Comparing Key Features of TIMSS and U.S. State Assessments

A Guide for Education Leaders and Policymakers

Ben Dalton
Sandra Olivarez-Durden
Deborah Herget
RTI International

January 2022

Contents

List of Tables

Comparing Key Features of TIMSS and State Assessments

A Guide for Education Leaders and Policymakers

Introduction

The **Trends in International Mathematics and Science Study** (**TIMSS**) is an internationally comparable assessment of what students know and can do in mathematics and science. Administered to fourth- and eighth-graders worldwide since 1995, TIMSS provides countries a means of monitoring the performance of their education systems over time and in a global context. TIMSS is sponsored by the International Association for the Evaluation of Educational Achievement (IEA), an independent international collaborative, and conducted in the United States by the National Center for Education Statistics (NCES). The next administration of TIMSS will be in 2023.

To help state education agencies, policymakers, and practitioners better understand what TIMSS assesses and how its results and resources can be used, this guide describes key features of TIMSS in comparison to state content frameworks at fourth and eighth grades. This guide presents

1. an overview of the TIMSS 2023 mathematics and science frameworks;[1]
2. a comparison of the TIMSS 2023 mathematics and science frameworks to frameworks commonly adopted or adapted by states in mathematics (Common Core State Standards for Mathematics or CCSS-M[2]) and science (Next Generation Science Standards or NGSS[3]), respectively; and
3. a discussion of how TIMSS differs from state assessments in its goals, target populations, and methodology generally.

This guide is intended to be an introduction to TIMSS with the perspective of state and district educators and leaders in mind. Many additional comparisons and considerations can be made, such as how TIMSS and state standards relate to state and local curricula, how the distribution of assessment content in TIMSS compares to the distribution of assessment content in different states, and how TIMSS compares to other major assessments like the National Assessment of Educational Progress (NAEP). In addition, the

[1] Mullis, Martin, and von Davier (2021).
[2] National Governors Association Center for Best Practices and Council of Chief State School Officers (2010).
[3] NGSS Lead States (2013).

approach used in this report is one of many types of methodologies for comparing frameworks. References to publications using different methodologies are presented in **Appendix A**.

For further information on TIMSS, please visit https://nces.ed.gov/timss/ or contact the U.S. TIMSS Project Officer at NCES, Lydia Malley (Lydia.Malley@ed.gov).

The TIMSS Assessment Frameworks Compared to CCSS-M and NGSS

The TIMSS Assessment Frameworks

An assessment framework describes the content, skills, and constructs the assessment aims to measure. As assessments of mathematics and science learning among fourth- and eighth-graders, the TIMSS assessment frameworks encompass four tests: fourth-grade mathematics, eighth-grade mathematics, fourth-grade science, and eighth-grade science. For each grade and subject, the TIMSS frameworks are organized around two dimensions: (1) content domains and (2) cognitive domains.

Tables 1 and **2**, for mathematics and science, respectively, show the content domains as well as the emphasis (the percentage of total testing time) targeted for each content domain on the assessment. As can be seen, TIMSS measures the same content domains across grades, with grade-appropriate additions or refinements at the higher grade.

Table 1. Mathematics content domains and target percentage distributions in TIMSS 2023

Content domain	Percent
Fourth grade	
Number	50
Measurement and Geometry	30
Data	20
Eighth grade	
Number	30
Algebra	30
Geometry and Measurement	20
Data and Probability	20

SOURCE: Mullis, Martin, and von Davier (2021), *TIMSS 2023 Assessment Frameworks*.

In mathematics, content in the Number domain is given more emphasis at the fourth grade than the eighth grade, when students are expected to understand more advanced whole number concepts and procedures as well as more about rational numbers and ratios, proportions, and percentages than students at fourth grade. Algebra is a separate content domain at eighth grade, although introductory algebraic content is included in the Number domain at fourth grade. The eighth-grade domain of Geometry and Measurement places more emphasis on purely geometric topics than at fourth grade. Similarly, the eighth-grade domain of Data and Probability covers basic statistics and fundamentals of probability in addition to the topics of reading, representing, and interpreting data covered at the fourth grade.

Table 2. Science content domains and target percentage distributions in TIMSS 2023

Content domain	Percent
Fourth grade	
Life Science	45
Physical Science	35
Earth Science	20
Eighth grade	
Biology	35
Chemistry	20
Physics	25
Earth Science	20

SOURCE: Mullis, Martin, and von Davier (2021), *TIMSS 2023 Assessment Frameworks*.

In science, more emphasis is given to Life Science at the fourth grade than to its counterpart, Biology, at the eighth grade. Chemistry and Physics, which are covered by Physical Science in fourth grade, are recognized as separate domains and given additional emphasis in the eighth-grade assessment.

In both mathematics and science, these broad content domains are broken down into topic areas, and each topic area broken down into individual topics. In addition, given its diversity of subject matter, the science framework further specifies objectives under each topic. Appendix **table B-1** lists the full breakdown of topic areas and topics for mathematics. **Table B-2** lists the breakdown of topic areas, topics, and objectives for science.

The cognitive domains that TIMSS measures are the same for mathematics and science: *knowing*, *applying*, and *reasoning*. However, the emphasis on these cognitive domains varies by subject and grade level, as shown in **table 3**. The higher-order cognitive process of reasoning receives more emphasis in the eighth-grade assessments, especially in science.

Table 3. Target percentage distributions of TIMSS 2023 assessments devoted to cognitive domains

	Mathematics		Science	
Domain	***Fourth grade***	***Eighth grade***	***Fourth grade***	***Eighth grade***
Knowing	40	35	40	35
Applying	40	40	40	35
Reasoning	20	25	20	30

SOURCE: Mullis, Martin, and von Davier (2021), *TIMSS 2023 Assessment Frameworks*.

These cognitive domains describe the thinking processes students are expected to engage in when encountering the items in TIMSS 2023.

- *Knowing* refers to specific facts, concepts, procedures, processes, relationships, and equipment that students should know in the given subject.
- *Applying* refers to the ability of students to apply knowledge, relationships, methods, and concepts to commonly faced contexts and problems.
- *Reasoning* involves the logical, systematic thinking that students need to use in mathematics to solve problems, make inferences, and deal with complex relationships, and the scientific reasoning students need to use in science to design experiments, develop hypotheses, analyze data, and make conclusions. Reasoning involves more complex or less common problems than applying.

Together with content specified in the content domains and thinking processes specified in the cognitive domains, some items in the TIMSS 2023 science assessment also assess one or more of five science practices, which are elements of scientific achievement that represents a student's ability to engage in scientific investigation and answer questions about problems encountered in real life. The five science practices are

1. asking questions based on observations and theories;
2. designing investigations and generating evidence;
3. working with data;
4. answering research questions; and
5. making arguments from evidence.

TIMSS assesses these science practices primarily with science problem solving and inquiry tasks (PSIs), which are in-depth, problem-based investigations and inquiries. Non-PSI items in TIMSS can also incorporate one or more of the science practices. Neither PSI items nor science practices have formal target percentages in the TIMSS framework.

Comparing TIMSS Content to CCSS-M and NGSS

How does TIMSS content compare to the content of assessments used by states to measure the performance of their fourth- and eighth-graders in mathematics and science? There is no single answer to this question, as each state develops its own assessment frameworks (or adapts available frameworks) and test specifications for their subject-matter tests. That said, most states have adopted or been heavily influenced by the CCSS for mathematics and the NGSS for science. These are content standards that define student learning goals and not *assessment* frameworks that define test content; however, the focus of these standards provides an indication of the content that states may include in their assessments.

