be able to formulate explanations in terms of cause-and-effect relationships between variables and in light of scientific understanding. At this level, students may also begin to consider alternative explanations and apply or extend their conclusions to new situations.

TIMSS 2011 Contextual Framework

Chapter 3



Chapter 3

TIMSS 2011 Contextual Framework

Overview

This chapter provides the foundation for the information that will be collected via the TIMSS background questionnaires given to the students themselves as well to their classroom teachers and school heads or principals. Participating countries also complete questionnaires about the national contexts and curriculum for instruction in mathematics and science. Because learning takes place within a context and not in isolation, TIMSS makes every attempt to collect information about the important factors that foster improved teaching and learning in mathematics and science. The questionnaires concentrate on procedures and practices that have been shown to be effective in increasing achievement in mathematics and science. In this way, countries can better evaluate their TIMSS results; in terms of the prevalence of the home or school situation or instructional practice in their country and its relationship with student achievement.

There are numerous contextual factors that affect students' learning. For example, type of school, school resources, instructional approaches, teacher characteristics, student attitudes, and home support for learning contribute heavily to student learning and achievement. For a fuller appreciation of what the TIMSS achievement results mean and how they may be used to improve student learning in mathematics and science, it is important to understand the contexts in which learning takes place. TIMSS in every cycle collects a range of information about these contexts for learning, together with assessing students' performance in mathematics and science. Just as the mathematics and science frameworks describe what should be assessed in those areas, the contextual framework identifies the major characteristics of the educational and social contexts that will be studied with a view to improving student learning.

Students in their fourth or eighth year of schooling typically have gained most of their mathematics and science learning at school and home, influenced to some extent by experiences outside of school. School, classroom, and home environments that support each other can create extremely effective climates for learning. To reflect this situation, the *TIMSS 2011 Contextual Framework* encompasses four broad areas:

- National and Community Contexts
- School Contexts
- Classroom Contexts
- Student Characteristics and Attitudes

The TIMSS Curriculum Model

Building on IEA's experience and the previous cycles of TIMSS, TIMSS 2011 uses the curriculum as a major organizing concept in considering how educational opportunities are provided, and the factors that influence how these opportunities are used effectively. TIMSS examines the curricular goals, how the educational system is organized to facilitate the implementation of these goals, and how effectively these goals are attained.

At the national and community level, for example, the value systems of the people, the population demographics, and the amount of available resources can influence how much mathematics and science societies intend their students to learn and the contexts in which learning takes place. An effective school organization and a safe and cooperative school environment facilitate the implementation of the intended curriculum. That is also true for an educated and motivated teaching force, well equipped classrooms, and a supportive classroom atmosphere. Furthermore, effective teaching strategies, the availability and use of technology as well as coverage of the curricular content contribute to a successful attainment of the curricular goals.

Students vary in their prerequisite knowledge and skills and the support they receive from their homes as well as the motivation and interest to learn mathematics and science. Schools' and teachers' success in implementing the curriculum and contributing to student learning is influenced by the prerequisites that students themselves bring to the educational enterprise as well as their attitudes toward learning.

To better understand the contextual factors that affect students' learning in mathematics and science, TIMSS utilizes background information from a variety of sources. To provide information about the national contexts that shape the content and organization of the intended curriculum as well as political decision making processes, TIMSS publishes the TIMSS Encyclopedia (Mullis, Martin, Olson, Berger, Milne, & Stanco, 2008). The TIMSS 2011 Encyclopedia will be a collection of descriptions of mathematics and science education in the participating countries. It will also include an introduction that focuses on the national contexts for the support and implementation of mathematics and science curricula and policies across countries based on responses to curriculum questionnaires. To gather information about the school, classroom, and student factors associated with the delivery of mathematics and science instruction and student characteristics and attitudes, TIMSS 2011 will collect responses to background questionnaires completed by the students tested, their teachers, and their school principals or heads. For countries participating in both TIMSS and PIRLS at the fourth grade there is a special opportunity to collect information from students' parents or caregivers.

National and Community Contexts

Cultural, social, political, and economic factors provide the context for a country's education system and the mathematics and science curricula. The decisions about educational organization, structure, resources, facilities, teacher qualification, and curriculum are often separate from what actually gets taught. The success a country has in providing effective mathematics and science instruction depends on the value of mathematics and science in the society, the resources available, and the mechanisms it can assemble for providing effective contexts for learning mathematics and science.

Demographics and Resources

The characteristics of a country's population and the national economy can have a tremendous impact on the relative ease or difficulty of providing effective contexts for learning mathematics and science, and on the availability and extent of the resources required. The sheer size of a country geographically can create difficulties in delivering a uniformly rigorous curriculum, as can a very large population. Having economic resources enables better educational facilities and greater numbers of well-trained teachers and administrators. It also provides the opportunity to invest in education through widespread community programs and by making materials and technology more readily available in classrooms and homes.

Countries with a large and diverse population and few material and human resources generally face greater challenges than those in more favorable circumstances (Bos, Schwippert, & Stubbe, 2007; Gradstein & Schiff, 2004; Kirsch, Braun, Yamamoto, & Sum, 2007; Taylor & Vinjevold, 2000; Trong, 2009). Nationally and locally, the diversity of languages used, levels of adult literacy, and other social and health demographics can influence the difficulty of the educational task. Changing populations due to migration within and across country borders also may affect priorities in education policy and require additional resources.

Organization and Structure of the Education System

Curriculum development in particular involves consideration of the society that the education system serves. The curriculum reflects the needs and aspirations of the students, the nature and function of learning, and the formulation of statements on what learning is important. In understanding the curriculum students are intended to learn, it is important to know who makes the curricular decisions, what types of decisions are made, and how decisions are communicated to the education community.

How educational policies are established and implemented influences how schools operate and how successful they are in attaining the curricular and educational goals. Some countries have highly centralized systems of education in which most policy-related and curricular decisions are made at the national or regional level, and there is a great deal of uniformity in education in terms of curriculum, textbooks, and general policies. Other countries have much more decentralized systems in which many important decisions are made at the local and school levels, resulting in greater variation in how schools operate and students are taught.

The way students proceed through school (also referred to as "student flow") is a feature of education systems that varies across countries (Martin, Mullis, & Foy, 2008; Mullis, Martin, & Foy, 2008). Particularly relevant for considering achievement by the fourth year of schooling is the age of entry to formal schooling and the age when formal instruction begins. Due to the complexity of the cognitive demands, students in countries that begin formal schooling at a younger age do not necessarily begin to receive formal instruction in mathematics, and particularly in science, in their first year of schooling. By the eighth year of students' schooling, in addition to an understanding of promotion and retention policies, it is important to have information about the types of schools students attended at the primary and junior-secondary level, and whether instruction was organized in a tracked or comprehensive program of study. The presence of an examination system with consequences for program placement or grade promotion can have a significant influence on how students learn. Of special interest are recent or planned structural changes in the education system and their effectiveness for improving mathematics and science learning and instruction.

The Mathematics and Science Curricula

The way the curriculum is documented and how the curriculum implementation is organized at the primary and junior-secondary level has a significant impact on students' opportunities to learn mathematics and science. Curricular documents define and communicate expectations for students in terms of the knowledge, skills, and attitudes to be developed or acquired through their formal education. The nature and extent of the mathematics and science goals to be attained in school are important to policy makers and curriculum specialists in all countries. Also important is how these goals are kept current in the face of scientific and technological advances, and how the demands and expectations of the society and the workplace change. As a related issue, curricular documents can include policies about using technology (e.g., calculators, computers, or the Internet) in schools and classrooms.

Although mastery of the subject is a major focus of mathematics and science curricula in most countries, countries differ considerably in how mastery is defined, and how the curriculum specifies that mastery should be achieved. For example, acquiring basic skills, memorizing rules, procedures or facts, understanding mathematical concepts, applying mathematics to "real-life" situations, communicating or reasoning mathematically, and problem solving in every day or novel situations are approaches to teaching mathematics that have been advocated in recent years and are used to varying degrees in different countries. In science, focus on the acquisition of basic science facts, the understanding and application of science concepts, emphasis on formulating a hypothesis, designing and conducting investigations to test hypotheses, and communicating scientific explanations are teaching strategies that are emphasized in some countries more than in others.

At the school level, the relative emphasis and amount of time specified for mathematics, science, and other subjects up through various grade levels can greatly affect the opportunities to learn. Practices such as tracking and streaming can expose students to different curricula. In science, teaching the major components of science as separate subjects can result in different experiences for students compared with the science-as-single-subject approach.

Many countries have systems in place for monitoring and evaluating the implementation of the curriculum and for assessing the status of their education systems. Commonly used methods include national or regional standardized tests, school inspection, and audits. Policy makers also may work collaboratively with the school community (or selected subpopulations) to develop, implement, and evaluate the curriculum. Also, many countries train teachers in the content and pedagogic approaches specified in the curriculum. Such training may be an integral part of the teacher education curriculum, or it may be included in professional development programs for practicing teachers. The implementation of the curriculum can be further supported through the development and use of teaching materials, including textbooks, instructional guides, and ministerial notes, that are specifically tailored to the curriculum.

The Schools

The environment and organization of a school influences the ease and effectiveness of the implementation of curricular goals. Accepting that an effective school is not simply a collection of discrete attributes, but rather a well-managed integrated system where each action or policy directly affects all other parts, TIMSS focuses on a set of indicators of school quality that research has shown to characterize schools that are effective and successful in attaining curricular goals.

School Characteristics

School size, its location, and characteristics of the student body impact how the school system works. There is no clear agreement among researchers and educators about what constitutes a "small" or "large" school. Research has shown that small schools are more intimate learning communities. Small schools tend to provide more safe environments and are characterized by a better sense of community (Hill & Christensen, 2007; Klonsky, 2002; Wasely, Fine, Gladden, Holand, King, Mosak, & Powell, 2000). Schools, however, must be large enough to be cost effective, and provide for a supportive infrastructure such as libraries, laboratories, gymnasia, but not be so large as to become organizationally cumbersome to run (Martin, Mullis, Gregory, Hoyle, & Shen, 2000).

Schools in economically depressed neighborhoods may provide an environment less conductive to learning than schools in areas well-to-do economically. In some countries schools in urban areas may provide for a more supportive environment because of better staffing conditions and the student population coming from economically more advantaged backgrounds (Erberber, 2009; Johansone, 2009). Also, schools in urban areas may have better access to community resources (museums, libraries, etc.). In contrast, in other countries schools in urban areas are located in neighborhoods with considerable poverty and little community support (Darling-Hammond, 1996).

School Organization for Instruction

Whether as part of a larger national, regional, or local education system, or because of decisions made at the school level, mathematics and science instruction is carried out within certain organizational constraints. For example, TIMSS found that instructional time, and in particular the time devoted to mathematics and science, can influence achievement. Other school level policies, such as grouping arrangements, may affect achievement indirectly by influencing the social interactions in the classroom and students' motivation to learn (Saleh, Lazonder, & De Jong, 2005).

The school principal plays a critical role in the development of professional learning communities (Louis, Kruse, & Raywid, 1996). Research has shown that the school leadership style has an indirect effect on student achievement (Bruggenkate, 2009). This leadership generally involves a clear articulation of the school's mission and managing curriculum, but can have different dimensions (Davies, 2009; Marzano, Waters, & McNulty, 2005; Robinson, 2007). An effective school leader brings coherence to the "complexities of schooling" by aligning the structure and culture of the school with its core purpose (DuFour, Ekar, & DuFour, 2005). This includes guiding the school in setting directions and seeking future opportunities, monitoring that the school's goals are met, as well as building and sustaining an effective learning environment and a positive school climate.

School Climate for Learning

School climate comprises many factors, including values, cultures, safety practices, and organizational structures that cause a school to function and react in particular ways. Respect for individual students and teachers, a safe and orderly environment, constructive interactions among administrators, teachers, parents, and students all contribute to a positive school climate and lead to higher student achievement (Greenberg, Skidmore, & Rhodes, 2004). For validation purposes, it is important to collect information about school climate as perceived by students, teachers, and principals.

Although a safe and orderly school environment does not in and of itself guarantee high levels of student achievement, student learning can be more difficult in schools where student discipline is a problem, where students are regularly absent or late to class, or where they fear injury or loss of personal property (Osher, Dwyer, & Jimerson, 2006). The sense of security that comes from having few behavior problems and little or no concern about student or teacher safety at school promotes a stable learning environment.

Research has shown that good attendance by students and teachers is related to higher achievement. If students do not attend school regularly, they dramatically reduce their opportunity to learn. Previous TIMSS research has shown that students have lower achievement in schools where principals report attendance problems.

