Connecticut Next Generation Science Standards Assessment

2020–2021

Volume 1
Annual Technical Report

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1. INTRODUCTION

The Connecticut Next Generation Science Standards (NGSS) Assessment is a science assessment for grades 5, 8, and 11. The *2020–2021 Connecticut NGSS Assessment Technical Report* is provided to document and make transparent all methods used in item development, test construction, psychometrics, standard setting, test administration, and score reporting, including summaries of student results and evidence and support for the intended uses and interpretations of the test scores. The technical reports are reported as six separate, self-contained volumes as described in the following list:

1) **Annual Technical Report.** This volume is updated each year and provides a global overview of the tests administered to students annually.

2) **Test Development.** This volume summarizes the procedures used to construct test forms and provides summaries of the item bank and development process.

3) **Standard Setting.** This volume documents the methods and results of the Connecticut NGSS Assessment standard-setting process.

4) **Evidence of Reliability and Validity.** This volume provides technical summaries of the test quality and special studies conducted to support the intended uses and interpretations of the test scores.

5) **Test Administration.** This volume describes the security protocols, accessibility features (including accommodations), methods used, and system characteristics developed to administer tests.

6) **Score Interpretation Guide.** This volume describes the score types reported and details the appropriate inferences that can be drawn from each score reported.

The Connecticut State Department of Education (CSDE) communicates the quality of the Connecticut NGSS Assessment by making these technical reports accessible to the public on the state's website.

1.1 BACKGROUND AND HISTORICAL CONTEXT OF TESTS

In 2015, Connecticut adopted three-dimensional science standards (the Next Generation Science Standards) based on *A Framework for K–12 Science Education* (National Research Council, 2012). The CSDE and its assessment vendor, Cambium Assessment, Inc. (CAI), developed and administered a new online assessment to measure these new standards. Piloted in 2016–2017, field-tested in 2017–2018, and administered operationally for the first time in 2018–2019, the Connecticut NGSS Assessment measures the science knowledge and skills of Connecticut students in grades 5, 8, and 11. The CSDE cancelled the spring 2020 administration of the Connecticut NGSS Assessment due to statewide school closures that followed the onset of the COVID-19 pandemic. In spring 2021, the CSDE and CAI resumed administration of the Connecticut NGSS Assessment.

The CSDE provides an overview of the science assessment at: https://portal.ct.gov/SDE/Student-Assessment/NGSS-Science/NGSS-Science. Information about the NGSS is available at: www.nextgenscience.org.

1.2 Purpose and Intended Uses of the Connecticut NGSS Assessment

The Connecticut NGSS Assessment is a criterion-referenced test established using principles of evidence-centered design to yield overall and discipline-level test scores at the student level and other levels of aggregation that reflect student achievement of the Connecticut NGSS Assessment. The three-dimensional science standards (i.e., the NGSS) establish a set of knowledge and skills that all students need to be prepared for a wide range of high-quality post-secondary opportunities, including higher education and entering the workplace. The three-dimensional NGSS reflects the latest research and advances in modern science and differs from previous science standards in multiple ways. First, rather than describing general knowledge and skills that students should know and be able to do, they describe specific performances that demonstrate what students know and can do. The NGSS refers to such performed knowledge and skills as *performance expectations* (PEs).

Second, while unidimensionality is a typical goal of standards (and the items that measure them), the NGSS is intentionally multi-dimensional. Each performance expectation incorporates all three dimensions from the NGSS Framework—a science or engineering practice, a disciplinary core idea, and a crosscutting concept. Third, while traditional standards do not consider other subject areas, the NGSS connects to other subjects like the Common Core mathematics and English language arts (ELA) standards. Another unique feature of the NGSS is the assumption that students should learn all science disciplines rather than a select few, as is traditionally done in many high schools, where students may elect, for example, to take biology and chemistry but not physics or astronomy.

The Connecticut NGSS Assessment supports instruction and student learning by providing valuable feedback to educators and parents, which can be used to form instructional strategies to remediate or enrich instruction. An array of reporting metrics is provided to evaluate performance at the student and aggregate levels and to monitor improvement at the student and group levels over time.

The Connecticut NGSS Assessment tests draw items from an item bank that consists of Independent College and Career Readiness (ICCR) items and items owned by several other states that share a Memorandum of Understanding (MOU) which shares content, leadership, and new ideas and methods. In 2021, the full members of the MOU were Connecticut, Hawaii, Idaho, Montana, Oregon, Rhode Island, Utah, Vermont, West Virginia, and Wyoming. CAI had a supporting and coordinating role. New Hampshire, North Dakota, and South Dakota observed and participated in some activities. CAI and the CSDE worked together to ensure that the items in the test forms which were constructed for all grades within the state uniquely measured the three-dimensional NGSS.

Table 1 outlines the required uses and citations for the Connecticut NGSS Assessment based on the Connecticut General Statutes §10-14n and the federal *Every Student Succeeds Act* (ESSA) plan. The Connecticut NGSS Assessment fulfills all the requirements described in Table 1.

Table 1. Required Uses and Citations for the Connecticut NGSS Assessment

Required Use	Required Use Citation
Indicator of academic achievement and progress	ESSA section 1111(b)(2)(B)(ii)
Test administration frequency and grade levels	ESSA section 1111(b)(2)(B)(v)(II) 10-14n. (a)(2) 10-14n. (b)(3)
Disaggregation of test scores	ESSA section 1111(b)(3)(C)(xiii)
Publication of test scores	ESSA section 1111(b)(3)(C)(xii) 10-14n. (g)

1.3 PARTICIPANTS IN THE DEVELOPMENT AND ANALYSIS OF THE CONNECTICUT NGSS ASSESSMENT

The CSDE manages the Connecticut state assessment programs with the assistance of several participants, including Connecticut educators, a Technical Advisory Committee (TAC), and vendors. The CSDE fulfills the diverse requirements of implementing Connecticut's statewide assessments while meeting or exceeding the guidelines established in the *Standards for Educational and Psychological Testing* (American Educational Research Association [AERA], American Psychological Association [APA], & National Council on Measurement in Education [NCME], 2014).

1.3.1 Connecticut State Department of Education

The Student Assessment, Performance Office manages test development, administration, scoring, and results reporting for the statewide comprehensive assessment programs, including coordinating with other CSDE offices, Connecticut public schools, and vendors.

1.3.2 Connecticut Educators

Connecticut educators participate in most aspects of the conceptualization and development of the Connecticut NGSS Assessment. Educators participate in developing the academic standards, clarifying how these standards are assessed, test design, and reviewing test questions and passages.

1.3.3 Technical Advisory Committee

The CSDE convenes an advisory committee panel twice each year to discuss psychometrics, test development, and administrative and policy issues relevant to the current and future Connecticut assessments. This committee is comprised of several nationally recognized assessment experts and highly experienced practitioners from several Connecticut school districts.

1.3.4 Cambium Assessment, Inc.

CAI (formerly the American Institutes for Research [AIR]) is the vendor that was selected through the state-mandated competitive procurement process. CAI is responsible for developing test content, building test forms, conducting psychometric analyses, administering and scoring test forms, and

reporting test results for the Connecticut NGSS Assessment described in this report. Additionally, CAI is responsible for developing and maintaining the ICCR item bank.

1.3.5 Caveon Test Security

Caveon Test Security monitored web pages and social media during the spring 2021 test administration to ensure that secure testing materials such as items and prompts were not leaked.

1.4 Available Test Formats and Special Versions

The Connecticut NGSS Assessment is administered online using a linear-on-the-fly (LOFT) test design. Science items are centered on a scientific phenomenon. They can consist of shorter (stand-alone) items or items with several parts (item clusters) requiring the student to interact with them in various ways. The science test was an independent field test in spring 2018 and went operational in spring 2019. Starting in 2021 and going forward, additional items will be field-tested to build out the item bank.