One overall key difference between the TIMSS assessments and the CCSS-M or NGSS and their associated grade-level assessments is that TIMSS assessments measure content at the end of a grade span (grade 4 or 8), while state standards often define content (and state tests often assess content learned) for a specific grade. In other words, the TIMSS assessments are designed to cover cumulative learning through the grade tested; state standards and their accompanying tests are often designed to define learning in a specific grade and may or may not include concepts from earlier grades. (There are some exceptions.[4]) Accordingly, the discussion below compares TIMSS content to content from multiple grades' standards from CCSS-M and NGSS.

Mathematics

In mathematics, the CCSS are divided into 11 domains, each of which is broken into clusters, with multiple standards in each cluster (National Governors Association Center for Best Practices and Council of Chief State School Officers 2010). **Table 4** lists the CCSS-M domains for the K-4 and 5-8 grade spans (corresponding to the cumulative nature of the TIMSS assessments at grades 4 and 8). Note that the CCSS-M build across grades, so that, for example, the Operations and Algebraic Thinking domain includes standards in the higher grades that expand on earlier grade standards. The difference across these grade

[4] All states have grade-level standards for mathematics in grades K-8, but states vary as to whether they have grade-level or grade-span standards and testing for science. In NGSS, science performance expectations (PEs) are specified for each grade K-5 and for the grade span 6-8. The NGSS PEs in Engineering Design are also by grade span (K-2, 3-5, 6-8).

spans is that the CCSS-M in grades 5-8 cover more explicit and advanced algebraic topics as well as statistics and probability topics. For the full list of CCSS-M domains, clusters, and standards in mathematics in elementary school, see http://www.corestandards.org/Math/.

Table 4. Mathematics content domains included in the TIMSS 2023 assessment framework and the CCSS-M

Grade 4 TIMSS	Grades K-4 CCSS-M	K	1	2	3	4
Number	Counting and Cardinality	■				
	Number and Operations in Base Ten	■	■	■	■	■
	Number and Operations Fractions				■	■
	Operations and Algebraic Thinking	■	■	■	■	■
Measurement and Geometry	Geometry	■	■	■	■	■
	Measurement and Data	■	■	■	■	■
Data						
Grade 8 TIMSS	**Grades 5-8 CCSS-M**		**5**	**6**	**7**	**8**
Number	Number and Operations in Base Ten		■			
	Number and Operations Fractions		■			
	Ratio and Proportional Relationships			■	■	
	Number Systems			■	■	■
Algebra	Operations and Algebraic Thinking		■			
	Expressions and Equations			■	■	■
	Functions					■
Geometry and Measurement	Geometry		■	■	■	■
	Measurement and Data		■			
Data and Probability	Statistics and Probability			■	■	■

NOTE: Shaded cells indicate standards in the given domain.
SOURCE: National Governors Association Center for Best Practices and Council of Chief State School Officers (2010), *Common Core State Standards for Mathematics*. Mullis, Martin, and von Davier (2021), *TIMSS 2023 Assessment Frameworks*.

Table 4 also compares the CCSS-M content domains covered in grades K-4 and 5-8 with the TIMSS mathematics content domains. As shown, there is considerable similarity at this broad organizational level, with the primary difference being that TIMSS defines content domains more broadly. For example, for the fourth grade, TIMSS defines a broad content domain of Number whereas CCSS-M defines four number-related content domains.

The CCSS-M do not define cognitive domains or processes in the same way as the TIMSS assessment framework. However, most state assessments do define "depth of knowledge" (DOK) levels that are analogous to the TIMSS cognitive domains. DOK refers to the level of cognitive demand or complexity required to answer an item correctly (Webb 1997). The four levels are (1) recall and reproduction, (2) skills and concepts, (3) strategic thinking, and

(4) extended thinking. State assessments typically require a distribution of items by the first three DOK levels (the fourth level requires items that are too long for most tests).

The CCSS-M, on the other hand, define mathematical practices that represent "processes and proficiencies" that students should develop. Some state assessment frameworks or specifications also include the following CCSS-M practices:

- Make sense of problems and persevere in solving them
- Reason abstractly and quantitatively
- Construct viable arguments and critique the reasoning of others
- Model with mathematics
- Use appropriate tools strategically
- Attend to precision
- Look for and make use of structure
- Look for and express regularity in repeated reasoning

The eight practices are listed for each grade; however, the CCSS-M do not specify the balance of practices students should master, either overall or by grade level.

Science

In science, the NGSS are organized differently than both TIMSS and CCSS-M. The NGSS are defined as performance expectations (PEs) that integrate three dimensions of learning science—disciplinary core ideas (DCIs), science and engineering practices, and crosscutting concepts—that were first described in *A Framework for K-12 Science Education* (National Research Council 2012), on which the NGSS (NGSS Lead States 2013) are based. For comparison purposes, PEs can be thought of as an equivalent unit to content standards in mathematics. Like those content standards, they draw from a framework that identifies important content, skills, and cognitive processes, and they describe what students are expected to know and be able to do. However, PEs are different because they integrate and translate expectations from the three dimensions into a performance that can be assessed to demonstrate achievement of the standards. This is shown in **table 5**, which is an example of a PE at the fourth grade in Physical Science.

As the table shows, NGSS also articulates connections to other core ideas within science at the same grade, within science in other grades, and with standards in mathematics and English language arts/literacy. Some states view or adopt the PEs only as their standards, while other states include the PEs and one or more of the three dimensions as standards.

NGSS PEs and the DCIs on which they draw are organized into four disciplines: Physical Science; Life Science; Earth and Space Science; and Engineering, Technology, and Applications of Science. Each DCI is divided into sub-ideas (e.g., PS3.B in table 5). Each sub-idea further elaborates on what students should understand at the end of a grade or grade span. For the first three disciplines, PEs are separate for each of grades K-5 and combined for middle school (6-8) and high school (9-12) grades. For the fourth discipline, Engineering, Technology, & Applications of Science, PEs are defined for K-2, 3-5, 6-8, and 9-12 grade spans. For a complete list of PEs for all disciplines at all grade levels, see https://www.nextgenscience.org/.

Note that DCIs and sub-ideas can underlie multiple PEs if combined with different practices and/or crosscutting concepts. In addition, multiple DCIs or sub-ideas can contribute to the same PE, as shown in the example in table 5.

Table 5. Example of an NGSS performance expectation for fourth-grade Physical Science

Students who demonstrate understanding can

4-PS3-4. **Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.*** [Clarification Statement: Examples of devices could include electric circuits that convert electrical energy into motion energy of a vehicle, light, or sound; and, a passive solar heater that converts light into heat. Examples of constraints could include the materials, cost, or time to design the device.] [*Assessment Boundary: Devices should be limited to those that convert motion energy to electric energy or use stored energy to cause motion or produce light or sound.*]

Science and Engineering Practices

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 3-5 builds on K-2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.

- Apply scientific ideas to solve design problems.

Disciplinary Core Ideas

PS3.B: Conservation of Energy and Energy Transfer

- Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy.

PS3.D: Energy in Chemical Processes and Everyday Life

- The expression "produce energy" typically refers to the conversion of stored energy into a desired form for practical use.

ETS1.A: Defining Engineering Problems

- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. *(secondary)*

Crosscutting Concepts

Energy and Matter

- Energy can be transferred in various ways and between objects.

Connections to Engineering, Technology, and Applications of Science

Influence of Engineering, Technology, and Science on Society and the Natural World

- Engineers improve existing technologies or develop new ones.

Connections to Nature of Science

Science is a Human Endeavor

- Most scientists and engineers work in teams.
- Science affects everyday life.