Similarly, teachers' absences have an impact on student achievement by reducing students' opportunities to learn and teachers being absent or leaving school before the end of the school year are an increasing problem (Abadzi, 2007; Clotfelter, Ladd, & Vigdor, 2007; Miller, Murnane, & Willett, 2007). The school environment is also enhanced when staff members show a positive attitude toward students, collaborate in curricular and extracurricular activities, and participate in professional development.

Teaching Staff

Research attributes much of school leaders' success to the professional development opportunities that they provide for their staff members, particularly teaching staff. The professional development of teachers is of central importance to any attempts to change or reform an education system. Unless teachers participate in ongoing professional development activities, they risk being uninformed about key developments in education and in their subject areas that have occurred since they received their initial training. Effective principals are more creative in finding ways to secure the resources necessary to make professional development opportunities available to their teachers (Cotton, 2003).

The general purpose of teacher evaluation is to safeguard and improve the quality of instruction received by students. There are numerous ways to evaluate teachers. One way found to be effective is principals observing classrooms and providing their teachers feedback about their teaching (Butler, 1997). Other methods used for evaluating teacher quality include teacher peer review and monitoring of student achievement. Successful principals, however, do not only monitor and report student progress data, but also ensure that these are used to improve instruction.

School Resources

The extent and quality of school resources is also critical for quality instruction (Greenwald, Hedges, & Laine, 1996; Lee & Barro, 2001). These may include resources as basic as trained teachers or adequate classroom space, as well as less essential but beneficial resources like comfortable furniture and surroundings.

Teaching and learning can be facilitated by allocating the facilities, materials, and equipment necessary to achieve the specified learning goals. Results from TIMSS indicate that students in schools that are well resourced generally have higher achievement than those in schools where shortages in resources affect the capacity to implement the curriculum. Two types of resources—general and subject specific—affect the curriculum implementation. General resources include teaching materials, budget for supplies, school buildings, heating/cooling and lighting systems, and classroom space. Subject-specific resources for mathematics and science may include computers, computer software, calculators, laboratory equipment and materials, library materials, and audio-visual resources.

While computers are undoubtedly changing the educational landscape, schools operate with finite resources, and the allocation of money, time, and space for technology may divert scarce resources from other priorities, such as increasing teachers' salaries and professional development, lowering student-teacher ratios, and the provision of teaching resources including laboratory equipment and space. Though research on the effectiveness of technology in the classroom is indeed somewhat inconclusive, there is evidence indicating that computer access and use have a positive impact on student achievement (Laffey, Espinosa, Moore, & Lodree, 2003). The effective use of technology requires suitable training of teachers, students, and school staff. Use of computers can also be enhanced by providing access to the Internet for educational purposes. Factors limiting computer use include the lack of appropriate software and hardware, software not congruent with the curriculum, lack of teacher training and support, and lack of funding for computer repair and maintenance.

Parental Involvement

The success of a school can be greatly influenced by a cooperative attitude among school administrators, teachers, and parents (National Education Association, 2008). A significant body of research indicates that when parents participate in their children's education, the result is an increase in students' academic achievement and an improved overall attitude toward school (Dearing, Kreider, & Weiss, 2008). Home-school cooperation, however, requires outreach by the school. Successful schools reach out to their parent communities and provide opportunity and structure for the parents to get involved (Epstein, 2001; Sheldon & Epstein, 2005). Parental involvement may range from volunteering for field trips and fundraising to serving on school committees to revise curricula and actively participating in personnel or school finance decisions. One approach to strengthening the home-school connection is to help parents support children with their mathematics and science schoolwork. Schools may organize training workshops for parents in mathematics and science or offer information sessions on learning strategies and the curriculum.

Classroom Contexts

The teacher is the primary agent of curriculum implementation and a very influential determinant of the classroom environment (Lundberg & Linnakyla, 1993; Rivkin, Hanushek, & Kain, 2005). Teachers vary in their preparation and training, teaching experience, attitudes, and use of particular instructional approaches. Also, the behaviors, attitudes, and preparedness of the students in the classroom may influence the teacher's instructional choices, thereby affecting student learning (Kurtz-Costes & Schneider, 1994).

Even though the curricular policies and resources of the school often set the tone for accomplishments in the classroom, and the school provides a general context for learning, students' day-to-day classroom activities are likely to have a more direct impact on their mathematics and science achievement. The instructional approaches and materials used are clearly important for establishing teaching and learning patterns in the classroom, including the curriculum topics that are actually addressed, the strategies employed to teach these, and the availability of resources, such as computers or laboratory equipment.

Teacher Education and Development

Research suggests that to ensure excellence teachers should have high academic skills, teach in the field in which they received their training, have more than a few years of experience, and participate in high-quality induction and professional development programs (Mayer, Mullens, & Moore, 2000). The qualification and competence of teachers can be critical, and prospective teachers need coursework for knowledge and understanding, experience from practical training in schools, and a good induction process.

TIMSS has shown that there is considerable variation across countries in the level of education teachers complete as well as in the percentage of students taught mathematics or science by teachers with a major in the subject. Research has shown that teachers who have subject specific academic degrees are generally more successful than teachers teaching "out of field" (Goldhaber & Brewer, 2000). In the 21st century, it is even more important than ever for a teacher to have extensive content and curriculum knowledge as well as pedagogical knowledge, knowledge about learners and their characteristics, and knowledge about information technology (Darling-Hammond, 2006; Ertmer, 2003; Hill & Lubienski, 2007).

The extent of teachers' continuing education and exposure to recent developments within the field of teaching mathematics and science is also important. Professional development through seminars, workshops, conferences, and professional journals can help teachers to increase their effectiveness and broaden their knowledge (Yoon, Duncan, Lee, Scarloss, & Shapley, 2007). In some countries and jurisdictions, teachers are required to participate in such activities. Moreover, it has been suggested that the profession of teaching is one that requires lifelong learning, and that the most effective teachers continue to acquire new knowledge and skills throughout their careers.

The transition from university to a school teaching position can be difficult. Consequently, in many countries a large percentage of new teachers leave the profession after only a few years of teaching (Tillmann, 2005; Moskowitz & Stephens, 1997). The extent to which schools take an active role in the acculturation and transition of the new teacher may be important for maintaining a stable teaching force. Mentoring programs, modeling of good teacher practice by peers, and induction programs designed by experienced teachers within the school may be important aids to the beginning teacher.

Teacher Characteristics

Some literature examines the influence of teacher gender, age, and experience on student achievement. Studies have suggested that students learn more when taught by experienced teachers than they do when taught by teachers with just a few years experience. However, the relationship between experience and achievement may be affected by many factors. For example, assignment policies within schools may result in the more highly skilled teachers getting specialized classes, or older teachers getting higher-track classes. The need for long serving teachers to engage in professional development, and the extent to which they do so, can also impact their effectiveness. Controlling for other factors, teaching experience is found to make a difference, particularly in the early years of teaching (Clotfelter, Ladd, & Vigdor, 2006; Hanushek, Kain, O'Brien, & Rivkin, 2005). Findings about the differential impact of male and female teachers also vary by many factors, such as the students' gender, ethnic background, or socioeconomic status (Dee, 2006; UNESCO, 2006).

Teacher attitudes, such as motivation and self-efficacy, shape their students' learning experiences and academic achievement. Teachers who are satisfied with their profession and the working conditions at their school are more motivated to teach and prepare their instruction. Dissatisfying factors may be low salaries, too many teaching hours, lack of equipment and workspace, and lack of communication and collaboration among teaching staff. Collaboration among teachers is widely considered critical for creating and maintaining schools as professional learning communities, where instructional ideas and innovations are shared. Research suggests that if teachers work together to become more collaborative and work oriented, student learning can be increased (Wheelan & Kesselring, 2005). Teachers that discuss their work with colleagues and collaborate in planning and implementing lessons usually feel less isolated and are less likely to leave teaching (Johnson, Berg, & Donaldson, 2005).

Teachers' self-efficacy refers to their sense of personal ability to organize and execute their teaching. Teachers with high beliefs in their abilities are more open to new ideas and less likely to experience emotional burnout. Research has shown that teachers' self-confidence in their teaching skills is not only associated with their professional behavior, but also with students' performance and motivation (Bandura, 1997; Henson, 2002).

Classroom Characteristics

Because most of the teaching and learning in school take place in the classroom, instructional activities often are influenced by the classroom environment. The fundamental characteristics of the classroom include class size, instructional time, and class composition.

Some research indicates that smaller class sizes during the early years of schooling may benefit students' academic development. Smaller classes may be the result of a variety of government policies that cap class size. For example, class size reduction may reflect selective resource allocation to special needs or practical classes. Because of these different reasons for policies on class size, research findings are somewhat ambiguous (Nye, Hedges, & Konstantopoulos, 2001). Whatever the reason for the class size, there is little doubt that it shapes the classroom environment and affects how teachers implement the instruction.

Results from TIMSS show that there is variation between countries in the intended instructional time prescribed in the curriculum and the time implemented in the classroom. On average, however, there was very close agreement between the curriculum guidelines and teachers' reports about the implementation. Research for developing countries has shown that it is especially important that instructional time is used effectively toward the learning goals and not wasted for secondary activities not related to instructional content (Abadzi, 2007).

The students themselves can be very important to the classroom atmosphere. Because prior knowledge guides learning, students need the prerequisites before they can make gains in mathematics and science achievement. Effective teachers assess students' language skills and conceptual understanding, and link new ideas, skills, and competencies to prior understandings. Students with some physical or psychological barrier, such as lack of nutrition or sleep deprivation, are not able to attend and participate as well in the moment of instruction. A classroom full of alert, well-fed students will be more ready to learn than tired and hungry students or students with unaddressed disabilities (McLaughlin, McGrath, Burian-Fitzgerald, Lanahan, Scotchmer, Enyeart, & Salganik, 2005).

Instructional Materials and Technology

Another aspect of the classroom that is relevant for successful implementation of the intended curriculum is the availability and use of technology and other instructional materials experienced by students in schools. Computers and the Internet provide students ways to explore concepts in-depth, trigger enthusiasm and motivation for learning, enable students to learn at their own pace, and provide students with access to vast information sources. Besides giving students access to the Internet, computers can serve a number of other educational purposes. While initially limited to learning drills and practice, they are now used in a variety of ways including tutorials, simulations, games, and applications. New software enables students to pose their own problems and explore and discover mathematics and scientific properties on their own. Computer software for modeling and visualization of ideas can open a whole new world to students and help them connect these ideas to their language and symbol systems. For computers to be integrated effectively into instruction, teachers have to feel comfortable to use them and receive adequate technical and pedagogical support.

Calculator use varies widely among, and even within countries, but generally is increasing steadily as cost becomes less of an impediment and mathematics curricula evolve to take calculators into account. Many countries have policies regulating the access to and use of calculators, especially at the earlier grade levels. What those policies are and how they change over the grades can be important in understanding the curriculum. Calculators can be used in exploring number recognition, counting, and the concepts of larger and smaller. They can allow students to solve numerical problems faster by eliminating tedious computation and thus become more involved in the learning process. How best to make use of calculators, and what role they should have, continue to be questions of importance to mathematics curriculum specialists and teachers.

In addition to textbooks or workbooks, resources used in mathematics instruction include tools or visual representations of mathematical objects that help students understand quantities and procedures. Research has explored the different ways these objects can be used to facilitate learning basic mathematical skills and solving mathematical problems (Manalo, Bunnell, & Stillman, 2000; Witzel, Mercer, & Miller, 2003).

Curriculum Topics Taught

A major focus of the implemented curriculum is the extent to which the mathematics and science topics in the TIMSS frameworks are covered in the classroom. TIMSS addresses this question by asking the mathematics and science teachers of the students assessed to indicate whether each of the topics tested has been covered in class, either in the current or previous years, and the percentage of time in class devoted to each of the TIMSS mathematics and science content domains. TIMSS characterizes the coverage and level of rigor of the mathematics and science courses taught in participating countries by describing the main focus of the work in the classes being tested.

Instructional Activities

Teachers employ a variety of strategies to encourage students to learn. Students learn best when they are interested and involved.

Major instructional practices that increase motivation include setting goals, bringing interesting materials to class, relating what students are learning to their daily lives, and providing extrinsic rewards and praise. To move students from extrinsic to intrinsic motivation teachers can express genuine care for their students' cognitive, emotional, and physical needs, give students knowledge-building experiences, and increase their self-esteem and self-efficacy in mathematics and science by asking them to solve problems and explain their answers (Pintrich, 2003). For example, studies have shown students who conduct hands-on learning activities outperform their peers as do students who have the benefit of individualized instruction (Wenglinsky, 2000). In science, research has shown higher achievement for eighth grade students to be associated with increased frequency of doing hands-on activities in science, student discussion of measurements and results from hands-on activities, and students working with others on a science activity or project as well as with increased frequency of reading textbooks and writing longer answers about science (Braun, Coley, Jia, & Trapani, 2009).