Students unable to participate in the online administration have the option to use print-on-demand—a feature that provides the same items administered to students online in a paper format. Spanish versions of the Connecticut NGSS Assessment (developed to meet the same content standards as the English versions) are available for all tested grades. Students participating in the computer-based Connecticut NGSS Assessment can use standard online testing features in the Test Delivery System (TDS), including a selection of font colors and sizes and the ability to zoom in and out or highlight text. In addition to the resources available to all students, options are available to accommodate students with an Individualized Education Program (IEP) or Section 504 Plan. These include braille, American Sign Language (ASL), closed captioning, and large print. Students with disabilities have the option to take the Connecticut NGSS Assessment with or without accommodations or to take an alternate assessment. For additional information about testing features and accommodations, refer to Volume 5, Test Administration.

1.5 Student Participation

All students in Connecticut public schools are required to participate in statewide assessments. The Connecticut NGSS Assessment is administered in the spring. Table 2 shows the number of students who were tested (number tested) and the number of students whose scores were included for analyses in this technical report (number reported).

Table 3 shows the demographic characteristics of the student population, by counts and percentages, in the spring administration of the 2020–2021 Connecticut NGSS Assessment. The subgroups reported are gender, ethnicity, students with limited English proficiency (LEP), special education students, and economically disadvantaged students.

Table 2. Number of Students Participating in the Connecticut NGSS Assessment, Spring 2021

Grade	Number Tested	Number Reported
5	35,044	34,938
8	36,565	36,391
11	29,856	29,789

Table 3. Distribution of Demographic Characteristics of Student Population

Group	Grade 5		Grade 8		Grade 11	
	N	*%*	*N*	*%*	*N*	*%*
All Students	34,938	100.00	36,391	100.00	29,789	100.00
Female	17,162	49.12	17,808	48.94	14,567	48.90
Male	17,774	50.87	18,575	51.04	15,212	51.07
African American	4,254	12.18	4,496	12.35	3,102	10.41
American Indian/Native Alaskan	99	0.28	81	0.22	71	0.24
Asian	1,857	5.32	1,921	5.28	1,692	5.68
Hispanic	9,748	27.90	9,481	26.05	5,896	19.79
Multi-Racial	1,500	4.29	1,374	3.78	886	2.97
Pacific Islander	33	0.09	38	0.10	29	0.10
White	17,447	49.94	19,000	52.21	18,113	60.80
Limited English Proficiency	3,211	9.19	2,020	5.55	1,045	3.51
Special Education	5,402	15.46	5,367	14.75	3,606	12.11
Economically Disadvantaged	14,887	42.61	14,685	40.35	9,066	30.43

2. SUMMARY OF OPERATIONAL PROCEDURES

2.1 TEST ADMINISTRATION

Table 4 shows the testing windows for the 2020–2021 Connecticut NGSS Assessments.

Table 4. Connecticut NGSS Assessment Testing Windows

Tests	Grade	Start Date	End Date	Mode
NGSS Summative Assessments	11	2/1/2021	6/4/2021	Online Computer Linear-on-the-Fly Tests; Paper-Pencil Fixed-Form Tests
	5, 8	3/29/2021	6/4/2021	

Tests	Grade	Start Date	End Date	Mode
NGSS Interim Assessments	5, 8, 11	9/1/2020	6/11/2021	Online Fixed-Form Tests

The key personnel involved with test administration for the Connecticut State Department of Education (CSDE) included district test coordinators (DTCs), school test coordinators (STCs), and test administrators (TAs) who proctored the test. *Test Administration Manuals* (TAMs) (available at https://ct.portal.cambiumast.com/resources) were provided so that personnel involved with the statewide assessment administrations could maintain both standardized administration conditions and test security.

The CAI Secure Browser was required to access the online Connecticut NGSS Assessments. The online browser provided a secure environment for student testing by disabling the hot keys, copy and screen capture capabilities, and preventing access to the desktop (Internet, email, and other files or programs installed on school machines). During the online assessment, students could pause a test, review previously answered questions, and modify their responses if the test had not been paused for more than 20 minutes. Students do not have a required time limit for each test session, but schools are given approximate time estimates for how long each test may take for most students for test administration planning purposes. For additional information about the test administration, refer to Volume 5, Test Administration.

2.2 SIMULATIONS

Before the operational testing window begins, CAI employs a simulation approach. Simulations are performed for all Connecticut NGSS Assessments. CAI delivers the Connecticut NGSS Assessment under a linear-on-the-fly (LOFT) test design. The test is delivered using the same item selection algorithm that CAI uses to deliver adaptive tests, except that only the test blueprint is considered during the item-selection process. Simulations were conducted to configure the algorithm settings, evaluate whether individual tests adhered to the test blueprint and correlated highly with student ability, and monitor item exposure rates. The simulation approaches and results are discussed in Volume 2, Test Development.

2.3 UNIVERSAL TOOLS, DESIGNATED SUPPORTS, AND ACCOMMODATIONS

The accessibility supports discussed in this document include embedded (digitally provided) and non-embedded (non-digitally or locally provided) universal features available to all students as they access instructional or assessment content; designated supports available to those students for whom the need has been identified by an informed educator or team of educators; and accommodations generally available for students for whom there is documentation on an Individualized Education Program (IEP) or Section 504 Plan. For English learners (ELs), Spanish language versions of the Connecticut NGSS Assessment are available.

Scores achieved by students using designated supports are included for federal accountability purposes. All educators making these decisions were trained on the process and understand the range of designated supports available.

Accommodations are changes in procedures or materials that ensure equitable access to instructional and assessment content and generate valid assessment results for students who need them. Embedded accommodations (e.g., text-to-speech [TTS]) are provided digitally through instructional or assessment technology, and non-embedded designated features (e.g., scribe) are non-digital. State-approved accommodations do not compromise the learning expectations, constructs, or grade-level standards. These accommodations help students with a documented need generate valid assessment outcomes that fully demonstrate what they know and are able to do. From the psychometric point of view, the purpose of providing accommodations is to "increase the validity of inferences about students with disabilities by offsetting specific disability-related, construct-irrelevant impediments to performance" (Koretz & Hamilton, 2006, p. 562).

Connecticut TAs and STCs are responsible for ensuring that arrangements for accommodations are made before the test administration dates. The available accommodation options for eligible students include: braille, American Sign Language (ASL), closed captioning, streamline, abacus, assistive technology (e.g., adaptive keyboards, touch screens, switches), calculation device, print-on-demand, multiplication table, and scribe. Descriptions for each of these accommodations can be found in Volume 5, Test Administration.

Table 5 and Table 6 list the number of testing sessions in which a student was provided with each designated support or accommodation during the spring 2021 test administration.

Table 5. Number of Testing Sessions with Allowed Designated Supports

Designated Supports	Grade		
	5	8	11
Embedded			
Color Choices	11	14	-
Language—Spanish	360	474	204
Masking	156	80	13
Mouse Pointer	-	-	1
Print Size	42	24	10
Streamlined Mode	162	134	4
Text-to-Speech: Stimuli and Items	7,345	5,029	1,484
Non-Embedded			
Bilingual Dictionary	90	205	225
Color Overlay	1	4	1
Magnification	11	8	5
Native Language Reader Directions	37	28	6
Noise Buffer	19	12	1
Read Aloud: Stimuli and Items	75	46	61
Read Aloud: Stimuli and Items (Spanish)	36	16	8
Separate Setting	3,374	2,821	907

Table 6. Number of Testing Sessions with Allowed Accommodations

Accommodations	Grade		
	5	**8**	**11**
Embedded			
Permissive Mode	74	17	9
Text-to-Speech: Stimuli and Items	7,345	5,029	1,484
Non-Embedded			
Alternate Response Options (Requires Permissive Mode)	10	-	1
Large Print	4	1	3
Sign Language for Test Items	9	8	9
Specialized Calculator	25	62	23
Speech-to-Text (Requires Permissive Mode)	1	-	-

3. ITEM BANK AND TEST DESIGN

3.1 SHARED SCIENCE ASSESSMENT ITEM BANK

CAI works with a group of states to develop science assessments to assess the NGSS and other standards influenced by the same science framework. Many of these states have signed an MOU to share item specifications and items. CAI coordinates this group of states and holds contracts to develop and deliver the items for most of them.