Connections to other DCIs in fourth grade: N/A

Articulation of DCIs across grade levels: **K.ETS1.A** ; **2.ETS1.B** ; **5.PS3.D** ; **5.LS1.C** ; **MS.PS3.A** ; **MS.PS3.B** ; **MS.ETS1.B** ; **MS.ETS1.C**

Common Core State Standards Connections:

ELA/Literacy –

W.4.7 Conduct short research projects that build knowledge through investigation of different aspects of a topic. (4-PS3-4)

W.4.8 Recall relevant information from experiences or gather relevant information from print and digital sources; take notes and categorize information, and provide a list of sources. (4-PS3-4)

Mathematics –

4.OA.A.3 Solve multistep word problems posed with whole numbers and having whole-number answers using the four operations, including problems in which remainders must be interpreted. Represent these problems using equations with a letter standing for the unknown quantity. Assess the reasonableness of answers using mental computation and estimation strategies including rounding. *(4-PS3-4)*

* The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

SOURCE: NGSS Lead States (2013), *Next Generation Science Standards: For States, By States*.

Table 6 compares the TIMSS science framework content domains and the NGSS disciplines. The major difference is that NGSS includes an Engineering, Technology, and Applications of Science discipline that is not included in TIMSS. In addition, NGSS disciplines are the same for both grade 4 and middle school grades, whereas TIMSS articulates a distinction between Chemistry and Physics as content domains at grade 8, compared to Physical Science at grade 4.

Table 6. TIMSS 2023 assessment framework science content domains and NGSS science disciplines for grades 4 and 8

Grade 4 TIMSS	Grade 4 NGSS
Life Science	Life Science
Physical Science	Physical Science
Earth Science	Earth and Space Science
—	Engineering, Technology, and Applications of Science*
Grade 8 TIMSS	**Grades 6-8 NGSS**
Biology	Life Science
Chemistry	Physical Science
Physics	
Earth Science	Earth and Space Science
—	Engineering, Technology, and Applications of Science

— No equivalent content area.
* Performance expectations in the Engineering, Technology, and Applications of Science discipline are defined for grades 3-5 instead of for grade 4.
SOURCE: Mullis, Martin, and von Davier (2021), *TIMSS 2023 Assessment Frameworks*; NGSS Lead States (2013), *Next Generation Science Standards: For States, By States*.

A more detailed comparison of the TIMSS topics and NGSS PEs would show additional differences, such as the topic of human health being explicitly addressed in TIMSS for Life Science but not in NGSS. At grade 4, both PEs specified for fourth grade and PEs in earlier grades would have to be compared to the TIMSS topics and objectives for a full understanding of how their content coverage differs.

Although the TIMSS science objectives do not specify practices like the NGSS PEs, the TIMSS assessment framework does describe practices to be assessed. **Table 7** shows the NGSS science and engineering practices compared to the TIMSS science practices. Each TIMSS science practice is parallel to an NGSS science practice. However, NGSS specifies some additional practices such as "obtaining, evaluating, and communicating information."

Table 7. Science practices included in the TIMSS 2023 assessment framework and NGSS

TIMSS Science Practices	NGSS Science and Engineering Practices
1. Asking questions based on observations and theories 2. Designing investigations and generating evidence 3. Working with data 4. Answering research questions 5. Making arguments from evidence	1. Asking questions (for science) and defining problems (for engineering) 2. Developing and using models 3. Planning and carrying out investigations 4. Analyzing and interpreting data 5. Using mathematics and computational thinking 6. Constructing explanations (for science) and designing solutions (for engineering) 7. Engaging in argument from evidence 8. Obtaining, evaluating, and communicating information

SOURCE: Mullis, Martin, and von Davier (2021), *TIMSS 2023 Assessment Frameworks*; NGSS Lead States (2013), *Next Generation Science Standards: For States, By States*.

Content Comparison Caveats

The above comparisons are not meant to indicate any shortcomings among TIMSS, CCSS, and NGSS frameworks or content. TIMSS is a specific assessment with a framework that guides assessment development and analysis of test results. It is designed with a broad lens, incorporating perspectives on curriculum and learning from a wide variety of countries. CCSS and NGSS are standards for achievement designed to guide curriculum and assessment development within the United States; each state determines its own curriculum and designs its own assessments to gauge learning. The specific assessments that states use are articulated in a variety of other documents, including assessment blueprints, test specifications, and pools of test items. Assessments designed with CCSS, NGSS, or state adaptations of them may show more or less alignment with TIMSS than suggested by this general overview.

In addition, the above comparisons focus on broad issues of content, cognitive processes, and disciplinary practices. The comparisons shown above may yield different results if based on an item-by-item analysis of content. Likewise, TIMSS establishes benchmarks for performance that may differ from state-level proficiency benchmarks. Comparisons of these other features will show a different dimension of how TIMSS compares to state-level assessments.

TIMSS Goals and Design Compared to State and National Assessments

In addition to differences in the assessment frameworks and sets of standards as described above, TIMSS differs in other important ways from assessments given by states. The primary difference is that TIMSS is designed as a research study, not an accountability measure or a tool for making decisions about school improvement or intervention. In other words, TIMSS is a low-stakes test for students and schools, while state assessments may have implications for school accountability and teacher evaluations. TIMSS's target population, design, use of results, and technical reporting differ from those of state assessments because of TIMSS's research focus.

Target Population

- State assessments are given to all students within a grade or course in the state. In contrast, TIMSS is given to a sample of students in each participating country. This sample is nationally representative but may not be representative of a state or school's fourth- or eighth-grade population.
- In the United States, TIMSS assesses students in both public schools, including charter schools, and private schools. State assessments typically only assess public school students, although private school students are eligible to take state assessments in some states.
- Although students with disabilities and English language learners participating in TIMSS are allowed access to most accommodations that they receive on their state assessments, not all such students participate in TIMSS. TIMSS does not include students with disabilities that participate in state alternate assessment programs or English language learners enrolled in U.S. schools less than one full academic year before TIMSS testing.

Design

- TIMSS is administered once every 4 years. Most state assessments are administered every year.
- TIMSS is administered in March through June in the United States. The timing of TIMSS in any given state may differ from (and is more flexible than) the timing of state assessments.
- TIMSS 2023 assessments will be fully computer based. Some state assessments may use or provide paper-based test options.

- Testing procedures may differ. The length of the test, test instructions, proctoring, and testing aids may all differ from state assessment procedures. For example, TIMSS 2023 allows limited calculator use for its fourth-grade mathematics or science tests (although all items are designed to be answerable without calculators).
- In addition to the achievement test, TIMSS also includes a postassessment student survey and surveys of teachers and school administrators.

Use of Results

- TIMSS provides international benchmarking and comparisons with other education systems around the world. State assessment results are not necessarily directly comparable to other states' results nor non-U.S. systems.
- TIMSS consistently provides the ability to measure changes in U.S. student performance over time. Results have been reported on a 0 to 1,000 scale since 1995. Although some states' assessments are designed to measure long-term trends, others may be designed only to measure short-term trends or have changed over time, making trends more difficult to measure.
- TIMSS reports results (in each subject) as an overall scale, a scale for each major content domain, and a scale for each major cognitive domain. TIMSS also reports the percentage of students reaching each benchmark performance level. The international benchmarks are clearly articulated and illustrated with example items from different domains. State reporting practices may differ.
- TIMSS is designed to measure national performance, not individual student achievement or individual schools' achievement levels. Results cannot be used to gauge the performance of specific students or schools.
- The *TIMSS Encyclopedia* provides documentation of curriculum and education policy approaches in mathematics and science across participating countries (e.g., Herz et al. 2020).

Technical Reporting

- As an assessment of a sample of students, TIMSS is not designed to measure individual student performance. Instead, it provides a measure of group performance at the national level and among demographic and ability subgroups.
- Accordingly, TIMSS results are estimates of the true (but unknown) achievement of fourth- and eighth-graders. The statistical uncertainty of TIMSS results must be accounted for when reporting results or comparing results over time, across

countries, or between student groups. In state assessments that cover the entire population of public school students, the results have less statistical uncertainty.