Reports on how much emphasis is placed on integrating technology into different aspects of instruction also provide important information about classroom experiences. As discussed earlier, use of the Internet and computer software can expand students' learning opportunities. Also, calculators are becoming more widely used in many countries.

Homework is a way to extend instruction and assess student progress. The amount of homework assigned for mathematics and science varies both within and across countries. In some countries, homework is assigned typically to students who need it the most. In other countries, students receive homework as enrichment exercise. For this reason research on the effectiveness of homework shows mixed results (Cooper, Robinson, & Patall, 2006; Trautwein, 2007).

Assessment

In addition to homework, teachers have a number of ways to monitor student progress and achievement. TIMSS results show that teachers devote a fair amount of time to student assessment, whether as a means of gauging what students have learned to guide future learning, or for providing feedback to students, teachers, and parents. The frequency and format of assessment are important indicators of teaching and school pedagogy. Informal assessments during instruction help teachers identify the needs of particular individuals, evaluate the pace of the presentation, and adapt the instruction. Formal tests, both teacher-made and standardized assessments, typically are used to make important decisions about the students, such as grades or marks, or about schools for accountability purposes. Teachers use a variety of formats and test a wide range of content and cognitive skills. The types of questions included in tests and quizzes can send strong signals to students about what is important.

Student Characteristics and Attitudes

Students bring experiences and expectations to the classroom that affect their learning aptitude and motivation. Schools' and teachers' success in implementing the curriculum is influenced by students' prerequisite knowledge and skills as well as their attitudes toward learning mathematics and science.

Student Demographics and Home Background

Students come to school from different backgrounds and with different experiences. There is ample evidence that student achievement in mathematics and science is related to student characteristics (e.g., gender, language spoken) and home background factors (e.g., immigration status, socioeconomic background).

While for decades there has been a concern about girls lagging behind in mathematics and science, currently the majority of research shows the achievement difference between boys and girls in mathematics and science to be minimal and smaller than the difference associated with home background factors (Coley, 2001; McGraw, Lubienski, & Strutchens, 2006). TIMSS has shown that there is no large overall difference in average mathematics and science achievement between boys and girls across participating countries, on average, although the situation varies from country to country. In contrast, TIMSS has shown a learning gap between students who do and do not have the language of instruction as their primary language.

In many countries, increasing migration has resulted in a significant population with immigrant backgrounds whose native language is not the language of instruction. Immigrant students often encounter difficulties as they adjust to a new environment and culture and receive instruction that is different from the language spoken at home (Lolock, 2001; Schmid, 2001). In some countries, immigrant students are at a double disadvantage due to their parents' education and socioeconomic background.

Research consistently shows a strong positive relationship between achievement and indicators of socio-economic status, such as parents' or caregivers' level of education or occupation class (Bradley & Corwyn, 2002; Haveman & Wolfe, 2008; Willms, 2006). Other home background factors that have also been shown to be important include the number of books in the home, the presence of a study desk, and the availability of a computer and an Internet connection (National Center for Education Statistics, 2006; Woessmann, 2004). Such factors are also indicative of the home support for learning and may influence students' overall educational aspirations.

Social capital theory argues that a strong home-school connection is indicative of students' educational success. That is because "better connected" families can provide more effective support to their children and help with their schoolwork. Social resources have been found to have a positive impact on student achievement, though the effectiveness of parental support for schoolwork is somewhat ambiguous (Marks, Cresswell, & Ainley, 2006; Lee & Bowen, 2006). Parents may be more likely to help with schoolwork when they are able to and are interested in engaging with the content, aside from their children's marks or grades. At the same time, parents may only help when their child is struggling and in need of academic support.

Students' experiences before school starts are pertinent to their later success. Small children engage in more or less structured early numeracy activities in their homes and pre-school which stimulate their interest and enhance the development of their abilities (Melhuish, Phan, Sylva, Sammons, Siraj-Blatchford, & Taggart, 2008; Sarama & Clements, 2009). These activities include playing with blocks or construction toys, reciting counting rhymes or singing counting songs, playing games involving shapes, and playing other types of games that involve quantitative reasoning. Young children's mathematical skills vary significantly across countries and are strongly related to their family's socioeconomic background (Clements & Sarama, 2009; West, Denton, & Germino-Hausken, 2000).

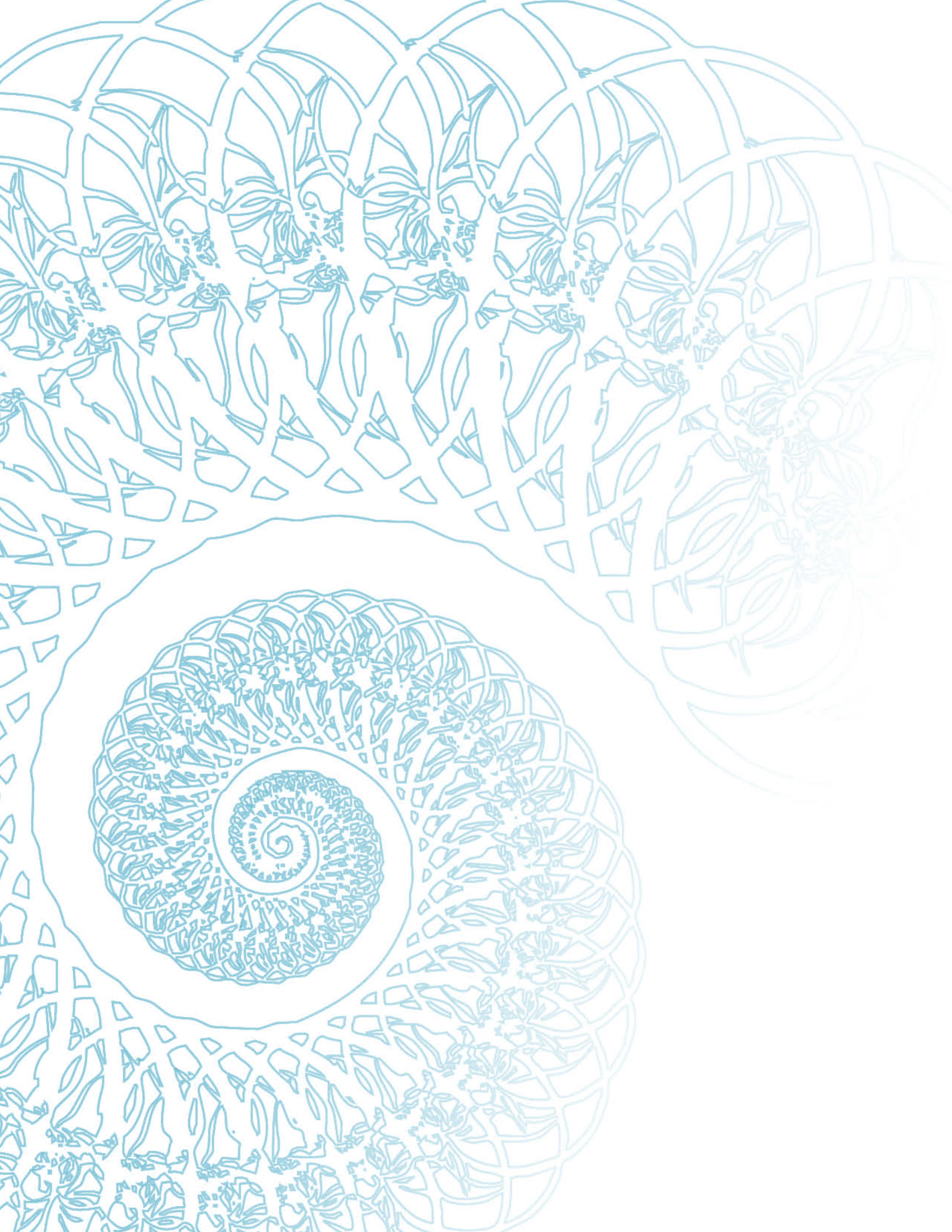
Student Attitudes Toward Learning Mathematics and Science

Helping students to develop positive attitudes toward mathematics and science is an important goal of the curriculum in many countries. Students' motivation to learn can be affected by whether they find the subject enjoyable, place value on the subject, and think it is important in the present and for future careers. Personal interest in a subject motivates the learner and facilitates the learning in going beyond surface level information. In addition, students' motivation can be affected by their self confidence in learning the subject. TIMSS results have shown that students with more self-efficacy or higher self-esteem typically perform better in mathematics and science. Because motivation to learn includes having a feeling that you can succeed, it is important for students to have a strong self-concept about their abilities in order to continue building on current levels of learning to move to higher plateaus. A positive attitude toward mathematics and science and a strong self-concept encourage students to engage with the instruction and show persistence, effort, and attentiveness. Students showing high levels of engagement typically perform higher and high achievers, again, have a strong self-concept and positive attitude (Akey, 2006; Singh, Granville, & Dika, 2002).

Like the amount of homework assigned by the teacher, the time students spend on homework assignments varies across countries and the relationship with achievement is somewhat ambiguous. Higher achieving students may be more motivated to spend time on homework. Lower achieving students, however, may take longer to complete their tasks. There are indications that it is not the amount of time spent on homework per se, but the degree of conscientiousness and motivation to complete the homework assignments and the homework quality that matters. The diligence put into homework and how well it turns out may be stronger predictors of academic success than the time spent on it (Trautwein, Luedtke, Kastens, & Koeller, 2006).

TIMSS 2011 Assessment Design

Chapter 4



Chapter 4

TIMSS 2011 Assessment Design

Overview

The TIMSS 2011 international assessment of student achievement at fourth and eighth grades comprises written tests in mathematics and science together with sets of questionnaires that gather information on the educational and social contexts for achievement. Central to the TIMSS 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' improvement or decline by tracking trends in student performance from one assessment cycle to the next. This requires an assessment that is wide ranging in its coverage of mathematics and science and innovative in its measurement approach. Conducted on a four-year cycle, with each assessment linked to the one that preceded it, TIMSS provides regular and timely data for educators and policy makers on trends in students' mathematics and science achievement.

In addition to measuring trends in achievement at fourth and eighth grades, administering TIMSS at fourth and eighth grades every four years provides the opportunity to monitor achievement changes within a grade cohort, as the fourth grade students in one TIMSS cycle become the eighth grade students in the next cycle. Further, the TIMSS fourth grade assessment provides data that complement PIRLS, IEA's Progress in International Reading Literacy Study, which assesses reading comprehension at fourth grade every five years. The fifth in the TIMSS series of assessments, TIMSS 2011 will be the first TIMSS assessment to have data collection in the same school year as PIRLS, providing a rare opportunity for countries to collect internationally comparable information on mathematics, science, and reading at the fourth grade in the same year and on the same students.[1]

Student Populations 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. The TIMSS target populations 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 is the International Standard Classification of Education developed by the UNESCO Institute for Statistics and provides an international standard for describing levels of schooling across countries. The ISCED system describes the full range of schooling, from pre-primary (Level 0) to the second level of tertiary education (Level 6). ISCED Level 1 corresponds to primary education or the first stage of basic education. The first year of Level 1 should mark the beginning of "systematic apprenticeship of reading, writing and mathematics" (UNESCO, 1999). Four years after this would be the target grade for fourth grade TIMSS, and is the fourth grade in most countries. Similarly, eight years after the first year of ISCED Level 1

1 Countries participating in PIRLS and TIMSS at the fourth grade in 2011 have the option of administering the assessments to the same students or to separate student samples. Most countries are planning to administer the two assessments to the same students.

is the target grade for eighth grade TIMSS, and is the eighth grade in most countries. However, given the cognitive demands of the assessments, TIMSS wants 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

TIMSS 2011 will provide a comprehensive picture of the mathematics and science achievement of fourth- and eighth-grade students in each participating country. This will include achievement in each of the content and cognitive domains (as defined in Chapters 1 and 2) as well as overall mathematics and science achievement. Consistent with the goal of a comprehensive description of mathematics and science achievement, the complete TIMSS 2011 assessment consists of a large pool of mathematics and science questions (known as items) at each grade level. However, to keep the assessment burden on any one student to a minimum, each student is presented with only a sample of the items, as described in the next section. Following data collection, student responses are placed on common mathematics and science scales at each grade level to provide an overall 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[2] provide a common metric on which countries can compare their fourth and eighth grade students' progress in mathematics and science from assessment to assessment. The TIMSS mathematics and science achievement scales were established in 1995 to have a scale average of 500 and a standard deviation of 100,

2 TIMSS provides separate scales for mathematics and for science at each grade level, as well as for each content and cognitive domain.

corresponding to the international means and standard deviations across all of the countries that participated in TIMSS 1995 at the fourth and eighth grades. Using items that were administered in both 1995 and 1999 assessments as a basis for linking the two sets of assessment results, and working separately for mathematics and science, the TIMSS 1999 data also were placed on the scale so that countries could gauge changes in students' mathematics and science achievement since 1995. Using similar procedures, again separately for mathematics and science, the TIMSS 2003 data[3] and the TIMSS 2007 data were placed on the TIMSS scale, as will be the data from TIMSS 2011. This will enable TIMSS 2011 countries that have participated in TIMSS since its inception to have comparable achievement data from 1995, 1999, 2003, 2007, and 2011, and to plot changes in performance over this period.[4]

As previously mentioned, in addition to the achievement scales for mathematics and science overall, TIMSS 2011 will construct scales for reporting relative student performance in each of the mathematics and science content and cognitive domains. More specifically, in mathematics at the fourth grade there will be three content scales, corresponding to the three content domains of number, geometric shapes and measures, and data display and four at the eighth grade—number, algebra, geometry, and data and chance. In science, there also will be three content scales at fourth grade: life science, physical science, and earth science, and four at the eighth grade: biology, chemistry, physics, and earth science. The *TIMSS 2011 Assessment Frameworks* specify three cognitive domains, knowing, applying, and reasoning, which span the mathematics and science content at both grades. Reporting scales will be constructed for each cognitive domain in mathematics and science at each grade level.