CAI also built the ICCR science item pool in partnership with these states. These CAI-owned items make up a substantial part of the item bank and are shared with partner states. Connecticut signed the MOU, and therefore, the item pool available for the Connecticut NGSS Assessment includes items from the following three sources:

1. Items owned by Connecticut
2. Items shared by other states within the MOU collaboration
3. Items shared from the ICCR item bank

A detailed description of the Shared Science Assessment Item Bank development process is included in Volume 2, Test Development. All these items follow the same specifications, test development processes, and review processes. In 2018, CAI field tested more than 540 item clusters and stand-alone items, of which 451 (including items from all sources) were accepted and made available as operational items in 2019. In 2019, 347 item clusters and stand-alone items were field tested, of which 268 were accepted and made available for operational use in future administrations. In 2021, 545 item clusters and stand-alone items were field tested, of which 458 were accepted and made available for operational use in future administrations.

The Shared Science Assessment Item Bank is used for operational tests in 10 states in 2021, including Connecticut. Four additional state tests will become operational in 2022.

CAI's process for developing and field testing science items is detailed in Volume 2, Test Development. Here, note that the following best practices have been implemented at every turn:

- The goals, uses, and claims that the resulting tests would be designed to support were identified in a collaborative meeting from August 22–23, 2016, in an attempt to facilitate the transition from a framework for three-dimensional science standards, specifically the NGSS, to statewide summative assessments for science. CAI invited content and assessment leaders from 10 states and four nationally recognized experts who helped co-author the NGSS. Two nationally recognized psychometricians also participated.
- CAI staff and participating states collaborated to develop items and item specifications, which are documents designed to guide item writers as they craft test questions and stakeholders as they review those items. The item specifications were generally accompanied by sample items meeting those specifications. All specifications and sample items were reviewed by state content experts and committees of educators in at least one state.
- Items were reviewed by science experts in at least one state.
- Every item was reviewed by a content advisory committee (composed of state educators) in at least one state or in a cross-state educator review process.
- Every item was reviewed by a committee of educators charged with evaluating language accessibility, bias, and sensitivity in at least one state or a cross-state educator review.
- Every item was field tested, and items with questionable data were reviewed again by committees of educators.
- All scoring protocols (e.g., rubrics) were validated.
- In 2017, cognitive lab studies were conducted to evaluate and refine the process of developing item clusters aligned to the three-dimensional science standards. The results of the cognitive lab studies confirmed the feasibility of the approach (refer to Volume 4, Section 6.1, Cognitive Laboratory Studies).
- A second set of cognitive lab studies was conducted in 2018 and 2019. The goal of those studies was to determine if students using braille could understand the task demands of selected accommodated three-dimensional science-aligned item clusters. They also evaluated whether these students could navigate the interactive features of these item clusters in a manner that allowed them to fully display their knowledge and skills relative to the constructs of interest. In general, both the students who relied entirely on braille and/or Job Access With Speech (JAWS) and those who had some vision and were able to read the screen with magnification were able to find the information they needed to respond

to the questions, navigate the various response formats, and finish within a reasonable amount of time (refer to Volume 4, Section 6.1, Cognitive Laboratory Studies).

3.2 FIELD TESTING

All items that were part of the operational pool were field tested in 2018, 2019, and 2021, as described in Section 3.2.1, 2018 Field Test, Section 3.2.2, 2019 Field Test, and Section 3.2.3, 2021 Field Test.

3.2.1 2018 Field Test

In 2018, a large pool of items was field tested in nine states. For three states (Hawaii, Oregon, and Wyoming), unscored field-test items were added as an additional segment to the operational (scored) legacy science test. Two other states (Connecticut and Rhode Island) conducted an independent field test in which all students participated and were administered a full set of items, but no scores were reported. In the remaining four states (New Hampshire, Utah, Vermont, and West Virginia,), an operational field test was administered, meaning tests consisted of field-test items. Items became operational and were scored after the test administration if they were not rejected during rubric validation or item data review, as described later in this section. In total, 340 item clusters and 205 stand-alone items were administered in the elementary, middle, and high school grade bands. Table 7 presents the number of item clusters and stand-alone items administered in each grade band for each state.

Table 7. Number of Field-Test Items Administered, Spring 2018

Grade Band and Item Type	CT	HI	MSSA[a]	NH	OR	UT	WV	WY	Entire Bank
Elementary School	**135 (23)**	**24**	**69**	**58**	**26**	**–**	**91**	**14**	**153**
Cluster	78 (14)	13	40	34	20	–	56	6	86
Stand-Alone	57 (9)	11	29	24	6	–	35	8	67
Middle School	**174 (21)**	**27**	**56**	**55**	**28**	**98**	**123**	**17**	**241**
Cluster	115 (11)	13	26	30	22	98	90	5	171
Stand-Alone	59 (10)	14	30	25	6	–	33	12	70
High School	**149 (24)**	**23**	**75**	**60**	**38**	**–**	**–**	**14**	**151**
Cluster	81 (16)	14	34	33	30	–	–	6	83
Stand-Alone	68 (8)	9	41	27	8	–	–	8	68
Total	**458 (68)**	**74**	**200**	**173**	**92**	**98**	**214**	**45**	**545**

Note. Connecticut-owned items are indicated in the parentheses.
[a]MSSA = Rhode Island and Vermont's Multi-State Science Assessment.

For the states with a separate field-test segment (states with a legacy science test) and one of the states with an operational field test (Utah), fixed field-test forms were constructed (using a balanced incomplete design except for Utah) and spiraled across students.

For the independent and operational field tests (except for Utah), including Connecticut, items were administered using a LOFT test design. The difference between the test design for the independent field tests and operational field tests depended on the test blueprint. The only blueprint constraint imposed for the independent field tests was that students received four stand-alone items and two item clusters for each of the three science disciplines. In contrast, a full blueprint was implemented for the states with an operational field test. The blueprint for the Connecticut NGSS Assessment is discussed in Section 3.3, Test Design.

There was a target of a minimum sample size of 1,500 students per item for any given state. Most items were administered in two or more states so that the item pools for all individual states were linked through common items. Table 8, Table 9, and Table 10 present the number of item clusters and stand-alone items that were common between the item pools of any two states. The numbers below the shaded diagonal elements represent the number of all the field-test items, and the numbers above the shaded diagonal elements represent the number of common items at the time of the 2018 calibration. The shaded diagonal elements represent the number of items administered only in the given state, with the number of unique items at the time of calibration provided in parentheses. Table 8 presents the results for elementary school, Table 9 presents the results for middle school, and Table 10 presents the results for high school. The numbers at field testing are slightly different from the numbers at calibration for various reasons, such as items not passing rubric validation and versioning issues for some items in some states.

Table 8. Common Elementary School Field-Test Items Administered and Calibrated, Spring 2018

	State	CT	HI	MSSA[a]	NH	OR	UT	WV	WY
Cluster	**CT**	**3 (3)**	9	36	28	16	–	49	6
	HI	10	**0 (0)**	7	8	5	–	12	1
	MSSA	36	8	**0 (2)**	15	12	–	26	2
	NH	30	8	17	**1 (3)**	5	–	22	2
	OR	17	5	13	5	**1 (1)**	–	5	1
	UT	–	–	–	–	–	**–**	–	–
	WV	49	12	27	25	5	–	**0 (4)**	2
	WY	6	1	2	2	1	–	2	**0 (0)**
Stand-Alone	**CT**	**1 (3)**	5	25	22	2	–	33	7
	HI	5	**6 (6)**	0	0	0	–	4	0
	MSSA	26	0	**0 (1)**	10	4	–	13	3
	NH	24	0	11	**0 (2)**	0	–	15	2
	OR	2	0	4	0	**1 (1)**	–	0	0
	UT	–	–	–	–	–	**–**	–	–
	WV	35	4	14	17	0	–	**0 (2)**	1
	WY	8	0	3	3	0	–	2	**0 (1)**

	State	CT	HI	MSSA[a]	NH	OR	UT	WV	WY
Grade Band Total	**CT**	**4 (6)**	14	61	50	18	–	82	13
	HI	15	**6 (6)**	7	8	5	–	16	1
	MSSA	62	8	**0 (3)**	25	16	–	39	5
	NH	54	8	28	**1 (5)**	5	–	37	4
	OR	19	5	17	5	**2 (2)**	–	5	1
	UT	–	–	–	–	–	**–**	–	–
	WV	84	16	41	42	5	–	**0 (6)**	3
	WY	14	1	5	5	1	–	4	**0 (1)**