- TIMSS reports assessment results for the United States at the national level. In some administrations of TIMSS, individual states elect to administer TIMSS to a representative sample of their students, enabling state-level estimates of mathematics and science performance, including benchmarking a state's performance against that of other international education systems. National estimates of TIMSS results can be generated for students by gender, race/ethnicity, other student characteristics, and school characteristics. In state assessments that cover the entire population, more detailed breakdowns are possible.

When considering using the TIMSS framework, results, benchmark definitions, or other elements in evaluating or aligning state standards and assessment plans, these differences should be kept in mind.

Conclusion

TIMSS provides important information about and international benchmarking of the performance of fourth- and eighth-graders in mathematics and science at regular intervals. Summative state assessments are key accountability and improvement tools for measuring performance and progress of all students annually. Despite their different purposes and methods, they share a focus on similar content and can be used along with other sources of information to deepen education leaders' and policymakers' understanding of student achievement.

References

Herz, K., Neidorf, T., Arora, A., Yeomans, C. (2020). United States. In D.L. Kelly, V.A.S. Centurino, M.O. Martin, and I.V.S. Mullis, I.V.S. (Eds.), *TIMSS 2019 Encyclopedia: Education Policy and Curriculum in Mathematics and Science*. Chestnut Hill, MA: Boston College, TIMSS & PIRLS International Study Center. Retrieved September 30, 2021, from https://timssandpirls.bc.edu/timss2019/encyclopedia/index.html.

Mullis, I.V.S., Martin, M.O., and von Davier, M. (Eds.) (2021). *TIMSS 2023 Assessment Frameworks*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center and International Association for the Evaluation of Educational Achievement (IEA).

National Governors Association Center for Best Practices and Council of Chief State School Officers. (2010). *Common Core State Standards for Mathematics*. Retrieved February 17, 2021 from http://www.corestandards.org/Math/.

National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press. https://doi.org/10.17226/13165.

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press. Retrieved March 23, 2021 from https://www.nextgenscience.org/.

Webb, N.L. (1997). *Criteria for Alignment of Expectations and Assessments in Mathematics and Science Education*. Washington, DC: Council of Chief State School Officers. Retrieved April 3, 2021 from https://eric.ed.gov/?id=ED414305.

Appendix A. Resource List for Content Comparison Methods

As mentioned in the introduction, this guide describes how the TIMSS assessment frameworks and the national mathematics and science standards used by many states are organized. It also describes key features of the TIMSS and state assessments in terms of design and reporting. This provides a broad look at the boundaries of the TIMSS assessments compared to national/state standards and suggests potential for shared content.

However, to understand the degree to which the seemingly similar content overlaps, more in-depth, systematic methods that quantify and detail differences and similarities are needed. These methods may include the following:

- qualitatively reviewing framework descriptions;
- quantitatively rating the similarity of framework objectives with other framework's objectives or with curricular standards;
- cross-classifying assessment items from different programs to each other's framework categories to compare content (or cognitive) emphases (i.e., item classification);
- examining items qualitatively to reflect on similarities and differences in their nature (i.e., item analysis);
- rating framework objectives, standards, or items according to external rubrics of interest; and
- analyzing stimulus materials such as reading passages.

The following table provides a select list of published reports of studies that employed one or more of such methods. It is based on resources available at the NCES International Activities Program website, with annotations and additional available studies listed. Each of these studies relied on input from subject-matter and assessment experts, whether from the study teams or from external organizations.

Table A-1. Selected examples of content comparison studies

Publication date	Study	Brief description
Studies comparing TIMSS and one or more other programs		
October 2013	A Comparison of TIMSS 2011 Items and the NAEP 2011 Frameworks (2011)	Comparison of lower and middle grades mathematics and science assessments using item classification
August 2013	A Comparison of the 2011 Grade 8 NAEP and TIMSS Mathematics and Science Frameworks	Comparison of lower and middle grades mathematics and science assessments using qualitative and quantitative framework review
December 2008	Comparing TIMSS with NAEP and PISA in Mathematics and Science (2007)	Comparison of lower, middle, and upper grades mathematics assessments, including qualitative framework review and item classification
May 2006	Comparing Mathematics Content in the NAEP, TIMSS, and PISA 2003 Assessments (May 2006)	Comparison of lower, middle, and upper grades mathematics assessments, including qualitative framework review and item classification
March 2006	Comparing Science Content in the NAEP 2000 and TIMSS 2003 Assessments (March 2006)	Comparison of lower and middle grades science assessments, including qualitative framework review and item classification
June 2001	A Comparison of NAEP, TIMSS-R, and PISA (June 2001)	Comparison of middle and upper grades mathematics and science assessments, including qualitative framework review and item classification (including to external rubrics)
Studies comparing other assessments and standards		
July 2020	A Comparison Study of NAEP-TEL and ICILS	Comparison of middle grades technology literacy using quantitative framework review and item analysis

Publication date	Study	Brief description
May 2016	A Comparison Study of PISA 2012 and NAEP 2013 Mathematics Assessments: AIR-NAEP Working paper #02-2016	Comparison of middle and upper grades mathematics assessments using quantitative framework review, item classification (including to external rubrics), and item analysis
September 2015–May 2016	A Comparison Between the NGSS and NAEP Frameworks in Science, Technology and Engineering Literacy, and Mathematics Executive Summary Technical Report	Comparison of lower, middle, and upper grades science, technology, and engineering assessments, including qualitative and quantitative framework review
June 2013	A Comparison of the PIRLS 2011 and NAEP 2011 Fourth-Grade Reading Assessments (2011)	Comparison of lower grades reading assessments, including qualitative framework review, item classification, and passage analysis
December 2010	Comparison of the PISA 2009 and NAEP 2009 Reading Assessments (2010)	Comparison of middle and upper grades reading assessments, including qualitative framework review, item classification, and passage analysis
December 2007	Comparing PIRLS and PISA with NAEP in Reading, Mathematics, and Science (2007)	Compilation paper describing comparisons of lower, middle, and upper grades reading and middle and upper grades mathematics and science assessments, including qualitative framework review, item classification, and (for reading) passage analysis
April 2003	A Content Comparison of the NAEP and PIRLS Fourth-Grade Reading Assessments (April 2003)	Comparison of lower grades reading assessments, including qualitative framework review, item classification, and passage analysis

Appendix B. Supplementary Tables

Table B-1. TIMSS 2023 Mathematics Content Domains, Topic Areas, and Topics for Fourth and Eighth Grade

FOURTH GRADE
NUMBER
Whole Numbers
Recognize place value of numbers to 6-digits, connect representations of numbers (words, symbols, and models including number lines), and compare numbers.
Add and subtract up to 4-digit numbers.
Multiply (up to 3-digit by 1-digit and 2-digit by 2-digit numbers) and divide (up to 3-digit by 1-digit numbers).
Solve problems involving odd and even numbers, multiples and factors of numbers, rounding numbers (up to the nearest powers of 10), and making estimates.
Combine two or more properties of numbers or operations to solve a problem.
Expressions, Simple Equations, and Relationships
Find the missing number or operation in a number sentence (e.g., 17 + w = 29).
Match or write expressions or number sentences to represent problem situations that may involve unknowns.
Match, describe, or use relationships in a well-defined pattern (e.g., describe the relationship between adjacent terms and generate pairs of whole numbers given a rule).
Fractions and Decimals
Describe a fraction as part of a whole or collection; connect different representations of fractions (words, numbers, and models); compare the size of fractions; add and subtract simple fractions with like denominators of 2, 3, 4, 5, 6, 8, 10, 12, or 100.
Connect different representations of decimals (words, numbers, and models); compare and order decimals and relate decimals to fractions; round decimals; add and subtract decimals (up to two decimal places).
MEASUREMENT & GEOMETRY
Measurement
Measure, estimate, add, and subtract lengths (millimeters, centimeters, meters, kilometers).
Add and subtract mass (gram and kilogram), volume (milliliter and liter), and time (minutes and hours); select appropriate types and sizes of units and read scales.
Determine perimeters of polygons, areas of rectangles, areas of shapes covered with squares or partial squares, and volumes filled with cubes.
Geometry
Recognize and draw parallel and perpendicular lines, right angles, and angles smaller or larger than a right angle; compare the relative size of angles.
Use elementary properties, including line and rotational symmetry to describe and create common two-dimensional shapes (circle, triangles, quadrilaterals, and other polygons).
Use elementary properties to describe three-dimensional shapes (cubes, rectangular solids, cones, cylinders, and spheres), the differences among them, and how they relate to their two-dimensional representations.
DATA
Reading and Displaying Data
Read data from tables, pictographs, bar graphs, line graphs, and pie charts.
Create or complete tables, pictographs, bar graphs, line graphs, and pie charts.
Interpreting, Combining, and Comparing Data
Interpret data and use it to answer questions that go beyond directly reading data displays.
Combine or compare data from two or more sources, and draw conclusions based on two or more data sets.