3 Because TIMSS 1999 was conducted only at the eighth grade, the TIMSS 2003 fourth grade data were linked directly to the TIMSS 1995 data, omitting the 1999 linking step.

4 Countries that have participated in TIMSS at the fourth grade since the beginning will have comparable data from 1995, 2003, 2007, and 2011.

TIMSS 2011 Student Booklet Design

A major consequence of TIMSS' 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 2011 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 14 student achievement booklets, with each student completing just one booklet. Each item appears in two booklets, providing a mechanism for linking together the student responses from the various booklets. Booklets are distributed among students in participating classrooms so that the groups of students completing each booklet are approximately equivalent in terms of student ability. TIMSS uses item-response theory scaling methods to assemble a comprehensive picture of the achievement of the entire student population from the combined responses of individual students to the booklets that they are assigned.[5] This approach reduces to manageable proportions what otherwise would be an impossible student burden, albeit at the cost of greater complexity in booklet assembly, data collection, and data analysis.

To facilitate the process of creating the student achievement booklets, TIMSS groups the assessment items into a series of item blocks, with approximately 10-14 items in each block at the fourth grade and 12-18 at the eighth grade. As far as possible, within each block the distribution of items across content and cognitive domains matches the distribution across the item pool overall. As in the TIMSS 2007 assessment, TIMSS 2011 has a total of 28 blocks, 14 containing mathematics items and 14 containing science items. Student booklets were assembled from various combinations of these item blocks.

Following the 2007 assessment, 8 of the 14 mathematics blocks and 8 of the 14 science blocks were secured for use in measuring

5 The TIMSS scaling methodology is described in detail in Foy, Galia, & Li (2008).

trends in 2011. The remaining 12 blocks (6 mathematics and 6 science) were released into the public domain for use in publications, research, and teaching, to be replaced by newly-developed items for the TIMSS 2011 assessment. Accordingly, the 28 blocks in the TIMSS 2011 assessment comprise 16 blocks of trend items (8 mathematics and 8 science) and 12 blocks of new items developed for 2011. As shown in Exhibit 10, the TIMSS 2011 mathematics blocks are labeled M01 through M14 and the science blocks S01 through S14. Blocks with labels ending in odd numbers (01, 03, 05, etc.) contain the trend items from the 2007 assessment, as do blocks ending in 06. The remaining blocks with labels ending in even numbers contain the items developed for use for the first time in TIMSS 2011.

Exhibit 10: TIMSS 2011 Item Blocks – Fourth and Eighth Grades

Mathematics Blocks	Source of Items	Science Blocks	Source of Items
M01	Block M13 from TIMSS 2007	S01	Block S13 from TIMSS 2007
M02	New items for TIMSS 2011	S02	New items for TIMSS 2011
M03	Block M06 from TIMSS 2007	S03	Block S06 from TIMSS 2007
M04	New items for TIMSS 2011	S04	New items for TIMSS 2011
M05	Block M09 from TIMSS 2007	S05	Block S09 from TIMSS 2007
M06	Block M10 from TIMSS 2007	S06	Block S10 from TIMSS 2007
M07	Block M11 from TIMSS 2007	S07	Block S11 from TIMSS 2007
M08	New items for TIMSS 2011	S08	New items for TIMSS 2011
M09	Block M08 from TIMSS 2007	S09	Block S08 from TIMSS 2007
M10	New items for TIMSS 2011	S10	New items for TIMSS 2011
M11	Block M12 from TIMSS 2007	S11	Block S12 from TIMSS 2007
M12	New items for TIMSS 2011	S12	New items for TIMSS 2011
M13	Block M14 from TIMSS 2007	S13	Block S14 from TIMSS 2007
M14	New items for TIMSS 2011	S14	New items for TIMSS 2011

Fourth-grade students are expected to spend 18 minutes on each item block, and eighth-grade students 22½ minutes, on average. Consequently, the 28 blocks of fourth-grade items are estimated to contain almost 8½ hours of testing time and the eighth-grade blocks about 10½ hours. From past experience with TIMSS, National Research Coordinators from participating countries agreed that the testing time for any one student should not be increased from previous assessments. Thus, as in the past, the assessment time for each student booklet must fit into 72 minutes for fourth grade and 90 minutes for eighth grade. An additional 30 minutes for a student questionnaire also was planned at each grade level.

In choosing how to distribute assessment blocks across student achievement booklets, the major goal was to maximize coverage of the framework while ensuring that every student responded to sufficient items to provide reliable measurement of trends in both mathematics and science. A further goal was to ensure that achievement in the mathematics and science content and cognitive domains could be measured reliably. To enable linking among booklets while keeping the number of booklets to a minimum, each block appears in two booklets.

In the TIMSS 2011 booklet design, the 28 assessment blocks are distributed across 14 student achievement booklets (see Exhibit 11). The fourth- and eighth-grade booklet designs are identical, although the fourth-grade blocks contain 18 minutes of assessment items and the eighth grade blocks 22½ minutes. Each student booklet consists of four blocks of items; two blocks of mathematics items and two of science items. In half of the booklets, the two mathematics blocks come first, and then the two science blocks, and in the other half the order is reversed. Additionally, in most booklets two of the blocks contain trend items from 2007 and two contain items newly developed for TIMSS 2011. For example, as may be seen from Exhibit 11, students assigned Booklet 1 complete two blocks of mathematics items, M01 and M02, and two blocks of science items, S01 and S02. The items in blocks M01 and S01 are trend items from TIMSS 2007, while those in M02 and S02 are items new for TIMSS 2011. Similarly, students assigned Booklet 2 complete two science blocks, S02 and S03, followed by two mathematics blocks, M02 and M03. S02 and M02 contain the new items and S03 and M03 the trend items.

Exhibit 11: TIMSS 2011 Student Achievement Booklet Design – Fourth and Eighth Grades

	Assessment Blocks			
Student Achievement Booklet	Part 1		Part 2	
Booklet 1	M01	M02	S01	S02
Booklet 2	S02	S03	M02	M03
Booklet 3	M03	M04	S03	S04
Booklet 4	S04	S05	M04	M05
Booklet 5	M05	M06	S05	S06
Booklet 6	S06	S07	M06	M07
Booklet 7	M07	M08	S07	S08
Booklet 8	S08	S09	M08	M09
Booklet 9	M09	M10	S09	S10
Booklet 10	S10	S11	M10	M11
Booklet 11	M11	M12	S11	S12
Booklet 12	S12	S13	M12	M13
Booklet 13	M13	M14	S13	S14
Booklet 14	S14	S01	M14	M01

As summarized in Exhibit 12, each student completes one student achievement booklet consisting of two parts, followed by a student questionnaire. The individual student response burden for the TIMSS 2011 assessment is the same as in 2007, i.e., 72 minutes for the assessment and 30 minutes for the questionnaire at fourth grade, and 90 minutes and 30 minutes, respectively, at eighth grade.

Exhibit 12: TIMSS 2011 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	45 minutes
Break		
Student Questionnaire	30 minutes	30 minutes

Countries participating in TIMSS aim for a sample of at least 4,500 students to ensure that there are enough respondents for each item. The 14 student booklets are distributed among the students in each sampled class according to a predetermined order, so that approximately equal proportions of students respond to each booklet.

Question Types and Scoring Procedures

Students' knowledge and understanding of mathematics and science are assessed through a range of questions in each subject. As described in the *TIMSS 2011 Item Writing Guidelines* (Mullis & Martin, 2009), two question formats are used in the TIMSS assessment—multiple-choice and constructed-response. At least half of the total number of points represented by all the questions will come from multiple-choice questions. Each multiple-choice question is worth one score point. Constructed-response questions generally are worth one or two score points, depending on the nature of the task and the skills required to complete it. In developing assessment questions, the choice of item format depends on the mathematics or science being assessed, and the format that best enables students to demonstrate their proficiency.

Multiple-Choice Questions. In TIMSS, multiple-choice questions provide students with four response options, of which only one is correct. These questions can be used to assess any of the behaviors in the cognitive domains. Multiple-choice questions allow valid, reliable, and economical measurement of a wide range of content in a relatively short testing time. However, because they do not allow for students' explanations or supporting statements, these questions may be less suitable for assessing students' ability to make more complex interpretations or evaluations.

In assessing fourth- and eighth-grade students, it is important that linguistic features of the questions be developmentally appropriate. Therefore, the questions are written clearly and concisely. The response options also are written succinctly in order to minimize the reading load of the question. The options that are incorrect are written to be plausible, but not deceptive. For students who may be unfamiliar with this test question format, the instructions given at the beginning of the test include a sample multiple-choice item that illustrates how to select and mark an answer.

Constructed-Response Questions. For this type of test item students are required to construct a written response, rather than select a response from a set of options. Because they allow students to provide explanations, support an answer with reasons or numerical evidence, draw diagrams, or display data, constructed-response questions are particularly well-suited for assessing aspects of knowledge and skills that require students to explain phenomena or interpret data based on their background knowledge and experience.

The scoring guide for each constructed-response question describes the essential features of appropriate and complete responses. The guides focus on evidence of the type of behavior the question assesses. They describe evidence of partially correct and completely correct responses. In addition, sample student responses at each level of understanding provide important guidance to those who will be rating the students' responses. In scoring students' responses to constructed-response questions, the focus is solely on students' achievement with respect to the topic being assessed, not on their ability to write well. However, students need to communicate in a manner that will be clear to those scoring their responses.

In addition, scoring guides are designed to enable, for each item, identification of the various successful, partially successful, and unsuccessful approaches. Diagnosis of common learning difficulties in mathematics and science as evidenced by misconceptions and errors is an important aim of the study.

Since constructed-response questions constitute an important part of the assessment and are an integral part of the measurement of trends, it is very important for scoring guides to be implemented consistently in all countries and in each data collection year. To ensure consistent application of the scoring guides for trend items in the 2011 assessment, IEA has archived samples of student responses to the TIMSS 2007 assessments from each country; these are used to train scorers in 2011 and to monitor consistent application for those items appearing in both assessments.

Score Points. In developing the assessment, the aim is to create blocks of items that each provide, on average, about 15 score points at fourth grade and about 18 score points at eighth grade. Item blocks contain a variety of item types, including multiple-choice items (1 point each) and constructed-response items (1, 2, or more points) that allow for partial as well as full credit. The exact number of score points and the exact distribution of question types per block varies somewhat.

Releasing Assessment Material to the Public

The TIMSS assessment in 2011 is the fifth in the TIMSS series of regular four-year studies, and provides data on trends in mathematics and science achievement since 1995, 1999, 2003, and 2007. TIMSS will be administered again in 2015, 2019, and so on into the future. With each assessment, as the international reports are published, many items are released to provide the public with as much information as possible about the nature and contents of the assessment. At the same time, the measurement of trends is safeguarded by keeping secure a substantial proportion of the items. As items are released, new items will be developed to take their place.