Note. [a]MSSA = Rhode Island and Vermont's Multi-State Science Assessment

Table 9. Common Middle School Field-Test Items Administered and Calibrated, Spring 2018

	State	CT	HI	MSSA[a]	NH	OR	UT	WV	WY
Cluster	**CT**	**2 (6)**	12	22	26	19	44	77	5
	HI	11	**1 (0)**	3	6	6	0	9	1
	MSSA	23	3	**0 (1)**	9	1	7	22	2
	NH	26	6	10	**1 (2)**	7	0	17	3
	OR	19	6	1	7	**2 (2)**	0	5	1
	UT	48	0	7	0	0	**48 (52)**	43	0
	WV	83	10	21	18	6	48	**1 (9)**	2
	WY	5	1	2	3	1	0	2	**0 (0)**
Stand-Alone	**CT**	**2 (3)**	6	27	25	3	0	33	12
	HI	6	**8 (8)**	2	0	0	0	2	0
	MSSA	27	2	**0 (0)**	18	3	0	20	2
	NH	25	0	18	**0 (0)**	0	0	21	3
	OR	3	0	3	0	**0 (0)**	0	0	0
	UT	0	0	0	0	0	**0 (0)**	0	0
	WV	33	2	20	21	0	0	**0 (0)**	2
	WY	12	0	2	3	0	0	2	**0 (0)**
Grade Band Total	**CT**	**4 (9)**	18	49	51	22	44	110	17
	HI	17	**9 (8)**	5	6	6	0	11	1
	MSSA	50	5	**0 (1)**	27	4	7	42	4
	NH	51	6	28	**1 (2)**	7	0	38	6
	OR	22	6	4	7	**2 (2)**	0	5	1
	UT	48	0	7	0	0	**48 (52)**	43	0
	WV	116	12	41	39	6	48	**1 (9)**	4
	WY	17	1	4	6	1	0	4	**0 (0)**

Note. [a]MSSA = Rhode Island and Vermont's Multi-State Science Assessment

Table 10. Common High School Field-Test Items Administered and Calibrated, Spring 2018

	State	CT	HI	MSSA[a]	NH	OR	UT	WV	WY
Cluster	CT	**10 (16)**	13	30	29	30	–	–	5
	HI	13	**0 (0)**	7	7	8	–	–	1
	MSSA	32	7	**0 (2)**	13	12	–	–	1
	NH	32	7	14	**0 (3)**	12	–	–	3
	OR	30	8	12	12	**0 (0)**	–	–	1
	UT	–	–	–	–	–	**–**	–	–
	WV	–	–	–	–	–	–	**–**	–
	WY	6	1	1	3	1	–	–	**0 (1)**
Stand-Alone	CT	**4 (4)**	9	40	27	8	–	–	8
	HI	9	**0 (0)**	4	0	0	–	–	0
	MSSA	39	4	**0 (1)**	20	3	–	–	1
	NH	25	0	20	**0 (0)**	0	–	–	1
	OR	8	0	3	0	**0 (0)**	–	–	0
	UT	–	–	–	–	–	**–**	–	–
	WV	–	–	–	–	–	–	**–**	–
	WY	7	0	1	1	0	–	–	**0 (0)**
Grade Band Total	CT	**14 (20)**	22	70	56	38	–	–	13
	HI	22	**0 (0)**	11	7	8	–	–	1
	MSSA	71	11	**0 (3)**	33	15	–	–	2
	NH	57	7	34	**0 (3)**	12	–	–	4
	OR	38	8	15	12	**0 (0)**	–	–	1
	UT	–	–	–	–	–	**–**	–	–
	WV	–	–	–	–	–	–	**–**	–
	WY	13	1	2	4	1	–	–	**0 (1)**

Note. [a]MSSA = Rhode Island and Vermont's Multi-State Science Assessment

The common item design was used to calibrate all the items on a common science scale. The calibration model is explained in detail in Section 5, Item Calibration.

Following the (operational) field test administration, items went through a substantial validation process. The process began with rubric validation. In the science test, *scoring assertions* capture each measurable action of an item and articulate what evidence the student has provided to infer a specific skill or concept, while *rubrics* establish criteria, including rules, principles, and illustrations, to communicate expectations of students' success in providing that evidence. Rubric validation is a process in which a committee of state educators reviews student responses and the

proposed scoring of those responses. The responses reviewed are scientifically sampled to overrepresent responses that were most likely to have been mis-scored. Specifically, the sample overrepresents two types of responses: (1) low-scored responses from otherwise high-scoring students and (2) high-scored responses from otherwise low-scoring students.

During rubric validation, educators recommended revisions to rubrics where necessary. CAI staff revised the rubrics and rescored the entire sample to ensure that the rubric changes had all and only the intended effects.

Following rubric validation, classical item statistics were computed for the scoring assertions, including item difficulty and item discrimination statistics, testing time, and differential item functioning (DIF) statistics. The states established standards for the statistics. Any items violating these standards were flagged for a second educator review. Even though the scoring assertions were the basic units of analysis used to compute classical item statistics, the business rules to flag items for another educator review were established at the item level because assertions cannot be reviewed in isolation. A common set of business rules was defined for all the states participating in the (operational) field test, although some states decided to include additional items for data review. The item statistics were computed based on the data of the students testing in the state that owned the item. For Rhode Island and Vermont, which share their item development, the statistics were computed based on the combined data. For ICCR items, the data from Connecticut, New Hampshire, Rhode Island, Vermont, and West Virginia (states that used ICCR items and with either an independent or operational field test) were combined. For each state, a data review committee consisting of educators (i.e., science teachers) supported by CAI content experts reviewed the items that were owned by the state and flagged for data review according to the established business rules. For ICCR, cross-state review committees were established.

Table 11 presents the number of field-test items administered in Connecticut or another state, the number of items rejected before or during rubric validation, the number of items sent for data review, and the number of items rejected during data review. The numbers in parentheses present the number of items owned by Connecticut.

Table 11. Field-Test Item Administration, Rubric Validation, and Item Data Review, Spring 2018

Grade Band and Item Type	Number of Field-Test Items Administered	Number of Items Rejected Before/During Rubric Validation	Number of Items Sent to Data Review	Number of Items Rejected at Data Review[a]	Number of Items Remaining
Elementary School	**153 (23)**	**3 (0)**	**65 (6)**	**13 (3)**	**137 (20)**
Cluster	86 (14)	3 (0)	24 (3)	5 (2)	78 (12)
Stand-Alone	67 (9)	0 (0)	41 (3)	8 (1)	59 (8)
Middle School	**241 (21)**	**16 (2)**	**102 (6)**	**24 (3)**	**201 (16)**
Cluster	171 (11)	12 (0)	65 (1)	15 (0)	144 (11)
Stand-Alone	70 (10)	4 (2)	37 (5)	9 (3)	57 (5)
High School	**151 (24)**	**10 (3)**	**80 (9)**	**13 (5)**	**128 (16)**
Cluster	83 (16)	8 (2)	35 (5)	4 (3)	71 (11)
Stand-Alone	68 (8)	2 (1)	45 (4)	9 (2)	57 (5)
Total	**545 (68)**	**29 (5)**	**247 (21)**	**50 (11)**	**466 (52)**

Note. Connecticut-owned are indicated in the parentheses.
[a]Including three middle school clusters rejected after item data review.

Table 12 summarizes the operational Shared Science Assessment Item Bank for each of the three science disciplines after adding the 2018 field-test items that passed rubric validation and item data review. The numbers in parentheses present the number of items owned by Connecticut.