Table B-1. TIMSS 2023 Mathematics Content Domains, Topic Areas, and Topics for Fourth and Eighth Grade (continued)

EIGHTH GRADE
NUMBER
Integers
Recognize and use properties of numbers and operations; find and use multiples and factors, recognize prime numbers, evaluate positive integer powers of number, and square roots of whole numbers.
Add and subtract positive and negative numbers, including through movement and position on a number line or using various models (e.g., thermometers, losses and gains).
Fractions and Decimals
Using various models and representations, compare and order fractions and decimals, and identify equivalent fractions and decimals.
Add, subtract, and multiply with fractions and decimals, and divide fractions and decimals by a whole number.
Proportions, Ratios, and Percentages
Determine proportions and ratios of quantities (e.g. rates, scales on maps).
Apply or find percentages; convert between percentages and fractions or decimals.
ALGEBRA
Expressions, Operations, and Equations
Find the value of an expression or a formula given values of the variables.
Simplify algebraic expressions involving sums, products, differences, and positive integer powers; compare expressions to decide if they are equivalent.
Write expressions, equations, or inequalities to represent problem situations.
Solve linear equations, linear inequalities, and simultaneous linear equations in two variables, including validating values as solutions.
Relationships and Functions
Interpret, relate, and generate representations of linear functions in tables, graphs, or words; recognize properties of linear functions including slope and intercepts.
Interpret, relate, and generate representations of simple non-linear functions (e.g., quadratic) in tables, graphs, or words; generalize linear and non-linear pattern relationships or sequences, using words, or algebraic expressions.
GEOMETRY & MEASUREMENT
Geometry and Measurement
Recognize and draw types of angles and pairs of lines and use the relationships between angles on lines and in geometric figures, including those involving the measures of angles and line segments; read and plot points in the Cartesian plane.
Recognize two-dimensional shapes and use their geometric properties (e.g. sums of interior angles of triangles and quadrilaterals, properties of isosceles triangles), including to calculate length and area, and use the Pythagorean Theorem. Note: Two-dimensional shapes include circles; scalene, isosceles, equilateral, and right-angled triangles; trapezoids, parallelograms, rectangles, rhombuses, and other quadrilaterals; as well as other polygons including pentagons, hexagons, octagons, and decagons.
Determine the results of geometric transformations (translations, reflections, and rotations) in the plane; recognize and use properties of congruent and similar triangles and rectangles.
Recognize three-dimensional shapes and use their properties to calculate surface area and volume; relate three-dimensional shapes with their two-dimensional representations. Note: Three-dimensional shapes include prisms, pyramids, cones, cylinders, and spheres.
DATA & PROBABILITY
Data
Interpret data from one or more sources (e.g., interpolate and extrapolate, make comparisons, draw conclusions).
Organize and represent data to help answer questions. Representations include all those at fourth grade (tables, pictographs, bar graphs, line graphs, and pie charts) and in addition, histograms, dot plots, scatter plots, clustered and stacked bar charts, and infographics.
Summarize data distributions; calculate, use, or interpret mean and median; recognize the effect of spread and outliers.
Probability
For simple and compound events: determine theoretical probability (based on proportions of favorable outcomes, e.g., rolling a fair die or drawing marbles of a particular color from a bag); estimate empirical probability (based on experimental outcomes).

SOURCE: Mullis, Martin, and von Davier (2021), *TIMSS 2023 Assessment Frameworks*.

Table B-2. TIMSS 2023 Science Content Domains, Topic Areas, Topics, and Objectives for Fourth and Eighth Grade

FOURTH GRADE
LIFE SCIENCE
Characteristics and Life Processes of Organisms
Differences between living and non-living things and what living things require to live
Recognize and describe differences between living and non-living things (i.e., living things can reproduce, grow and develop, respond to stimuli, and die; and non-living things cannot).
Identify what living things require in order to live (i.e., air, food or nutrients, water, and an environment in which to live).
Physical and behavioral characteristics of major groups of living things
Compare and contrast physical and behavioral characteristics that distinguish major groups of living things (i.e., insects, birds, mammals, fish, reptiles, and flowering plants); distinguish groups of animals with backbones from groups of animals without backbones.
Identify or provide examples of members of major groups of living things (i.e., insects, birds, mammals, fish, reptiles, and flowering plants).
Functions of major structures in living things
Relate major structures in animals to their functions (e.g., bones support the body, lungs take in air, the heart circulates blood, the stomach digests food, muscles move the body).
Relate major structures in plants to their functions (i.e., roots absorb water and nutrients and anchor the plant, leaves make food, the stem supports the plant and transports water, food, and nutrients, petals attract pollinators, flowers produce seeds, and seeds produce new plants).
Life Cycles, Reproduction, and Heredity
Stages of life cycles and differences among the life cycles of common plants and animals
Identify stages of the life cycles of flowering plants (i.e., germination, growth and development, reproduction, and seed dispersal).
Recognize, compare, and contrast the life cycles of familiar plants and animals (e.g., trees, beans, humans, frogs, butterflies).
Inheritance and reproduction strategies
Recognize that plants and animals reproduce with their own kind to produce offspring with features that closely resemble those of the parents; distinguish between features of plants and animals that are inherited from their parents (e.g., number of petals, color of petals, eye color, hair color), and those that are not (e.g., some broken branches in a tree, length of human hair).
Identify and describe different strategies that increase the number of offspring that survive (e.g., a plant producing many seeds, mammals caring for their young).
Organisms, Environment, and Their Interactions
Physical features or behaviors of living things that help them survive in their environment
Associate physical features of plants and animals with the environments in which they live and describe how these features help them to survive (e.g., a thick stem, a waxy coating, and a deep root help a plant survive in an environment with little water; the coloring of an animal helps camouflage it from predators).
Associate behaviors of animals with the environments in which they live and describe how these behaviors help them to survive (e.g., migration or hibernation helps an animal to stay alive when food is scarce).
Responses of living things to environmental conditions
Recognize and describe how plants respond to environmental conditions (e.g., amount of available water, amount of sunlight).
Recognize and describe how different animals respond to changes in environmental conditions (e.g., light, temperature, danger); recognize and describe how the human body responds to changes in environmental conditions and how it reacts to physical activity (e.g., exercise).
The impact of humans on the environment
Recognize that human behavior has negative and positive effects on the environment (e.g., negative effects of air and water pollution, positive effects of reducing air and water pollution); provide general descriptions and examples of the effects of pollution on humans, plants, and animals.
Ecosystems
Common ecosystems
Relate common plants and animals (e.g., evergreen trees, frogs, lions) to common ecosystems (e.g., forests, ponds, grasslands).