According to the TIMSS 2011 design, 6 of the 14 assessment blocks in each subject will be released when the assessment results for 2011 are published, and the remaining 8 will be kept secure for use in later assessments. The released blocks will include three blocks containing trend items from 2003, two blocks of trend items from 2007, and one block of items used for the first time in 2011. The released items will be replaced with new items before the next survey cycle, in 2015.

Background Questionnaires

An important purpose of TIMSS is to identify the procedures and practices that are effective in improving students' learning in mathematics and science. To better understand the contextual factors detailed in Chapter 3 that affect students' learning, TIMSS administers background questionnaires to students, their teachers, and their school principals. TIMSS also administers curriculum questionnaires to specialists to collect information about educational policies and the national contexts that shape the content and implementation of the mathematics and science curricula across countries. Finally, the TIMSS Encyclopedia provides a more qualitative description of mathematics and science education in the participating countries. For countries participating in both TIMSS and PIRLS at the fourth grade, the *Learning to Read Survey* provides a special opportunity to collect information from students' parents and caregivers on their home backgrounds as well as quantitative readiness.

Student Questionnaire

A questionnaire is completed by each student who takes the TIMSS assessment. This questionnaire asks about aspects of students' home and school lives, including basic demographic information, their home environment, school climate for learning, and self-perception and attitudes toward mathematics and science. While some questions are identical in the fourth- and eighth-grade versions, the language is simplified in the fourth-grade version and specific content is altered to be appropriate for the respective grade level. The student questionnaire requires 15-30 minutes to complete.

Teacher Questionnaires

A teacher questionnaire is completed by the teachers of mathematics and science to the students sampled to take part in the TIMSS testing. This questionnaire is designed to gather information on teacher characteristics as well as the classroom contexts for teaching and learning mathematics and science, and the topics taught in these subjects.

In particular, the teacher questionnaire asks about teachers' backgrounds, their views on opportunities for collaboration with other teachers, their job satisfaction, and their education and training as well as professional development. The questionnaire also collects information on characteristics of the classes tested in TIMSS, instructional time, materials, and activities for teaching mathematics and science and promoting students' interest in the subjects, use of computers, assessment practices, and homework.

The fourth- and eighth-grade versions of the questionnaire are similar, with specific content targeted to teachers at the specific grade level. Although the general background questions are parallel across versions, questions pertaining to instructional and assessment practices, content coverage, and teachers' views about teaching the subject matter are tailored toward mathematics or science. Many questions, such as those related to classroom activities are specific to the classes sampled for TIMSS. This questionnaire requires about 30 minutes of teachers' time to complete.

School Questionnaire

The principal of each school participating in TIMSS is asked to respond to this questionnaire. It asks about school characteristics, instructional time, resources and technology, parental involvement, school climate for learning, teaching staff, the role of the principal, and students' school readiness. It is designed to take about 30 minutes.

Curriculum Questionnaires

The National Research Coordinator in each country is responsible for completing the mathematics and science curriculum questionnaire, drawing on the expertise of curriculum specialists and educators. The questionnaire is designed to collect basic information about the organization of the mathematics and science curriculum in each country, and about the content of these subjects intended to be covered up to the fourth and eighth grades. It also includes questions on attrition and retention policies, the local or national examination system as well as goals and standards for mathematics and science instruction.

TIMSS 2011 Encyclopedia

The *TIMSS 2011 Encyclopedia* provides context for mathematics and science instruction in the participating countries. Information from the curriculum questionnaire is reported along with information about countries' education systems and policies, including emphasis placed on mathematics and science. In addition, the mathematics and science curriculum in each country is summarized as is information about instructional time and use of instructional materials, equipment, and technology. Teachers' educational training and professional development is also described as well as information about examinations and assessments.

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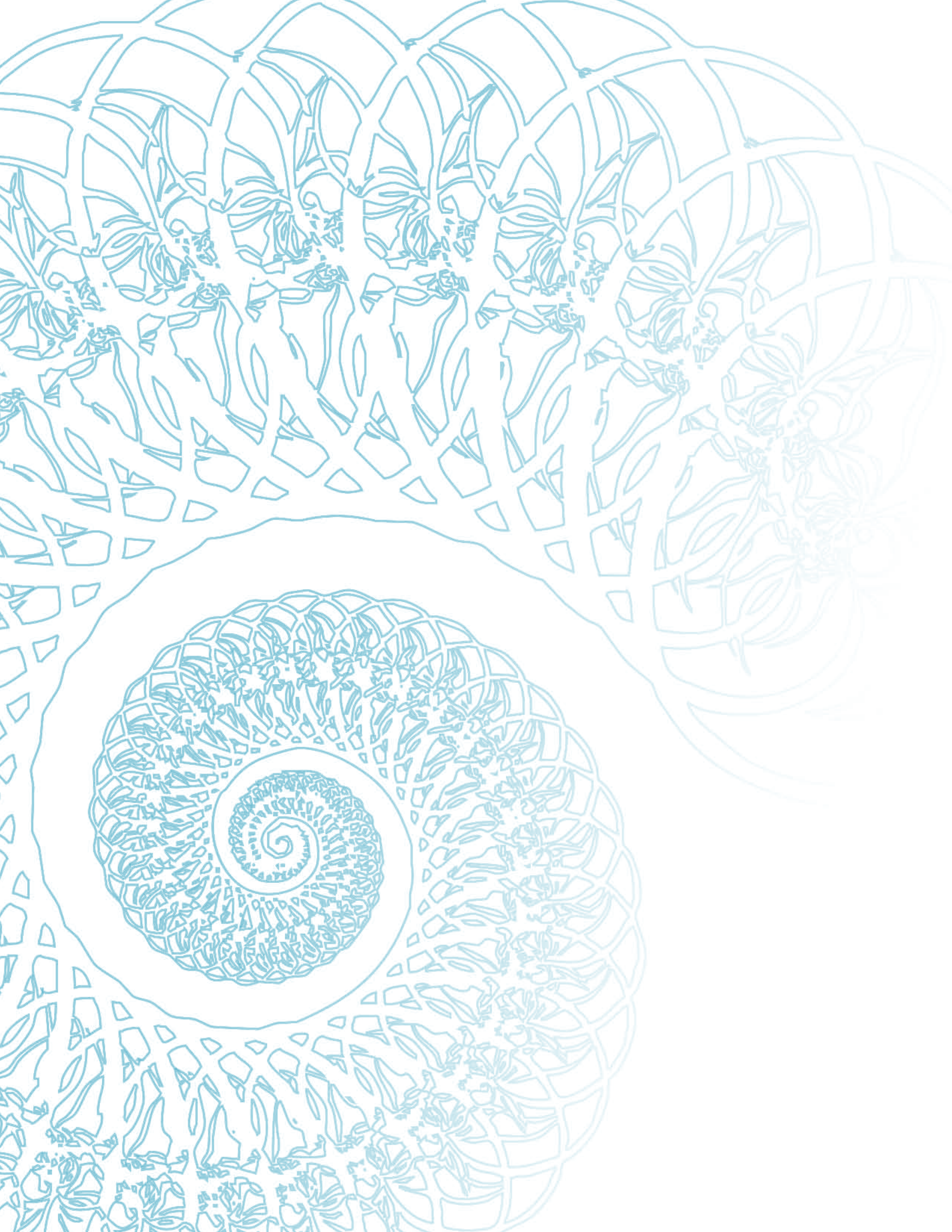

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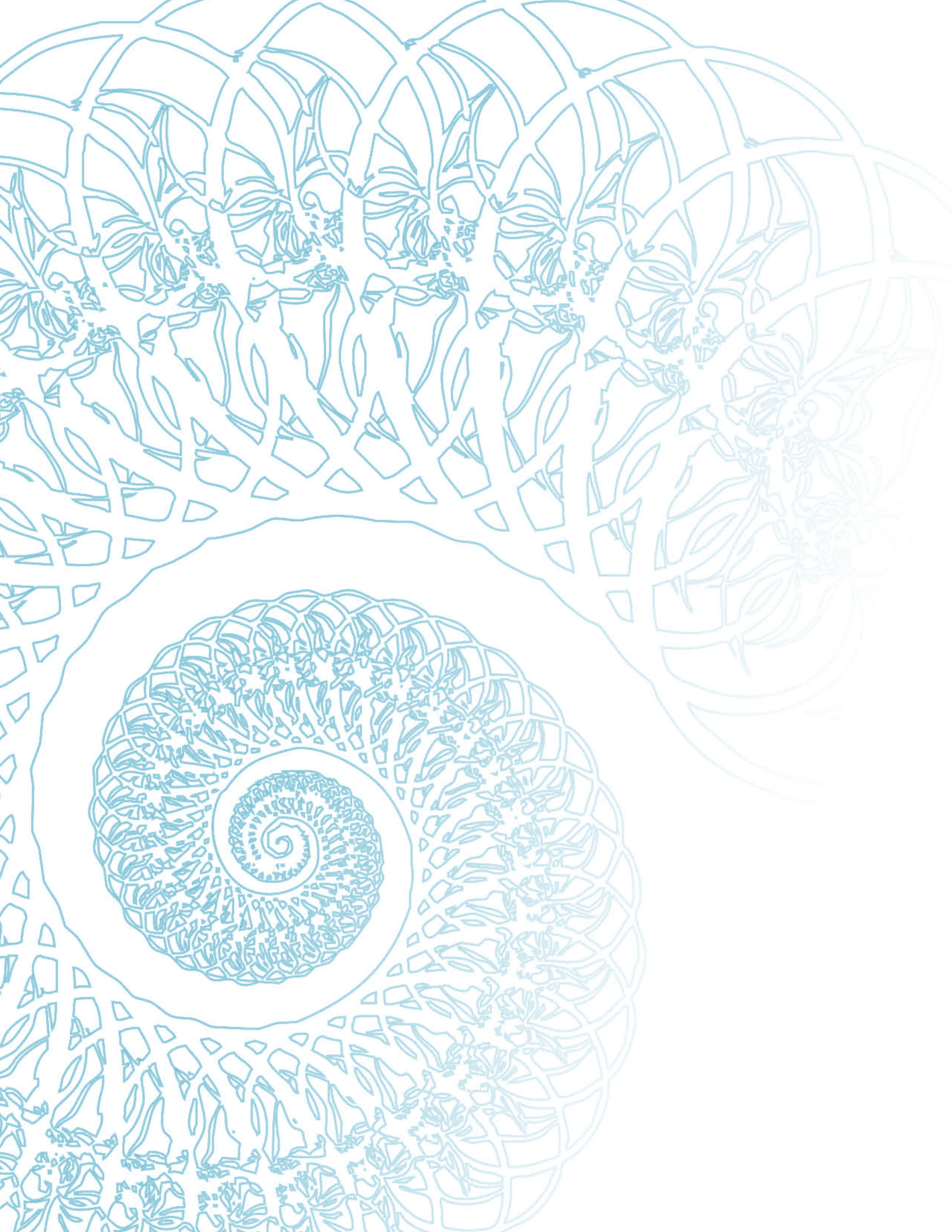
Acknowledgements

Appendix A



Appendix A

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TIMSS is a major undertaking of IEA, and together with PIRLS (Progress in International Reading Literacy Study), comprises the core of IEA's regular cycle of studies. IEA has delegated responsibility for the overall direction and management of these two projects to the TIMSS & PIRLS International Study at Boston College. Headed by Michael O. Martin and Ina V.S. Mullis, the study center is located in the Lynch School of Education. In carrying out these two ambitious international studies, the TIMSS & PIRLS International Study Center works closely with the IEA Secretariat in Amsterdam, the IEA Data Processing and Research Center in Hamburg, Statistics Canada in Ottawa, and Educational Testing Service in Princeton, New Jersey. Especially important is close coordination with the National Research Coordinators designated by the participating countries to be responsible for the complex tasks involved in implementing the studies in their countries. In summary, it takes extreme dedication on the part of many individuals around the world to make TIMSS a success and the work of these individuals across all of the various activities involved is greatly appreciated.