Table 12. Shared Science Assessment Item Bank, Spring 2018

Grade Band and Item Type	Science Discipline			Total[a]
	Earth and Space Sciences	*Life Sciences*	*Physical Sciences*	
Elementary School	**41 (3)**	**47 (8)**	**49 (9)**	**137 (20)**
Cluster	23 (3)	29 (5)	26 (4)	78 (12)
Stand-Alone	18 (0)	18 (3)	23 (5)	59 (8)
Middle School	**56 (5)**	**72 (7)**	**70 (4)**	**198 (16)**
Cluster	41 (3)	49 (6)	51 (2)	141 (11)
Stand-Alone	15 (2)	23 (1)	19 (2)	57 (5)
High School	**37 (4)**	**53 (5)**	**38 (7)**	**128 (16)**
Cluster	19 (2)	32 (5)	20 (4)	71 (11)
Stand-Alone	18 (2)	21 (0)	18 (3)	57 (5)
Total	**134 (12)**	**172 (20)**	**157 (20)**	**463 (52)**

Note. [a]Excludes three Utah-owned middle school clusters that do not align to the NGSS

3.2.2 2019 Field Test

In 2019, a second wave of items was field tested in nine states. For three states (Hawaii, Idaho [elementary school only], and Wyoming), unscored field-test items were added as a separate segment to the operational scored legacy science test. An independent field test, in which students were administered a full set of items, was conducted for a sample of Idaho middle schools. In the remaining six states (Connecticut, New Hampshire, Oregon, Rhode Island, Vermont, and West Virginia), field-test items were administered as unscored items embedded among the operational items. In total, 123 item clusters and 224 stand-alone items were administered as field-test items in the elementary, middle, and high school grade bands. Table 13 presents the number of field-test item clusters and stand-alone items administered in each grade band for each state. The numbers in parentheses in the column representing Connecticut present the number of items owned by Connecticut.

Table 13. Number of Field-Test Items Administered, Spring 2019

Grade Band and Item Type	CT	HI	ID	MSSA[a]	NH	OR	WV	WY	Entire Bank
Elementary School	**47 (24)**	**31**	**53**	**42**	**18**	**27**	**18**	**16**	**117**
Cluster	18 (10)	19	20	17	0	16	10	5	50
Stand-Alone	29 (14)	12	33	25	18	11	8	11	67

Grade Band and Item Type	CT	HI	ID	MSSA[a]	NH	OR	WV	WY	Entire Bank
Middle School	**56 (30)**	**23**	**53**	**46**	**28**	**26**	**26**	**15**	**127**
Cluster	14 (10)	9	17	10	4	9	8	5	38
Stand-Alone	42 (20)	14	36	36	24	17	18	10	89
High School	**69 (28)**	**21**	**–**	**37**	**29**	**28**	**–**	**25**	**103**
Cluster	25 (13)	14	–	18	2	13	–	2	35
Stand-Alone	44 (15)	7	–	19	27	15	–	23	68
Total	**172 (82)**	**75**	**106**	**125**	**75**	**81**	**44**	**56**	**347**

Note. Connecticut-owned items are indicated in the parentheses.
[a]MSSA = Rhode Island and Vermont's Multi-State Science Assessment

For the three states with a separate field-test segment (i.e., states with a legacy science test), field-test forms were constructed using a balanced incomplete design and spiraled across students. For the independent field test, items were administered under a LOFT design, where the only blueprint constraint imposed was that students received four stand-alone items and two item clusters for each of the three science disciplines.

In the states with an operational test, field-test items were embedded within the operational test. Some of the states with an operational test (New Hampshire, Rhode Island, and Vermont) opted for a test in which operational items were grouped by science discipline. For these three states, the field-test items were presented together in a fourth group of items. The sequence of the four sets of items (corresponding to the three disciplines and a set of field-test items) was randomized across students. Three other states (Connecticut, Oregon, and West Virginia) opted for a test design in which the items were not grouped by discipline. In these three states, field-test items were administered at random positions throughout the test. A student received either a field-test item cluster or a set of five field-test stand-alone items. The test design for the Connecticut NGSS Assessment is discussed in Section 3.3, Test Design.

A minimum sample size of 1,500 students per field-test item was targeted for any given state. Most items were administered in two or more states.

Table 14 to Table 16 present the number of item clusters and stand-alone items that were shared between the field-test pools of any two states. The numbers below the shaded diagonal elements represent the number of all administered field-test items, and the numbers above the shaded diagonal elements represent the number of common field-test items at the time of calibration. The shaded diagonal elements represent the number of field-test items administered only in the given state (with the number of unique field-test items at the time of calibration in parentheses).

Table 14 presents the results for elementary schools, Table 15 presents the results for middle schools, and Table 16 presents the results for high schools. The numbers of field-test items administered are slightly different from the numbers of field-test items at calibration because some items were rejected during rubric validation.

Table 14. Common Elementary School Field-Test Items Administered and Calibrated, Spring 2019

	State	CT	HI	ID	MSSA[a]	NH	OR	WV	WY
Cluster	**CT**	**2 (2)**	2	10	3	0	2	1	4
	HI	2	**0 (0)**	3	8	0	14	2	0
	ID	10	3	**4 (4)**	0	0	1	3	3
	MSSA	3	8	0	**3 (3)**	0	9	4	1
	NH	0	0	0	0	**0 (0)**	0	0	0
	OR	2	14	1	9	0	**1 (1)**	0	0
	WV	1	2	3	4	0	0	**1 (0)**	1
	WY	4	0	3	1	0	0	1	**0 (0)**
Stand-Alone	**CT**	**5 (5)**	1	13	1	9	0	0	2
	HI	1	**0 (0)**	10	6	0	6	0	0
	ID	13	11	**1 (1)**	12	1	9	2	4
	MSSA	1	7	13	**3 (3)**	5	8	5	6
	NH	9	0	1	5	**2 (3)**	0	0	6
	OR	0	7	10	9	0	**1 (1)**	0	0
	WV	0	0	2	5	0	0	**1 (1)**	0
	WY	2	0	4	6	7	0	0	**0 (0)**
Grade Band Total	**CT**	**7 (7)**	3	23	4	9	2	1	6
	HI	3	**0 (0)**	13	14	0	20	2	0
	ID	23	14	**5 (5)**	12	1	10	5	7
	MSSA	4	15	13	**6 (6)**	5	17	9	7
	NH	9	0	1	5	**2 (3)**	0	0	6
	OR	2	21	11	18	0	**2 (2)**	0	0
	WV	1	2	5	9	0	0	**2 (1)**	1
	WY	6	0	7	7	7	0	1	**0 (0)**

Note. [a]MSSA = Rhode Island and Vermont's Multi-State Science Assessment

Table 15. Common Middle School Field-Test Items Administered and Calibrated, Spring 2019

	State	CT	HI	ID	MSSA[a]	NH	OR	WV	WY
Cluster	CT	**5 (5)**	3	4	2	0	2	1	0
	HI	3	**0 (0)**	4	4	0	5	1	0
	ID	4	4	**2 (2)**	4	0	4	3	3
	MSSA	2	4	4	**1 (1)**	0	2	3	1
	NH	0	0	1	0	**3 (0)**	0	0	0
	OR	2	5	4	2	0	**1 (1)**	1	2
	WV	1	1	3	3	0	1	**0 (0)**	2
	WY	0	0	3	1	0	2	2	**0 (0)**
Stand-Alone	CT	**10 (9)**	2	13	9	10	3	6	0
	HI	2	**0 (0)**	9	9	0	6	3	0
	ID	13	9	**2 (2)**	11	1	12	6	5
	MSSA	9	9	11	**1 (1)**	6	11	9	7
	NH	10	0	2	6	**3 (1)**	0	0	2
	OR	3	6	12	11	0	**0 (0)**	2	7
	WV	6	3	6	9	1	2	**0 (0)**	0
	WY	0	0	5	7	2	7	0	**0 (0)**
Grade Band Total	CT	**15 (14)**	5	17	11	10	5	7	0
	HI	5	**0 (0)**	13	13	0	11	4	0
	ID	17	13	**4 (4)**	15	1	16	9	8
	MSSA	11	13	15	**2 (2)**	6	13	12	8
	NH	10	0	3	6	**6 (1)**	0	0	2
	OR	5	11	16	13	0	**1 (1)**	3	9
	WV	7	4	9	12	1	3	**0 (0)**	2
	WY	0	0	8	8	2	9	2	**0 (0)**

Note. [a]MSSA = Rhode Island and Vermont's Multi-State Science Assessment

Table 16. Common High School Field-Test Items Administered and Calibrated, Spring 2019