Table B-2. TIMSS 2023 Science Content Domains, Topic Areas, Topics, and Objectives for Fourth and Eighth Grade (continued)

Relationships in simple food chains
Recognize that plants need (sun)light, air, and water to provide energy for life processes (i.e., growth and repair, movement, and reproduction); explain that animals eat plants or other animals to get the food they need to supply energy for life processes (i.e., growth and repair, movement, and reproduction).
Complete a model of a simple food chain using common plants and animals from common ecosystems, (e.g., a forest, a desert, a river, an ocean).
Describe the roles of living things at each link in a simple food chain (e.g., plants produce their own food; some animals eat plants, while other animals eat the animals that eat plants).
Identify common predators and their prey and describe their relationships.
Competition in ecosystems
Recognize and explain that some living things in an ecosystem compete with others for resources (e.g., food, light, space).
Human Health
Ways of maintaining good health
Describe everyday behaviors that promote good health (e.g., a balanced diet, exercising regularly, brushing teeth, getting enough sleep, wearing sunscreen); identify common food sources included in a balanced diet (e.g., fruits, vegetables, grains).
Relate the transmission of common communicable diseases to human contact (e.g., touching, sneezing, coughing); identify or describe some methods of preventing disease transmission (e.g., vaccination, washing hands, keeping a physical distance from people who are sick).
PHYSICAL SCIENCE
Classification and Properties of Matter and Changes in Matter
States of matter and characteristic differences of each state
Identify and describe three states of matter (i.e., a solid has a definite shape and volume, a liquid has a definite volume but not a definite shape, and a gas has neither a definite shape nor a definite volume).
Physical properties as a basis for classifying matter
Compare and sort objects and materials on the basis of physical properties (e.g., weight/mass, volume, state of matter, ability to conduct heat or electricity, ability to float or sink in water, ability to be attracted by a magnet). [Note: Students in the fourth grade are not expected to differentiate between mass and weight.]
Identify properties of metals (i.e., conducting electricity and conducting heat) and relate these properties to uses of metals (e.g., a copper electrical wire, an iron cooking pot).
Describe examples of mixtures and how they can be physically separated (e.g., sifting, filtration, evaporation, magnetic attraction).
Magnetic attraction and repulsion
Recognize that magnets have two poles and that like poles repel and opposite poles attract.
Recognize that magnets can be used to attract some metal objects.
Physical changes observed in everyday life
Identify observable changes in materials that do not result in new materials with different properties (e.g., dissolving, crushing an aluminum can).
Recognize that matter can be changed from one state to another by heating or cooling; describe changes in the state of water (i.e., melting, freezing, boiling, evaporation, and condensation).
Identify ways of increasing how quickly a solid material dissolves in a given amount of water (i.e., increasing the temperature, stirring, and breaking the solid into smaller pieces); distinguish between weak and strong concentrations of simple solutions (e.g., water sweetened with one versus two lumps of sugar).
Chemical changes observed in everyday life
Identify observable changes in materials that make new materials with different properties (e.g., decaying, such as food spoiling; burning; rusting).
Forms of Energy and Energy Transfer
Common sources and uses of energy
Identify sources of energy (e.g., the Sun, flowing water, wind, coal, oil, gas), and recognize that energy is needed for movement and transportation, manufacturing, heating, lighting, and powering electronic devices.
Light and sound in everyday life
Relate familiar physical phenomena (i.e., shadows, reflections, and rainbows) to the behavior of light.
Relate familiar physical phenomena (i.e., vibrating objects and echoes) to the production and behavior of sound.
Heat transfer
Describe what will happen when a hot object and a cold object are brought into contact (i.e., the temperature of the hot object decreases and the temperature of the cold object increases).

Table B-2. TIMSS 2023 Science Content Domains, Topic Areas, Topics, and Objectives for Fourth and Eighth Grade (continued)

Electricity and simple electrical systems
Recognize that electrical energy in a circuit can be transformed into other forms of energy (e.g., heat, light, sound).
Explain that simple electrical systems (e.g., a flashlight) require a complete (unbroken) electrical pathway.
Forces and Motion
Familiar forces and the motion of objects
Identify gravity as the force that draws objects to Earth.
Recognize that forces (i.e., pushing and pulling) may cause an object to change its motion; compare the effects of these forces (pushes and pulls) of different strengths in the same or opposite directions acting on an object; and recognize that friction force works against the direction of motion (e.g., friction working against a push or a pull makes it more difficult to move an object along a surface).
Simple machines
Recognize that simple machines, (e.g., levers, pulleys, gears, ramps) help make motion easier (e.g., make lifting things easier, reduce the amount of force required, change the distance, change the direction of the force).
EARTH SCIENCE
Earth's Physical Characteristics, Resources, and History
Physical characteristics of the Earth system
Recognize that Earth's surface is made up of land and water in unequal proportions (more water than land) and is surrounded by air; describe where fresh and salt water are found.
Earth's resources
Identify some of Earth's resources that are used in everyday life (e.g., water, wind, soil, forests, oil, natural gas, minerals).
Explain the importance of using Earth's renewable and nonrenewable resources responsibly (e.g., fossil fuels, forests, water).
Earth's history
Recognize that wind and water change Earth's landscape and that some features of Earth's landscape (e.g., mountains, river valleys) result from changes that happen very slowly over a long time.
Recognize that some remains (fossils) of animals and plants that lived on Earth a long time ago are found in rocks and make simple deductions about changes in Earth's surface from the location of these remains.
Earth's Weather and Climates
Weather and climates on Earth
Apply knowledge of changes of state of water to common weather events (e.g., cloud formation, dew formation, the evaporation of puddles, snow, rain).
Describe how weather (i.e., daily variations in temperature, humidity, precipitation in the form of rain or snow, clouds, and wind) can vary with geographic location.
Describe how average temperature and precipitation can change with the seasons and location; recognize that the average temperature on Earth has increased over the last century and some effects of this increase on Earth's physical characteristics (e.g., ocean levels have increased, ice caps have melted, rivers have dried up, deserts have grown bigger).
Earth in the Solar System
Objects in the Solar System and their movements
Describe the Solar System as the Sun and the planets that revolve around it; recognize that the Earth has a moon that revolves around it, and from Earth the Moon looks different at different times of the month.
Earth's motion and related patterns observed on Earth
Explain how day and night are related to Earth's daily rotation about its axis, and use the changing appearance of shadows during the day as evidence of this rotation.
Recognize that seasons in Earth's northern and southern hemispheres are related to Earth's annual movement around the Sun (and the tilt of Earth's axis).

Table B-2. TIMSS 2023 Science Content Domains, Topic Areas, Topics, and Objectives for Fourth and Eighth Grade (continued)