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 2011 began in September of 2008, and has involved extensive input and reviews by individuals at the TIMSS & PIRLS International Study Center, the IEA, the TIMSS 2011 National Research Coordinators, and the two TIMSS expert committees—the TIMSS 2011 Science and Mathematics Item Review Committee and the TIMSS 2011 Questionnaire Item

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Spain

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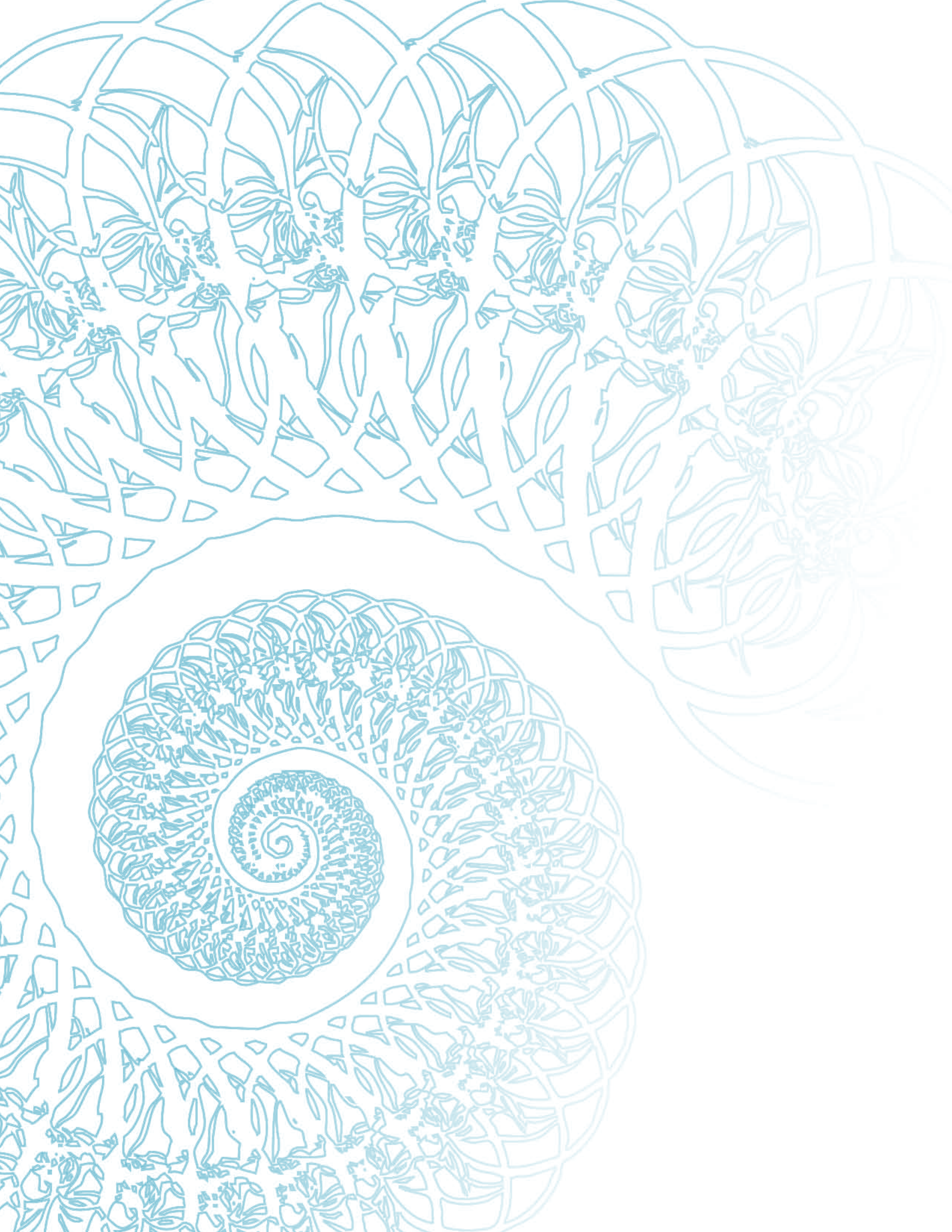
National Agency for Education
Sweden

Gerry Wheeler
United States

Example Mathematics Items

Appendix B



Example Mathematics Items Grade 4

1

A shelf is 240 cm long. Chris is putting boxes on the shelf. Each box takes up 20 cm of shelf space. Which of these number sentences shows how many boxes Chris can fit on the shelf? The number of boxes is shown as ▲.

Ⓐ 240 – 20 = ▲

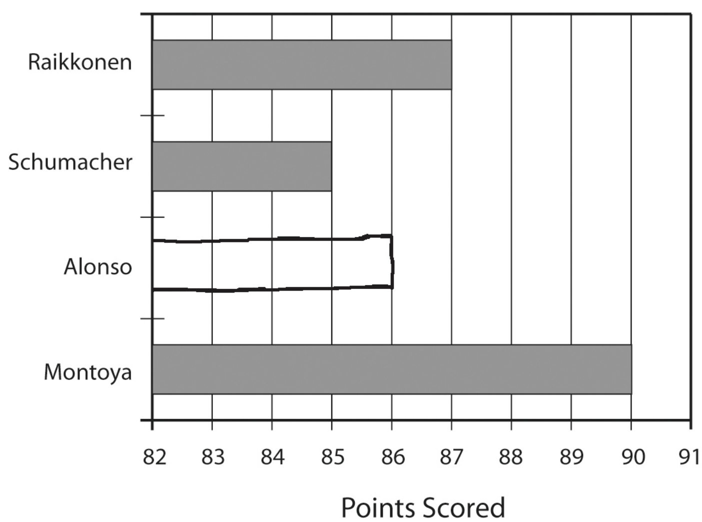
● 240 ÷ 20 = ▲

Ⓒ 240 + 20 = ▲

Ⓓ 240 × 20 = ▲

2

This graph shows the points obtained by 4 drivers in the car racing championship. Montoya is in first place. Alonso is in third place. Draw a bar which shows how many points Alonso has scored.



3

Al wanted to find how much his cat weighed. He weighed himself and noted that the scale read 57 kg. He then stepped on the scale holding his cat and found that it read 62 kg.

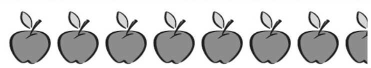
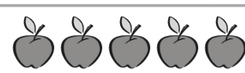
What was the weight of the cat in kilograms?

Answer: ____5____ kilograms

4

The graph shows the number of apples John picked each day.

each  stands for 10 apples

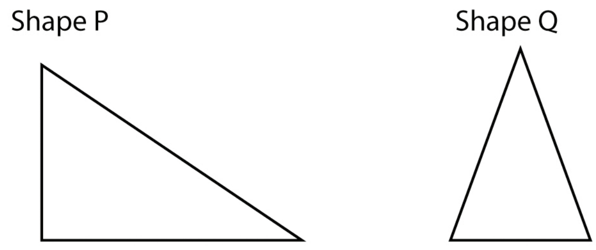
Monday	
Tuesday	
Wednesday	
Thursday	

On which day did John pick 5 apples?

- (A) Monday
- (B) Tuesday
- (C) Wednesday
- (D) Thursday

5

Two shapes are shown below. Describe one way they are the same and one way they are different.



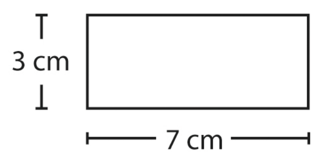
A. Same

Shapes P and Q both are triangles.

B. Different

Shape P has a right angle but shape Q does not.

6



What is the perimeter of this rectangle?

Ⓐ 7 cm

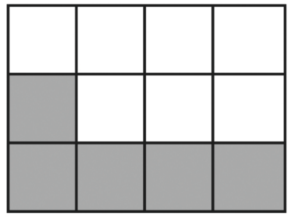
Ⓑ 10 cm

● 20 cm

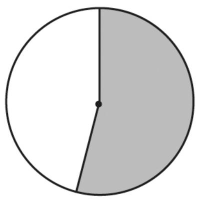
Ⓓ 21 cm

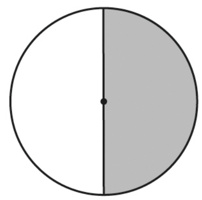
Example Mathematics Items Grade 8

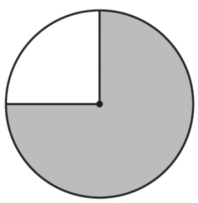
1

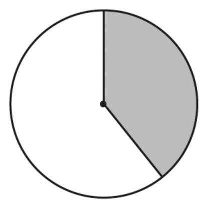


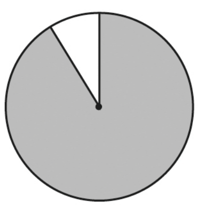
Which circle has approximately the same fraction of its area shaded as the rectangle above?

Ⓐ 

Ⓑ 

Ⓒ 

● 

Ⓔ 

2

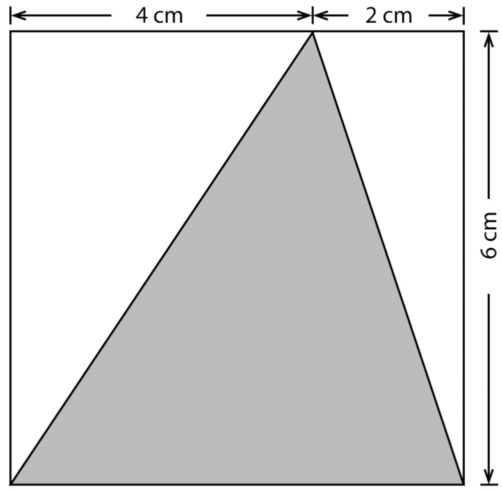
Joe knows that a pen costs 1 zed more than a pencil.
His friend bought 2 pens and 3 pencils for 17 zeds.
How many zeds will Joe need to buy 1 pen and 2 pencils?

Show your work.

Pencil : x zeds
Pen : $y = x + 1$ zeds
$2y + 3x = 17$
$2(x+1) + 3x = 17$
$2x + 2 + 3x = 17$ /−2
$5x = 15$ /:5
$x = 3$
One pencil costs 3 zeds.
$y = x + 1$
$y = 3 + 1 = 4$
One pen costs 4 zeds.
$x + 2y = 4 + 2 \cdot 3 = 4 + 6 = 10$
One pen and two pencils cost 10 zeds.

3

The figure shows a shaded triangle inside a square.



What is the area of the shaded triangle?

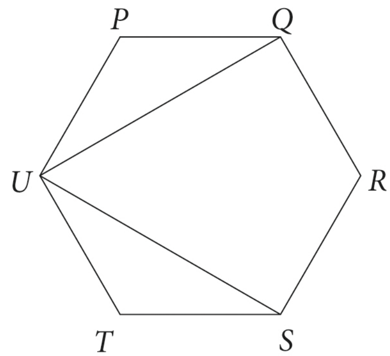
Answer: 18

4

Which of these is equal to $2(x + y) - (2x - y)$?

- (A) $3y$
- (B) y
- (C) $4x + 3y$
- (D) $4x + 2y$

5



PQRSTU is a regular hexagon. What is the measure of the angle *QUS*?

Ⓐ 30°

● 60°

Ⓒ 90°

Ⓓ 120°

6

There are 36 passengers on a bus. The ratio of children to adults on the bus is 5 to 4. How many children are on the bus?

Answer: 20

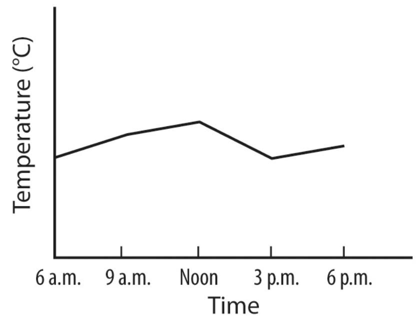
7

The table shows the temperatures at various times on a certain day.

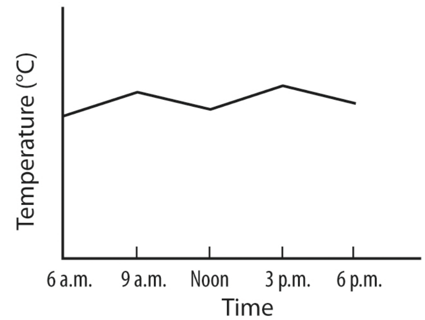
Time	6 a.m.	9 a.m.	Noon	3 p.m.	6 p.m.
Temperature °C	12	17	14	18	15

A graph, without a temperature scale, is drawn. Of the following, which could be the graph that shows the information given in the table?