	State	CT	HI	ID	MSSA[a]	NH	OR	WV	WY
Cluster	CT	**9 (9)**	10	–	11	0	8	–	1
	HI	11	**0 (0)**	–	8	0	11	–	0
	ID	–	–	**–**	–	–	–	–	–
	MSSA	12	9	–	**3 (2)**	0	7	–	2
	NH	0	0	–	0	**1 (0)**	1	–	0
	OR	8	11	–	7	1	**1 (1)**	–	0
	WV	–	–	–	–	–	–	**–**	–
	WY	1	0	–	2	0	0	–	**0 (0)**
Stand-Alone	CT	**14 (13)**	7	–	7	6	13	–	13
	HI	7	**0 (0)**	–	0	0	6	–	0
	ID	–	–	**–**	–	–	–	–	–
	MSSA	8	0	–	**3 (3)**	6	5	–	12
	NH	8	0	–	6	**10 (10)**	0	–	7
	OR	14	6	–	6	0	**0 (1)**	–	8
	WV	–	–	–	–	–	–	**–**	–
	WY	14	0	–	13	7	9	–	**0 (0)**
Grade Band Total	CT	**23 (22)**	17	–	18	6	21	–	14
	HI	18	**0 (0)**	–	8	0	17	–	0
	ID	–	–	**–**	–	–	–	–	–
	MSSA	20	9	–	**6 (5)**	6	12	–	14
	NH	8	0	–	6	**11 (10)**	1	–	7
	OR	22	17	–	13	1	**1 (1)**	–	8
	WV	–	–	–	–	–	–	**–**	–
	WY	15	0	–	15	7	9	–	**0 (0)**

Note. [a]MSSA = Rhode Island and Vermont's Multi-State Science Assessment

The calibration and linking of the field-test items in 2019 are explained in detail in Section 5.2, Item Calibration.

Following essentially the same process as explained in Section 3.2.1, 2018 Field Test items went through a substantial validation process. The following are minor modifications to the process followed in 2018 and 2019:

- In 2018, all item statistics were computed based on the data of the students testing in the state that owned the item. In 2019, all item statistics were computed based on the data of the students testing in the state that owned the item, *except for the statistics related to DIF*. Following the recommendations of several Technical Advisory Committees (TACs), the

states' data were combined in the calculation of DIF statistics whenever possible (i.e., for states with an independent field test or an operational test for which the relevant demographic variable was available).

- In 2018, for ICCR items, the data from Connecticut, New Hampshire, Rhode Island, Vermont, and West Virginia, the states that used ICCR items with either an independent or operational field test, were combined. In 2019, the data from Connecticut, Idaho (for middle school only), New Hampshire, Oregon, Rhode Island, Vermont, and West Virginia were combined.
- The business rule used to flag an item cluster for DIF was slightly modified by making it more liberal following the recommendations of several TACs. The modification is discussed in Section 4.4, Differential Item Functioning Analysis.

Table 17 presents the number of field-test items administered in Connecticut, or another state, the number of items rejected before or during rubric validation, the number of items sent for data review, and the number of items rejected during data review. The numbers in parentheses present the number of items owned by Connecticut.

Table 17. Field-Test Item Administration, Rubric Validation, and Item Data Review, Spring 2019

Grade Band and Item Type	Number of Items Field Tested	Number of Items Rejected Before/During Rubric Validation	Number of Items Sent to Data Review	Number of Items Rejected at Data Review	Number of Items Remaining[a]
Elementary School	**117 (24)**	**2 (0)**	**72 (18)**	**24 (4)**	**91 (20)**
Cluster	50 (10)	1 (0)	16 (4)	10 (1)	39 (9)
Stand-Alone	67 (14)	1 (0)	56 (14)	14 (3)	52 (11)
Middle School	**127 (30)**	**6 (1)**	**66 (18)**	**21 (6)**	**97 (23)**
Cluster	38 (10)	1 (0)	12 (3)	5 (2)	29 (8)
Stand-Alone	89 (20)	5 (1)	54 (15)	16 (4)	68 (15)
High School	**103 (28)**	**6 (1)**	**52 (17)**	**15 (7)**	**80 (20)**
Cluster	35 (13)	2 (0)	15 (7)	5 (3)	26 (10)
Stand-Alone	68 (15)	4 (1)	37 (10)	10 (4)	54 (10)
Total	**347 (82)**	**14 (2)**	**190 (53)**	**60 (17)**	**268 (63)**

Note. Connecticut-owned items are indicated in the parentheses.

[a]Number of items remaining excludes five AI scoring items (four ICCR and one MSSA-owned) field tested in spring 2019 that were not brought to item data review.

Table 18 summarizes the Shared Science Assessment Item Bank after adding the field-test items that were administered in 2019 and passed rubric validation and item data review. The numbers in parentheses present the number of items owned by Connecticut.

Table 18. Shared Science Assessment Item Bank, Spring 2019

Grade Band and Item Type	Combined Science Item Bank				
	Earth and Space Sciences	*Engineering and Technology*	*Life Sciences*	*Physical Sciences*	*Total*
Elementary School	**68 (11)**	**0 (0)**	**77 (12)**	**81 (17)**	**226 (40)**
Cluster	34 (7)	0 (0)	40 (6)	41 (8)	115 (21)
Stand-Alone	34 (4)	0 (0)	37 (6)	40 (9)	111 (19)
Middle School	**83 (9)**	**1 (0)**	**109 (20)**	**96 (9)**	**289 (38)**
Cluster	44 (3)	1 (0)	63 (12)	57 (3)	165 (18)
Stand-Alone	39 (6)	0 (0)	46 (8)	39 (6)	124 (20)
High School	**40 (7)**	**0 (0)**	**109 (12)**	**53 (17)**	**202 (36)**
Cluster	19 (4)	0 (0)	49 (8)	24 (9)	92 (21)
Stand-Alone	21 (3)	0 (0)	60 (4)	29 (8)	110 (15)
Total	**191 (27)**	**1 (0)**	**295 (44)**	**230 (43)**	**717 (114)**

Note. Connecticut-owned items are indicated in the parentheses.

3.2.3 2021 Field Test

In 2021, a third wave of items was field tested in 12 states. For one state (Wyoming), unscored field-test items were added as a separate segment to the operational scored legacy science test. An independent field test, in which students were administered a full set of items, was conducted in Idaho and Montana. In the remaining nine states (Connecticut, Hawaii, New Hampshire, North Dakota, Rhode Island, South Dakota, Utah, Vermont, and West Virginia), field-test items were administered as unscored items embedded among the operational items. In total, 223 item clusters and 322 stand-alone items were administered as field-test items in the elementary, middle, and high school grade bands. Table 19 presents the number of field-test item clusters and stand-alone items administered in each grade band for each state. The numbers in parentheses in the column representing Connecticut presents the number of field-test items owned by Connecticut.

Table 19. Number of Field-Test Items Administered, Spring 2021

Grade Band and Item Type	CT	HI	ID	MSSA[a]	MT	ND	NH	SD	UT	WV	WY	Entire Bank
Elementary School	**36 (28)**	**22**	**140**	**55**	**21**	**11**	**19**	**8**	**54**	**19**	**17**	**214**
Cluster	16 (11)	6	58	18	7	3	3	3	54	7	5	106
Stand-Alone	20 (17)	16	82	37	14	8	16	5	0	12	12	108
Middle School	**33 (24)**	**19**	**129**	**54**	**20**	**11**	**18**	**11**	**45**	**19**	**20**	**159**
Cluster	17 (14)	6	44	18	7	3	2	2	45	7	4	60
Stand-Alone	16 (10)	13	85	36	13	8	16	9	0	12	16	99
High School	**49 (49)**	**17**	**156**	**49**	**–**	**11**	**12**	**8**	**–**	**–**	**20**	**172**
Cluster	11 (11)	5	54	16	–	3	4	3	–	–	3	57
Stand-Alone	38 (38)	12	102	33	–	8	8	5	–	–	17	115
Total	**118 (101)**	**58**	**425**	**158**	**41**	**33**	**49**	**27**	**99**	**38**	**57**	**545**

Note. Connecticut-owned items are indicated in the parentheses.
[a]MSSA = Rhode Island and Vermont's Multi-State Science Assessment

For the state with a separate field-test segment (i.e., Wyoming), field-test forms were constructed using a balanced incomplete design and spiraled across students. For the independent field test, items were administered under a LOFT design, where the only blueprint constraint imposed was that students received four stand-alone items and two item clusters for each of the three science disciplines.