EIGHTH GRADE
BIOLOGY
Characteristics and Life Processes of Organisms
Differences among major taxonomic groups of organisms
Identify the defining characteristics that differentiate among major taxonomic groups of organisms (i.e., plants, animals, fungi; mammals, birds, reptiles, amphibians, fish, and insects).
Recognize and categorize organisms that are examples of major taxonomic groups of organisms (i.e., plants, animals, fungi; mammals, birds, reptiles, amphibians, fish, and insects).
Structures and functions of major organ systems
Locate and identify major organs (e.g., lungs, stomach, brain) and the components of major organ systems (e.g., respiratory system, digestive system) in the human body.
Compare and contrast major organs and major organ systems in humans and other vertebrates (e.g., lungs in humans compared with gills in fish).
Explain the role of major organs and major organ systems in sustaining life (e.g., organs involved in circulation and respiration).
Physiological processes in animals
Recognize responses of animals that work to maintain stable body conditions under external and internal changes (e.g., increased heart rate during exercise, feeling thirsty when dehydrated, feeling hungry when requiring energy, sweating in heat, shivering in cold).
Cells and Their Functions
The structures and functions of cells
Explain that living things are made of cells that both carry out life functions and reproduce by division.
Identify major cell structures (i.e., cell wall, cell membrane, nucleus, chloroplast, vacuole, and mitochondria) and describe the primary functions of these structures.
Recognize that cell walls and chloroplasts differentiate plant cells from animal cells.
Explain that tissues, organs, and organ systems are formed from groups of cells with specialized structures and functions.
The processes of photosynthesis and cellular respiration
Describe the basic process of photosynthesis (i.e., requires light, carbon dioxide, water, and chlorophyll; produces glucose/sugar; and releases oxygen).
Describe the basic process of cellular respiration (i.e., requires oxygen and glucose/sugar; produces energy; and releases carbon dioxide and water).
Life Cycles, Reproduction, and Heredity
Life cycles and patterns of development
Compare and contrast the life cycles and patterns of growth and development of different types of organisms (i.e., mammals, birds, amphibians, insects, and plants).
Sexual reproduction and inheritance in plants and animals
Recognize that sexual reproduction involves the fertilization of an egg cell by a sperm cell to produce offspring that are similar but not identical to either parent; relate the inheritance of traits to organisms passing on genetic material to their offspring.
Recognize that an organism's traits are encoded in its DNA; recognize that DNA is genetic information found in chromosomes located in the nucleus of each cell.
Distinguish inherited characteristics from acquired or learned characteristics.
Diversity, Adaptation, and Natural Selection
Variation as the basis for natural selection
Recognize that variations in physical and behavioral characteristics among individuals in a population give some individuals an advantage in surviving and passing on their characteristics to their offspring.
Relate species survival or extinction to reproductive success in a changing environment (natural selection).
Evidence for changes in life on Earth over time
Draw conclusions about the relative lengths of time different organisms and groups of organisms have existed on Earth using fossil evidence.
Describe how similarities and differences among living species and fossils provide evidence of the changes that occur in living things over time, and recognize that the degree of similarity of characteristics provides evidence of common ancestry.

Table B-2. TIMSS 2023 Science Content Domains, Topic Areas, Topics, and Objectives for Fourth and Eighth Grade (continued)

Ecosystems
The flow of energy in ecosystems
Identify and provide examples of producers, consumers, and decomposers; construct or interpret food web diagrams.
Describe the flow of energy in an ecosystem (e.g., energy flows from producers to consumers, and only a small part of the energy is passed from one level to the next); construct or interpret energy pyramids.
The cycling of water, oxygen, and carbon in ecosystems
Describe the role of living things in cycling water through an ecosystem (i.e., plants take in water from the soil and give off water through their leaves (transpiration); and animals take in water and release water during respiration and as waste).
Describe the role of living things in cycling oxygen and carbon through an ecosystem (i.e., plants take in carbon dioxide from the air and release oxygen into the air as part of photosynthesis and store carbon in their cells; and animals take in oxygen from the air and release carbon dioxide into the air as part of respiration).
Relationships among populations of organisms in an ecosystem
Describe and provide examples of competition among populations or organisms in an ecosystem.
Describe and provide examples of predation in an ecosystem.
Describe and provide examples of symbiosis (i.e., mutualism and parasitism) among populations of organisms in an ecosystem (e.g., birds or insects pollinating flowers, ticks living on deer or cattle).
Factors affecting population size in an ecosystem
Describe factors that affect the growth of plants and animals; identify factors that limit population size (e.g., disease, predators, food resources, drought, competition).
Predict how changes in an ecosystem (e.g., changes in the water supply, the introduction of a new population, hunting, migration) can affect available resources, and thus the balance among populations.
Human impact on the environment
Describe and explain how human behavior (e.g., re-planting forests, reducing air and water pollution, protecting endangered species) can have positive effects on the environment.
Describe and explain how human behavior (e.g., allowing factory waste water to enter water systems, burning fossil fuels that release greenhouse gases and pollutants into the air) can have negative effects on the environment; describe and provide examples of the effects of air, water, and soil pollution on humans, plants, and animals (e.g., water pollution can reduce plant and animal life in the water system).
Human Health
Causes, transmission, prevention of, and resistance to diseases
Describe causes, transmission, and prevention of common viral, bacterial, and parasite diseases (e.g., influenza, measles, HIV, COVID-19, tetanus, malaria).
Describe the role of the body's immune system in resisting disease and promoting healing (e.g., antibodies in the blood help the body resist infection and white blood cells fight infection); recognize that antibiotics can help the immune system suppress bacterial infections and antibiotics may become less effective when bacteria change.
The importance of diet, exercise, and other lifestyle choices
Explain the importance of diet, exercise, and other lifestyle choices in maintaining health and preventing illness (e.g., heart disease, high blood pressure, diabetes, skin cancer, lung cancer).
Identify the dietary sources and roles of nutrients in a healthy diet (i.e., vitamins, minerals, proteins, carbohydrates, and fats).
CHEMISTRY
Composition of Matter
Structure of atoms and molecules
Describe atoms as composed of subatomic particles (i.e., negatively charged electrons surrounding a nucleus containing positively charged protons and neutrons with no charge).
Describe the structure of matter in terms of particles (i.e., atoms and molecules) and describe molecules as combinations of atoms (e.g., H_2O, O_2, CO_2).
Elements, compounds, and mixtures
Describe the differences among elements, compounds, and mixtures; differentiate between pure substances (i.e., elements and compounds) and mixtures (homogeneous and heterogeneous) on the basis of their formation and composition.
The periodic table of elements
Recognize that the periodic table is an arrangement of the known elements; recognize and describe that the elements are arranged in order of the number of protons in the nuclei of the atoms of each element.
Recognize that an element's properties (e.g., metal or non-metal, reactivity) can be predicted from its location in the periodic table (i.e., row, or period, and column, or group/family) and that elements in the same group have some properties in common.

Table B-2. TIMSS 2023 Science Content Domains, Topic Areas, Topics, and Objectives for Fourth and Eighth Grade (continued)

Properties of Matter
Physical and chemical properties of matter
Distinguish between physical and chemical properties of matter.
Relate uses of materials to their physical properties (e.g., melting point, boiling point, solubility, thermal conductivity).
Relate uses of materials to their chemical properties (e.g., tendency to rust, flammability).
Physical and chemical properties as a basis for classifying matter
Classify substances according to physical properties that can be demonstrated or measured (e.g., density, melting or boiling point, solubility, magnetic properties, electrical or thermal conductivity).
Classify substances according to their chemical properties (e.g., reactivity, flammability).
Mixtures and solutions
Explain how physical methods can be used to separate mixtures into their components.
Describe solutions in terms of substance(s) (i.e., solid, liquid, or gas solutes) dissolved in a solvent and relate the concentration of a solution to the amounts of solute and solvent present.
Explain how temperature, stirring, and surface area in contact with the solvent affect the rate at which solutes dissolve.
Properties of acids and bases
Recognize everyday substances as acids or bases based on their properties (e.g., acids have pH less than 7; acidic foods usually have a sour taste; bases usually do not react with metals; bases feel slippery).
Recognize that both acids and bases react with indicators to produce different color changes.
Recognize that acids and bases neutralize each other.
Chemical Change
Characteristics of chemical changes
Differentiate chemical from physical changes in terms of the transformation (reaction) of one or more pure substances (reactants) into different pure substances (products).
Identify and describe evidence (i.e., temperature changes, gas production, precipitate formation, color change, or light emission) that a chemical change has taken place.
Matter and energy in chemical reactions
Recognize that matter is conserved during a chemical reaction and that all of the atoms present at the beginning of the reaction are present at the end of the reaction, but they are rearranged to form new substances.
Recognize that some chemical reactions release energy (heat) while others absorb it, and classify common chemical reactions (e.g., burning, neutralization, the mixing of substances in a chemical cold pack) as either releasing heat or absorbing energy (heat).
Recognize that chemical reactions occur at different rates and that the rate of reaction can be affected by changing the conditions under which the reaction is taking place (i.e., surface area, temperature, and concentration).
Chemical bonds
Recognize that a chemical bond results from the attraction between atoms in a compound and that the atoms' electrons are involved in this bonding.
PHYSICS
Physical States and Changes in Matter
Motion of particles in solids, liquids, and gases:
Recognize that atoms and molecules in matter are in constant motion and recognize the differences in relative motion and distance between particles in solids, liquids, and gases; apply knowledge about the movement of and distance between atoms and molecules to explain the physical properties of solids, liquids, and gases (i.e., volume, shape, density, and compressibility).
Relate changes in temperature of a gas to changes in its volume and/or pressure and changes in the average speed of its particles; relate expansion of solids and liquids to temperature change in terms of the average spacing between particles.
Changes in states of matter:
Describe changes of state (i.e., melting, freezing, boiling, evaporation, condensation, and sublimation) as resulting from an increase or decrease of thermal energy; explain that mass remains constant during changes of state.
Relate the rate of change of state to physical factors (e.g., surface area, the temperature of the surroundings).
Energy Transformation and Transfer
Forms of energy and the conservation of energy
Identify different forms of energy (e.g., kinetic, potential, light, sound, electrical, thermal, chemical).
Describe the energy transformations that take place in common processes (e.g., combustion in an engine to move a car, photosynthesis, the production of hydroelectric power); recognize that the total energy of a closed system is conserved.