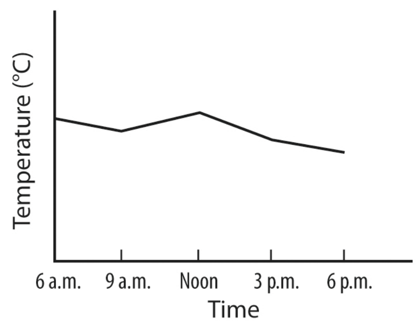
Ⓐ



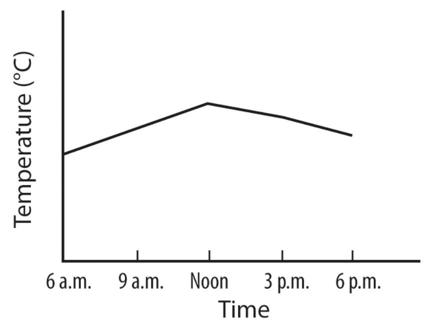
●



Ⓒ

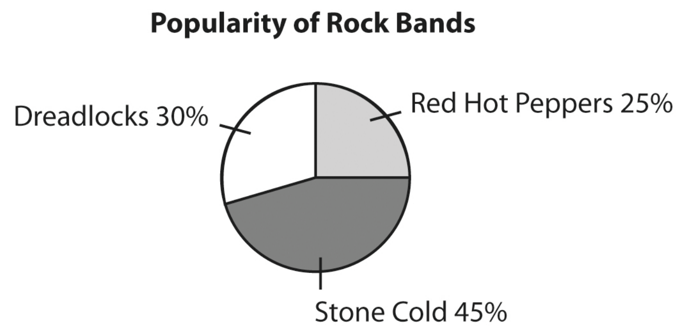


Ⓓ

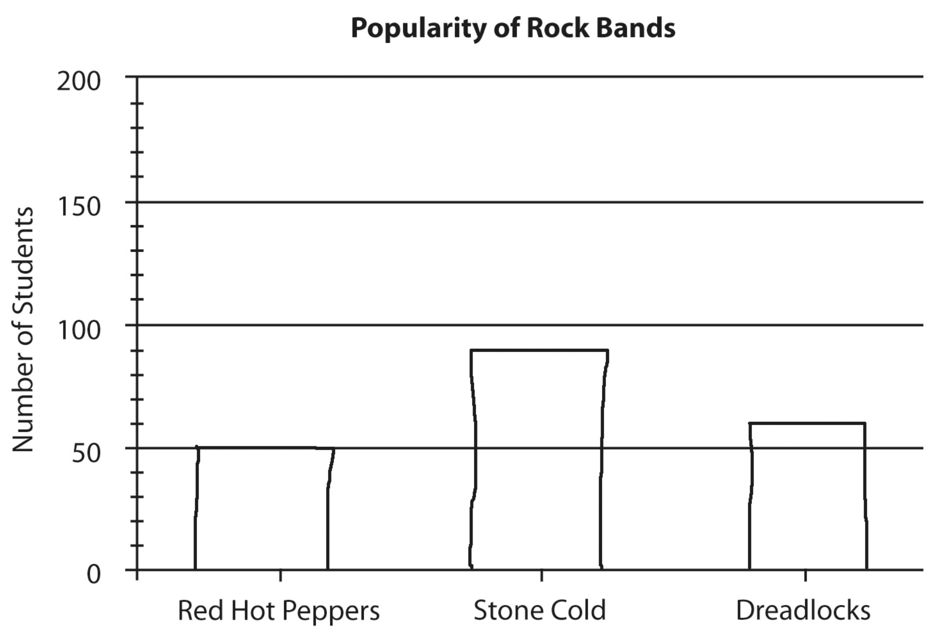


8

The results of a survey of 200 students are shown in the pie chart.

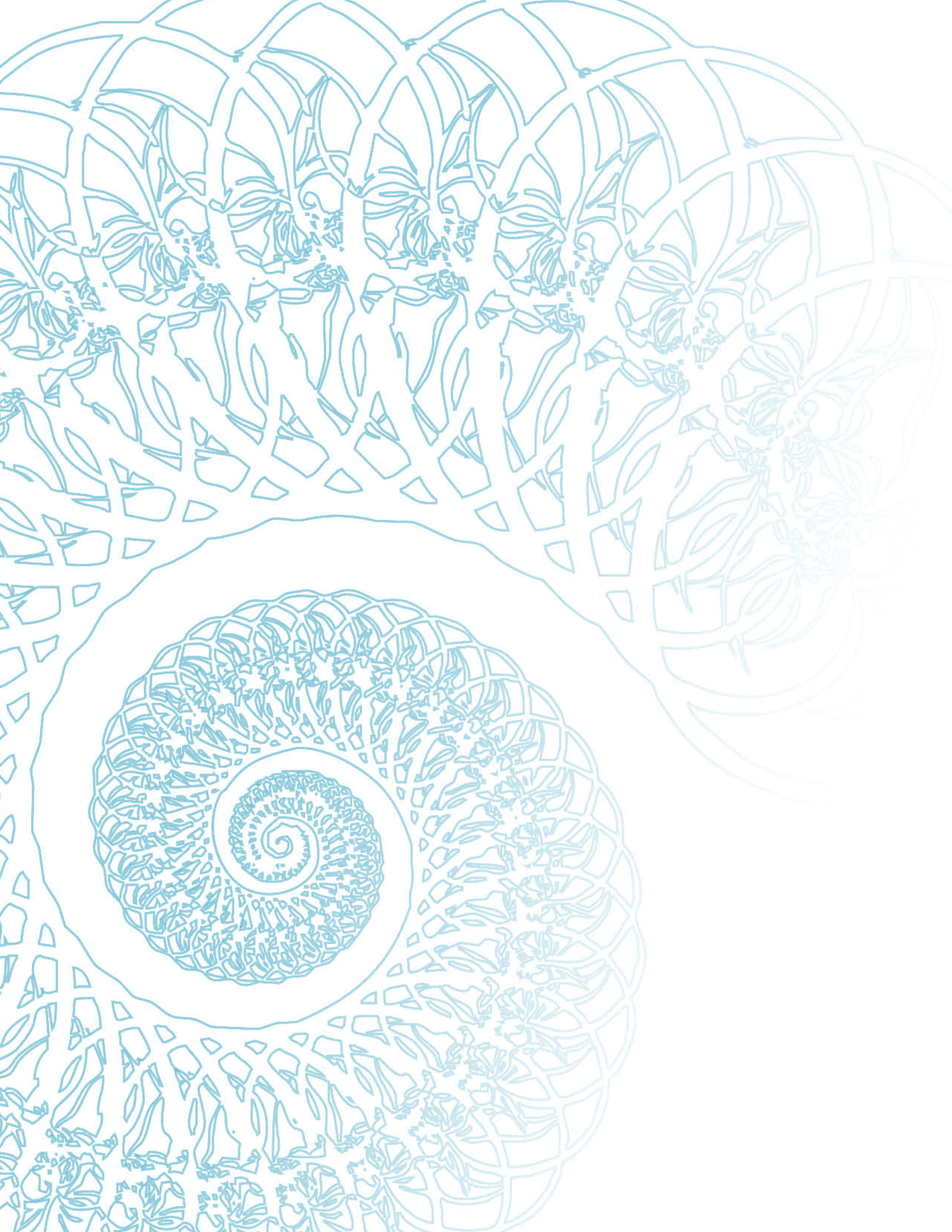


Make a bar chart showing the number of students in each category in the pie chart.



Example Science Items

Appendix C



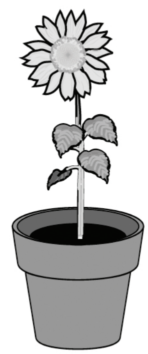
Example Science Items Grade 4

1

Carl and Jan each had a sunflower seed taken from the same plant. They took two identical pots and put potting soil in each. They then planted one seed in each pot. Carl looked after one pot in his home, and Jan looked after the other pot in her home.

After some time, they compared the plants and saw that there was a large difference in their growth, as shown in the pictures below.

Carl's plant



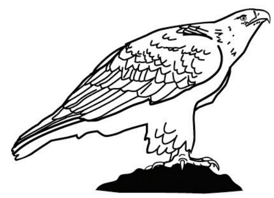
Jan's plant

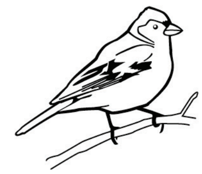
Describe one way in which Carl may have treated his plant differently from the way Jan treated hers.

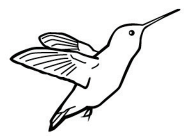
Carl might have given it more light and water.

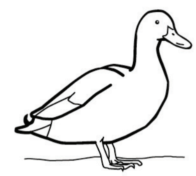
2

Which bird is most likely to eat small mammals?

● 

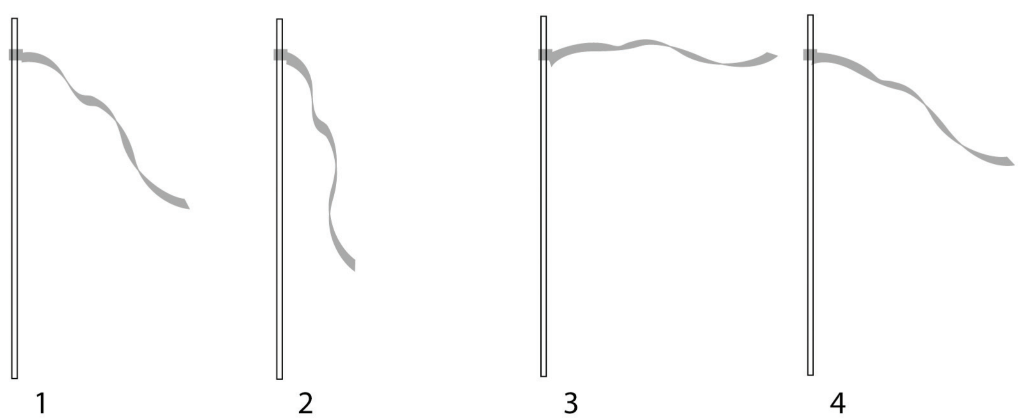
Ⓑ 

Ⓒ 

Ⓓ 

3

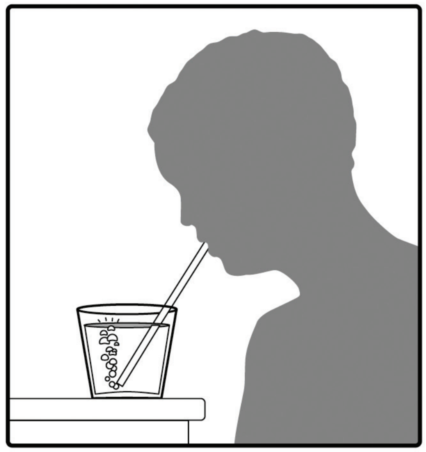
A ribbon is tied to a pole to measure the wind strength as shown below.



Write the numbers 1, 2, 3, and 4 in the correct order that shows the wind strength from the **strongest** to **weakest**.

Answer : 3, 4, 1, 2

4



When you blow into water using a straw, bubbles are formed and rise to the top. Why do the bubbles rise in water?

They rise because they are made from air which is lighter than water.

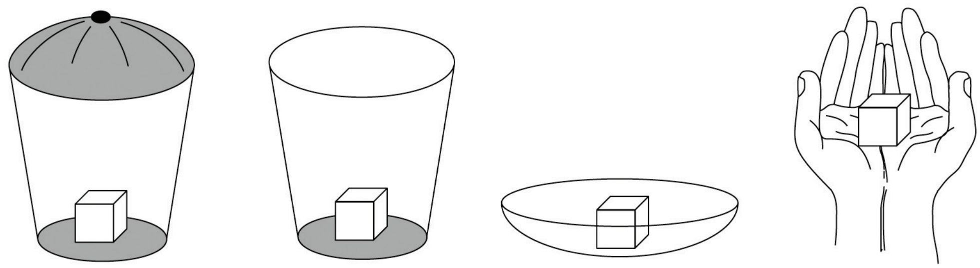
5

What is the main reason we can see the Moon?

- Ⓐ The Moon reflects light from the Earth.
- ● The Moon reflects light from the Sun.
- Ⓒ The Moon produces its own light.
- Ⓓ The Moon is larger than stars.

6

Which ice cube will take the longest time to melt?