For the states with an operational test, field-test items were embedded within the operational test. Some of the states with an operational test (New Hampshire, Rhode Island, and Vermont) opted for a test in which operational items were grouped by science discipline. For these three states, the field-test items were presented together in a fourth group of items. The sequence of the four sets of items (corresponding to the three disciplines and a set of field-test items) was randomized across students. Six other states (Connecticut, Hawaii, North Dakota, South Dakota, Utah, and West Virginia) opted for a test design in which the items were not grouped by discipline. In these six states, field-test items were administered at random positions throughout the test. A student received either a field-test item cluster or a set of four field-test stand-alone items. The test design for the Connecticut NGSS Assessment is discussed in Section 3.3, Test Design.

A minimum sample size of 1,500 students per field-test item was targeted for any given state. Most items were administered in two or more states. Table 20 to Table 22 present the number of item clusters and stand-alone items that were shared between the field-test pools of any two states. The numbers below the shaded diagonal elements represent the number of all administered field-test items, and the numbers above the shaded diagonal elements represent the number of common field-test items at the time of calibration. The shaded diagonal elements represent the number of field-test items administered only in the given state (with the number of unique field-test items at the time of calibration in parentheses). Table 20 presents the results for elementary schools, Table 21 presents the results for middle schools, and Table 22 presents the results for high schools. The numbers of field-test items administered were slightly different from the numbers of field-test items at calibration because some items were rejected during rubric validation.

Table 20. Common Elementary School Field-Test Items Administered and Calibrated, Spring 2021

	State	CT	HI	ID	MSSA[a]	MT	ND	NH	SD	UT	WV	WY
Item Clusters	CT	3 (3)	0	13	0	0	0	0	0	0	0	0
	HI	0	1 (1)	3	0	0	0	0	0	0	1	0
	ID	13	4	3 (2)	5	5	2	0	2	20	1	4
	MSSA	0	0	6	2 (2)	2	0	0	0	7	0	0
	MT	0	0	5	2	0 (0)	0	0	0	0	0	0
	ND	0	0	2	0	0	0 (0)	0	1	0	1	0
	NH	0	0	0	0	0	0	0 (0)	0	0	3	0
	SD	0	0	2	0	0	1	0	0 (0)	0	2	0
	UT	0	0	20	8	0	0	0	0	25 (24)	0	2
	WV	0	1	1	0	0	1	3	2	0	1 (1)	0
	WY	0	0	4	0	0	0	0	0	2	0	0 (0)
Stand-Alone Items	CT	3 (3)	0	14	2	0	0	0	0	0	0	1
	HI	0	0 (0)	12	1	0	0	2	3	0	1	0
	ID	14	12	3 (3)	30	13	4	3	3	0	4	9
	MSSA	2	1	30	0 (0)	12	0	3	1	0	0	0
	MT	0	0	13	12	0 (0)	0	0	0	0	0	0
	ND	0	0	4	0	0	0 (0)	2	0	0	0	1
	NH	0	2	4	3	0	2	0 (0)	2	0	3	1
	SD	0	3	3	1	0	0	2	0 (0)	0	0	0
	UT	0	0	0	0	0	0	0	0	0 (0)	0	0
	WV	0	1	4	0	0	1	3	0	0	3 (3)	0
	WY	1	0	9	0	0	1	1	0	0	0	0 (0)
Grade Band Total	CT	6 (6)	0	27	2	0	0	0	0	0	0	1
	HI	0	1 (1)	15	1	0	0	2	3	0	2	0
	ID	27	16	6 (5)	35	18	6	3	5	20	5	13

	State	CT	HI	ID	MSSA[a]	MT	ND	NH	SD	UT	WV	WY
	MSSA	2	1	36	2 (2)	14	0	3	1	7	0	0
	MT	0	0	18	14	0 (0)	0	0	0	0	0	0
	ND	0	0	6	0	0	0 (0)	2	1	0	1	1
	NH	0	2	4	3	0	2	0 (0)	2	0	6	1
	SD	0	3	5	1	0	1	2	0 (0)	0	2	0
	UT	0	0	20	8	0	0	0	0	25 (24)	0	2
	WV	0	2	5	0	0	2	6	2	0	4 (4)	0
	WY	1	0	13	0	0	1	1	0	2	0	0 (0)

Note. [a]MSSA = Rhode Island and Vermont's Multi-State Science Assessment

Table 21. Common Middle School Field-Test Items Administered and Calibrated, Spring 2021

	State	CT	HI	ID	MSSA[a]	MT	ND	NH	SD	UT	WV	WY
Item Clusters	CT	0 (0)	0	9	2	0	0	0	0	10	0	0
	HI	0	0 (0)	2	3	0	0	0	0	3	1	0
	ID	11	2	1 (1)	10	6	2	1	1	31	0	4
	MSSA	4	3	11	0 (0)	0	2	0	0	9	1	1
	MT	0	0	6	0	1 (1)	0	1	1	4	0	0
	ND	0	0	3	2	0	0 (0)	0	0	2	0	0
	NH	0	0	1	0	1	0	0 (0)	1	0	1	0
	SD	0	0	1	0	1	0	1	0 (0)	0	0	0
	UT	14	3	36	11	4	3	0	1	0 (0)	2	2
	WV	0	1	1	1	0	0	1	1	5	0 (0)	0
	WY	0	0	4	1	0	0	0	0	2	0	0 (0)
Stand-Alone Items	CT	2 (2)	0	12	2	0	0	0	3	0	0	2
	HI	0	0 (0)	10	1	0	0	0	0	0	2	0
	ID	13	10	2 (2)	29	10	6	12	7	0	5	15
	MSSA	2	1	29	0 (0)	10	2	1	1	0	2	4
	MT	0	0	12	10	0 (0)	0	0	0	0	0	0
	ND	0	0	7	2	0	0 (0)	1	0	0	0	0
	NH	0	0	12	1	0	1	0 (0)	2	0	1	3
	SD	3	0	7	1	0	0	2	0 (0)	0	3	4
	UT	0	0	0	0	0	0	0	0	0 (0)	0	0
	WV	0	2	6	3	0	1	1	3	0	0 (0)	0
	WY	2	0	15	4	0	0	3	4	0	0	0 (0)
Grade Band Total	CT	2 (2)	0	21	4	0	0	0	3	10	0	2
	HI	0	0 (0)	12	4	0	0	0	0	3	3	0
	ID	24	12	3 (3)	39	16	8	13	8	31	5	19

	State	CT	HI	ID	MSSA[a]	MT	ND	NH	SD	UT	WV	WY
	MSSA	6	4	40	0 (0)	10	4	1	1	9	3	5
	MT	0	0	18	10	1 (1)	0	1	1	4	0	0
	ND	0	0	10	4	0	0 (0)	1	0	2	0	0
	NH	0	0	13	1	1	1	0 (0)	3	0	2	3
	SD	3	0	8	1	1	0	3	0 (0)	0	3	4
	UT	14	3	36	11	4	3	0	1	0 (0)	2	2
	WV	0	3	7	4	0	1	2	4	5	0 (0)	0
	WY	2	0	19	5	0	0	3	4	2	0	0 (0)

Note. [a]MSSA = Rhode Island and Vermont's Multi-State Science Assessment

Table 22. Common High School Field-Test Items Administered and Calibrated, Spring 2021