Table B-2. TIMSS 2023 Science Content Domains, Topic Areas, Topics, and Objectives for Fourth and Eighth Grade (continued)

Thermal energy transfer and thermal conductivity of materials
Recognize that temperature remains constant during melting, boiling, and freezing, but thermal energy increases or decreases during a change of state.
Relate the transfer of thermal energy from an object or an area at a higher temperature to one at a lower temperature to cooling and heating; recognize that hot objects cool off and cold objects warm up until they reach the same temperature as their surroundings.
Compare the relative thermal conductivity of different materials.
Light and Sound
Properties of light
Describe or identify basic properties of light (i.e., speed; transmission through different media; reflection, refraction, absorption, and splitting of white light into its component colors); relate the apparent color of objects to reflected or absorbed light.
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.
Properties of sound
Describe or identify some basic properties of sound (i.e., is a wave phenomenon caused by vibrations, is characterized by loudness (amplitude) and pitch (frequency), requires a medium for transmission, is reflected and absorbed by surfaces, and has a relative speed through different media, which is always slower than light).
Relate common phenomena (e.g., echoes, hearing thunder after seeing lightning) to the properties of sound.
Electricity and Magnetism
Conductors and the flow of electricity in electrical circuits
Classify materials as electrical conductors or insulators; identify electrical components or materials that can be used to complete circuits.
Identify diagrams representing complete circuits.
Properties and uses of permanent magnets and electromagnets
Relate properties of permanent magnets (i.e., two opposite poles, attraction/repulsion, and strength of the magnetic force varies with distance) to uses in everyday life (e.g., a directional compass).
Describe the properties that are unique to electromagnets (i.e., the strength varies with current, number of coils, and type of metal in the core; the magnetic attraction can be turned on and off; and the poles can switch) and relate properties of electromagnets to uses in everyday life (e.g., doorbell, recycling factory).
Motion and Forces
Motion
Recognize the speed of an object as change in position (distance) over time and acceleration as change in speed over time.
Common forces and their characteristics
Describe common mechanical forces (e.g., normal, friction, elastic, buoyant); recognize and describe weight as a force due to gravity.
Recognize that forces have strength and direction; recognize that for every action force there is an equal and opposite reaction force; recognize and describe the difference in the force of gravity on an object when it is located on different planets (or moons).
Effects of forces
Describe the functioning of simple machines (e.g., levers, inclined planes, pulleys, gears).
Explain floating and sinking in terms of density differences and the effect of buoyant force.
Describe pressure in terms of force and area; describe effects related to pressure (e.g., water pressure increasing with depth, a balloon expanding when inflated).
Predict qualitative one-dimensional changes in motion (speed and direction) of an object based on the forces acting on it; recognize and describe how the force of friction affects motion (e.g., the contact area between surfaces can increase friction and impede motion).
EARTH SCIENCE
Earth's Structure and Physical Features
Earth's structure and physical characteristics
Describe the structure of the Earth (i.e., crust, mantle, inner core, and outer core) and the physical characteristics of these distinct parts.
Describe the distribution of water on Earth in terms of its physical state (i.e., ice, water, and water vapor), and fresh versus salt water.
Components of Earth's atmosphere and atmospheric conditions
Recognize that Earth's atmosphere is a mixture of gases; identify the relative abundance of its main components (i.e., nitrogen, oxygen, water vapor, and carbon dioxide), relate these components to everyday life processes involving oxygen, water vapor, and carbon dioxide (e.g., human lung function, photosynthesis).
Relate changes in atmospheric conditions (i.e., temperature and pressure) to changes in altitude.

Table B-2. TIMSS 2023 Science Content Domains, Topic Areas, Topics, and Objectives for Fourth and Eighth Grade (continued)

Earth's Processes, Cycles, and History
Geological processes
Describe the general processes involved in the rock cycle (e.g., the cooling of lava, heat and pressure transforming sediment into rock, weathering, erosion).
Identify or describe changes to Earth's surface (e.g., mountain building), resulting from major geological events (e.g., glaciation, the movement of tectonic plates and subsequent earthquakes and volcanic eruptions).
Explain the formation of fossils and fossil fuels; use evidence from the fossil record to explain how the environment has changed over long periods of time.
Earth's water cycle
Describe the processes in Earth's water cycle (i.e., evaporation, condensation into clouds, transportation, and precipitation) and recognize the Sun as the source of energy for the water cycle.
Describe the role of cloud movement and water flow in the circulation and renewal of fresh water on Earth's surface.
Weather and climate
Distinguish between weather (i.e., day-to-day variations in temperature, humidity, precipitation in the form of rain or snow, clouds, and wind) and climate (i.e., long-term typical weather patterns in a geographic area).
Interpret data or maps of weather patterns to identify climate types; relate the climate and seasonal variations in weather patterns to global and local factors (e.g., latitude, altitude, geography).
Identify or describe evidence for climate changes (e.g., changes related to ice ages, changes related to global warming).
Earth's Resources, Their Use and Conservation
Managing Earth's resources
Provide examples of Earth's renewable and nonrenewable resources.
Discuss advantages and disadvantages of different energy sources (e.g., sunlight, wind, flowing water, geothermal, oil, coal, gas, nuclear).
Describe methods of conservation of Earth's resources and methods of waste management (e.g., reduce, reuse, recycle).
Land and water use
Explain how common methods of land use (e.g., farming, logging, mining) can affect land and water resources.
Explain the importance of water conservation, and describe methods for ensuring that fresh water is available for human activities (e.g., desalination, purification).
Earth in the Solar System and the Universe
Observable phenomena on Earth resulting from movements of Earth and the Moon
Describe the effects of the Earth's annual revolution around the Sun, given the tilt of its axis (e.g., different seasons, different constellations visible at different times of the year).
Recognize that tides are caused by the gravitational pull of the Moon, and relate phases of the Moon and eclipses to the relative positions of Earth, the Moon, and the Sun.
The Sun, stars, Earth, Moon, and planets
Recognize that the Sun is a star and provides light and heat to each member of the Solar System; explain that the Sun and other stars produce their own light, but that other members of the Solar System are visible because of light reflected from the Sun.
Compare and contrast certain physical features of Earth with those of the Moon and other planets (e.g., presence and composition of an atmosphere, average surface temperature, presence of water, mass, gravity, distance from the Sun, period of revolution and rotation, ability to support life); recognize that the force of gravity keeps planets and moons in their orbits.

SOURCE: Mullis, Martin, and von Davier (2021), *TIMSS 2023 Assessment Frameworks*.