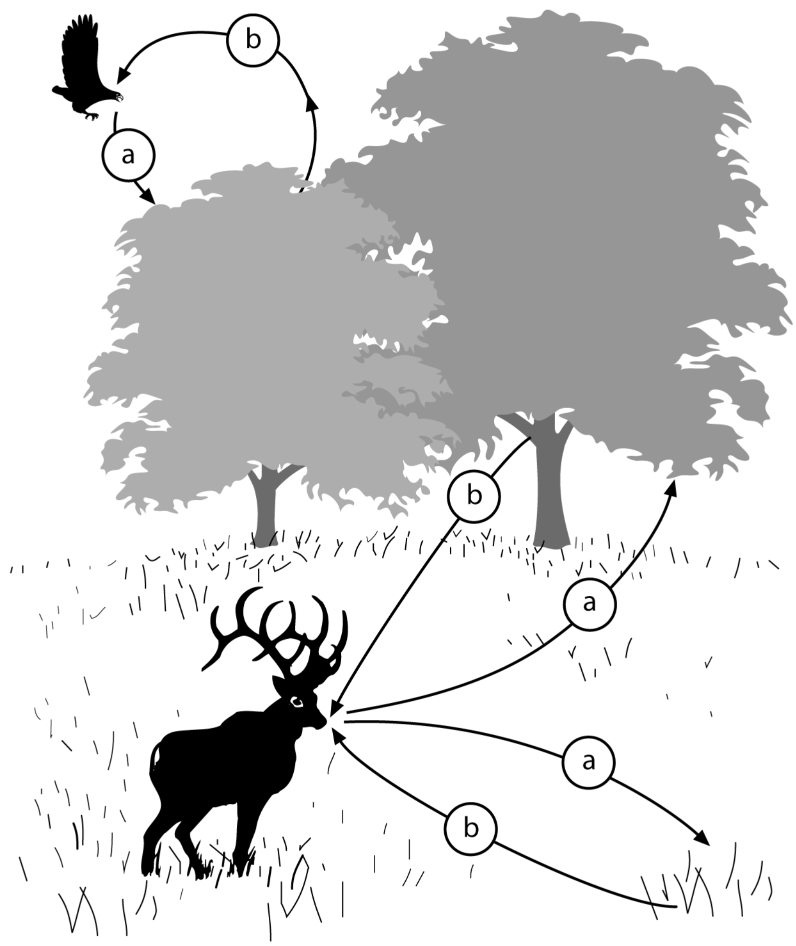


● Ⓑ Ⓒ Ⓓ

Example Science Items Grade 8

1

The diagram below shows an example of interdependence among organisms. During the day the organisms either use up or give off (a) or (b) as shown by the arrows.



Choose the right answer for (a) and (b) from the alternatives given.

Ⓐ (a) is carbon dioxide and (b) is nitrogen.

Ⓑ (a) is oxygen and (b) is carbon dioxide.

Ⓒ (a) is carbon dioxide and (b) is water vapor.

● (a) is carbon dioxide and (b) is oxygen.

2

Thato fell off his bicycle and spilled the bag of salt he was carrying. He collected the salt off the ground together with sand and tree leaves and put the mixture in a plastic bag.

In the table below, describe the steps used by Thato to separate the salt from the mixture of salt, sand, and leaves. State a reason for doing each step.
The first step has been done for you.

Step	Description of Step	Reason for Carrying Out the Step
1.	Put the mixture through a sieve.	This will remove the leaves.
2.	Add water	This will dissolve the salt
3.	Filter the salt solution	This will remove the sand
4.	Boil the salt water	This will evaporate the water

3

The mass of substances A and B are measured on a balance, as shown in Figure 1. Substance B is put into the beaker and substance C is formed. The empty beaker is put back on the balance, as shown in Figure 2.

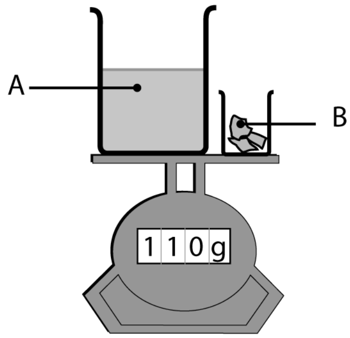


Figure 1

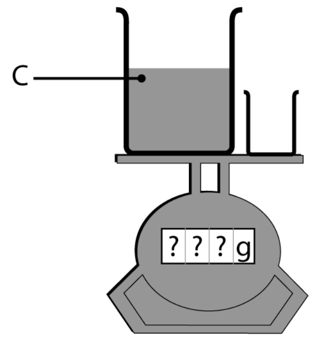


Figure 2

The scale in Figure 1 shows a mass of 110 grams.

What will it show in Figure 2?

(Check one box.)

- ☐ More than 110 grams
- ☑ 110 grams
- ☐ Less than 110 grams

Explain your answer.

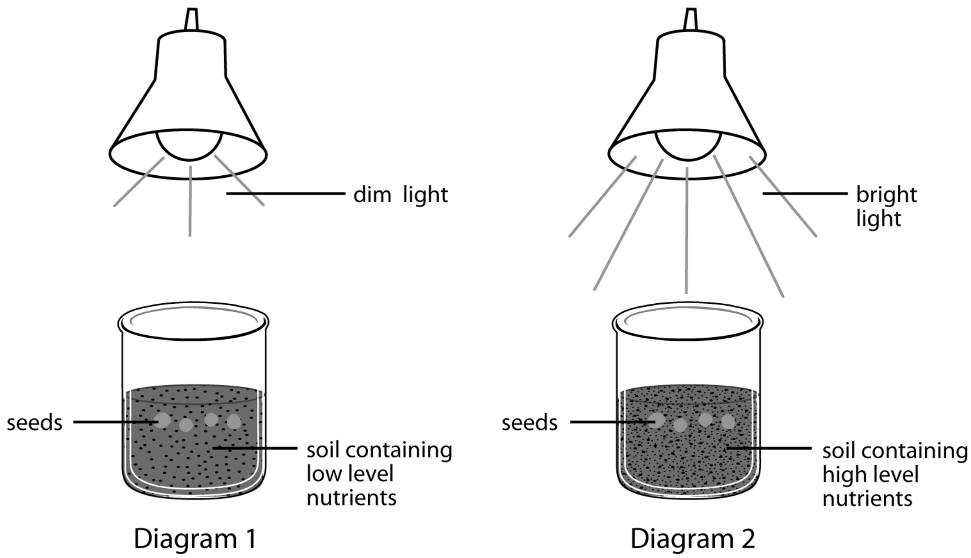
The mass will be the same because the mass of reactants equals the mass of products.

4

Fred has a packet of pea seeds that are genetically identical.

They are a variety of peas that produce tall stemmed pea plants.

He plants four pea seeds in a container in the conditions shown in Diagram 1. He plants four more pea seeds in a container in the conditions shown in Diagram 2. He waters the seeds every day.



What can be predicted about the height of the pea plants?

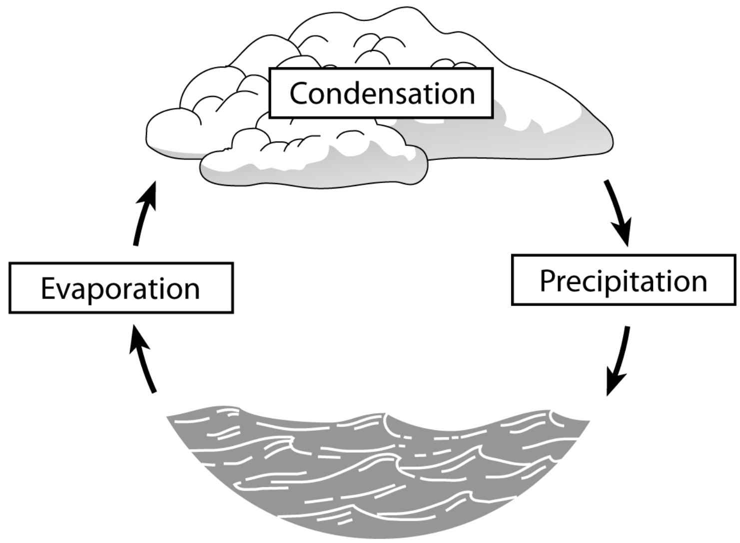
The height of the pea plants will be higher in Diagram 2.

Explain your answer.

The bright light will give the plants energy and the nutrients in the soil will help the peas grow.

5

The diagram below shows Earth's water cycle.



What is the source of energy for the water cycle?

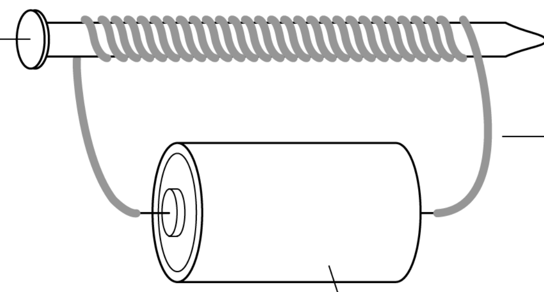
Ⓐ The Moon

● The Sun

Ⓒ The tides

Ⓓ The wind

6

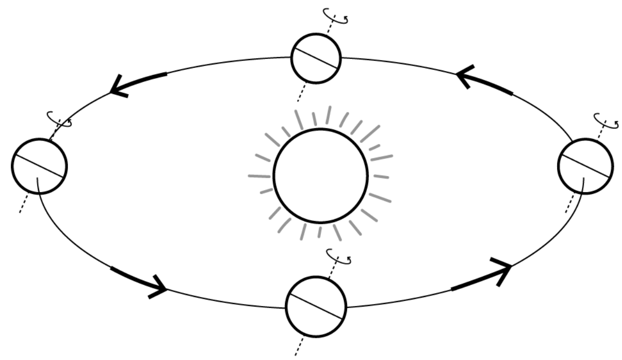


The figure shows an iron nail with an insulated wire coiled around it.
The wire is connected to a battery.

What will happen to the nail when current flows through the wire?

- Ⓐ The nail will melt.
- Ⓑ Electric current will flow through the nail.
- ● The nail will become a magnet.
- Ⓓ Nothing will happen to the nail.

7

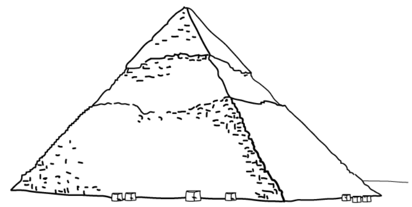


The diagram above shows the Earth's path around the Sun and the tilt of Earth's axis. Which of the following patterns on Earth is caused by the tilt of Earth's axis?

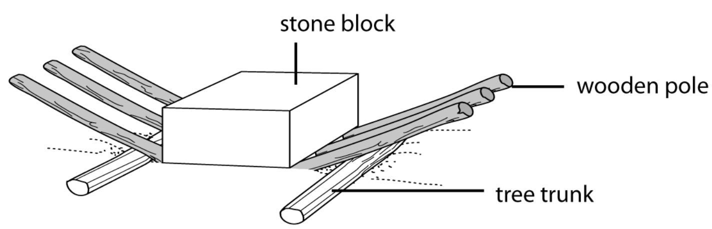
- ● seasons
- Ⓑ day and night
- Ⓒ years
- Ⓓ time zones

8

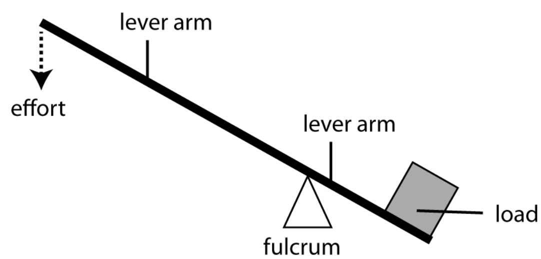
Peter and Joan are learning about the Great Pyramid of Cheops (Khufu) that is found in Egypt.



They wondered how the ancient Egyptians managed to lift the stone blocks to build the pyramid. They did some research on the Internet and found the diagram shown below.



Peter was not sure he understood the diagram so Joan drew a diagram to help him understand how the stone was lifted. Her diagram is shown below.

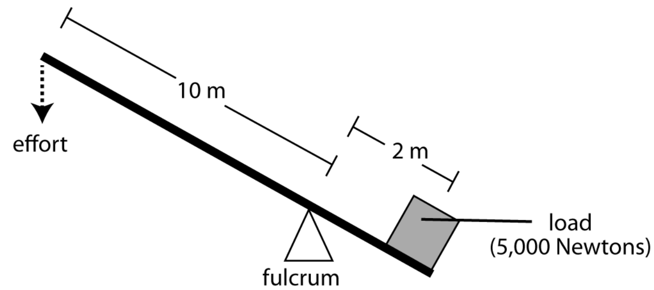


A. Match the parts of the Egyptian levers to the diagram of the lever Joan drew. One has been done for you.

Joan's Diagram	Egyptian Levers
Effort	Downward pull of the worker
Load	Stone block
Fulcrum	Tree trunk
Lever arm	Wooden pole

B. Peter and Joan read that six men could together lift a stone weighing 30,000 Newtons. Each man would then need to be able to lift one sixth of this weight (5,000 Newtons). They decided to work out how much effort each man had to exert on his wooden pole.

Peter added the length of each lever arm to Joan's diagram as shown below.



He looked up the following formula in a textbook:

$$\frac{\text{force exerted by load}}{\text{force exerted by effort}} = \frac{\text{length between effort and fulcrum}}{\text{length between load and fulcrum}}$$

How much force does each man have to exert to lift the block?

1,000 Newtons

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