	State	CT	HI	ID	MSSA[a]	MT	ND	NH	SD	UT	WV	WY
Item Clusters	CT	1 (1)	0	8	0	0	0	0	0	0	0	0
	HI	0	0 (0)	5	0	0	0	0	0	0	0	0
	ID	10	5	16 (15)	12	0	2	2	3	0	0	3
	MSSA	0	0	15	0 (0)	0	0	1	2	0	0	0
	MT	0	0	0	0	0 (0)	0	0	0	0	0	0
	ND	0	0	2	0	0	0 (0)	1	0	0	0	0
	NH	0	0	2	1	0	1	0 (0)	0	0	0	0
	SD	0	0	3	2	0	0	0	0 (0)	0	0	0
	UT	0	0	0	0	0	0	0	0	0 (0)	0	0
	WV	0	0	0	0	0	0	0	0	0	0 (0)	0
	WY	0	0	3	0	0	0	0	0	0	0	0 (0)
Stand-Alone Items	CT	3 (3)	0	31	3	0	0	0	0	0	0	1
	HI	0	0 (0)	11	1	0	0	0	0	0	0	0
	ID	31	11	9 (8)	24	0	7	4	5	0	0	14
	MSSA	3	1	25	0 (0)	0	0	3	4	0	0	1
	MT	0	0	0	0	0 (0)	0	0	0	0	0	0
	ND	0	0	7	0	0	0 (0)	1	0	0	0	0
	NH	0	0	4	3	0	1	0 (0)	0	0	0	0
	SD	0	0	5	4	0	0	0	0 (0)	0	0	1
	UT	0	0	0	0	0	0	0	0	0 (0)	0	0
	WV	0	0	0	0	0	0	0	0	0	0 (0)	0
	WY	1	0	15	1	0	0	0	1	0	0	0 (0)
Grade Band Total	CT	4 (4)	0	39	3	0	0	0	0	0	0	1
	HI	0	0 (0)	16	1	0	0	0	0	0	0	0
	ID	41	16	25 (23)	36	0	9	6	8	0	0	17

	State	CT	HI	ID	MSSA[a]	MT	ND	NH	SD	UT	WV	WY
	MSSA	3	1	40	0 (0)	0	0	4	6	0	0	1
	MT	0	0	0	0	0 (0)	0	0	0	0	0	0
	ND	0	0	9	0	0	0 (0)	2	0	0	0	0
	NH	0	0	6	4	0	2	0 (0)	0	0	0	0
	SD	0	0	8	6	0	0	0	0 (0)	0	0	1
	UT	0	0	0	0	0	0	0	0	0 (0)	0	0
	WV	0	0	0	0	0	0	0	0	0	0 (0)	0
	WY	1	0	18	1	0	0	0	1	0	0	0 (0)

Note. [a]MSSA = Rhode Island and Vermont's Multi-State Science Assessment

The calibration and linking of the field-test items in 2021 are explained in detail in Section 5.2, Item Calibration.

Table 23 presents the number of field-test items administered in Connecticut, or another state, the number of items rejected before or during rubric validation, the number of items sent for data review, and the number of items rejected during data review. The numbers in parentheses present the number of field-test items owned by Connecticut.

Table 23. Field-Test Item Administration, Rubric Validation, and Item Data Review, Spring 2021

Grade Band and Item Type	Number of Field-Test Items Administered	Number of Items Rejected Before/During Rubric Validation	Number of Items Sent to Data Review	Number of Items Rejected at Data Review	Number of Items Remaining[a]
Elementary School	**214 (28)**	**7 (0)**	**100 (15)**	**19 (4)**	**188 (24)**
Cluster	106 (11)	5 (0)	24 (3)	7 (1)	94 (10)
Stand-Alone	108 (17)	2 (0)	76 (12)	12 (3)	94 (14)
Middle School	**159 (24)**	**15 (4)**	**87 (7)**	**13 (1)**	**129 (19)**
Cluster	60 (14)	10 (3)	22 (2)	5 (0)	43 (11)
Stand-Alone	99 (10)	5 (1)	65 (5)	8 (1)	86 (8)
High School	**172 (49)**	**9 (2)**	**94 (29)**	**22 (7)**	**141 (40)**
Cluster	57 (11)	6 (2)	27 (3)	4 (1)	47 (8)
Stand-Alone	115 (38)	3 (0)	67 (26)	18 (6)	94 (32)
Total	**545 (101)**	**31 (6)**	**281 (51)**	**54 (12)**	**458 (83)**

Note. Connecticut-owned items are indicated in the parentheses.
[a]Two Hawaii-owned items were not shared to the Shared Science Assessment Item bank.

Table 24 summarizes the Shared Science Assessment Item Bank after adding the field-test items that were administered in 2021 and passed rubric validation and item data review. The numbers in parentheses present the number of items owned by Connecticut.

Table 24. Shared Science Assessment Item Bank, Spring 2021

Grade Band and Item Type	Science Discipline			Item Bank Total[a]
	Earth and Space Sciences	*Life Sciences*	*Physical Sciences*	
Elementary School	**136 (20)**	**128 (17)**	**149 (25)**	**413 (62)**
Cluster	65 (10)	66 (8)	76 (11)	207 (29)
Stand-Alone	71 (10)	62 (9)	73 (14)	206 (33)
Middle School	**114 (12)**	**156 (28)**	**137 (16)**	**407 (56)**
Cluster	55 (4)	76 (17)	67 (7)	198 (28)
Stand-Alone	59 (8)	80 (11)	70 (9)	209 (28)
High School	**68 (20)**	**163 (20)**	**106 (34)**	**337 (74)**
Cluster	27 (6)	64 (9)	42 (12)	133 (27)
Stand-Alone	41 (14)	99 (11)	64 (22)	204 (47)
Total	**318 (52)**	**447 (65)**	**392 (75)**	**1157 (192)**

Note. Connecticut-owned items are indicated in the parentheses.
[a]Two Hawaii-owned items were not shared to the Shared Science Assessment Item bank.

3.3 TEST DESIGN

The science tests were assembled under a LOFT test design, with the exception of the braille, paper-pencil, and remote forms. Tests were assembled using CAI's adaptive testing algorithm. The adaptive item selection algorithm selects items based on their content value and information value. At any given point during the test, the content value of an item is determined by its contribution to meeting the blueprint, given the content characteristics of the items that have already been administered. During the test, the content value increases for items that exhibit features that have not met their designated minimum as the end of the test approaches. Similarly, the content value decreases for items with content features for which the minimum has been met. The information value of an item is based on the item information function evaluated at the estimated proficiency. The proficiency estimate is updated throughout the test. Under a LOFT test design, the items are selected solely based on their contributions to meeting the blueprint by assigning a weight of zero to the information value of an item with respect to the underlying proficiency. The Connecticut NGSS Assessment blueprints are presented in Table 25 through Table 27. Details of CAI's item selection algorithm are described in Volume 2, Test Development and its Appendix J, Adaptive Algorithm Design. The braille and paper-pencil tests were accommodated fixed-forms. The remote forms were fixed-forms that allowed for assessing science among students taking the test remotely. They were fixed-forms to reduce the risk of the content of items being compromised. The form

construction of the accommodated and remote forms is discussed in Volume 2, Section 4.4, Paper-Pencil Accommodation Form Construction and Section 4.5, Remote Testing Form.

Table 25. Science Test Blueprint, Grade 5

Grade 5	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
Discipline—Physical Sciences, PE Total = 17	**2**	**2**	**4**	**4**	**6**	**6**
DCI—Motion and Stability: Forces and Interactions	**0**	**1**	**0**	**2**	**0**	**3**
3-PS2-1: Forces-balanced and unbalanced forces	0	1	0	1	0	1
3-PS2-2: Forces-pattern predicts future motion	0	1	0	1	0	1
3-PS2-3: Forces-between objects not in contact	0	1	0	1	0	1
3-PS2-4: Forces-magnets*	0	1	0	1	0	1
5-PS2-1: Space Systems	0	1	0	1	0	1
DCI—Energy	**0**	**1**	**0**	**2**	**0**	**3**
4-PS3-1: Energy-relationship between speed and energy of object	0	1	0	1	0	1
4-PS3-2: Energy-transfer of energy	0	1	0	1	0	1
4-PS3-3: Energy-changes in energy when objects collide	0	1	0	1	0	1
4-PS3-4: Energy-converting energy from one form to another*	0	1	0	1	0	1
5-PS3-1: Matter and Energy	0	1	0	1	0	1
DCI—Waves and Their Applications in Technologies for Information Transfer	**0**	**1**	**0**	**2**	**0**	**3**
4-PS4-1: Waves-waves can cause objects to move	0	1	0	1	0	1
4-PS4-2: Structure, Function, Information Processing	0	1	0	1	0	1
4-PS4-3: Waves-using patterns to transfer information*	0	1	0	1	0	1
DCI—Matter and Its Interactions	**0**	**1**	**0**	**2**	**0**	**3**
5-PS1-1: Structure and Properties of Matter	0	1	0	1	0	1
5-PS1-2: Structure and Properties of Matter	0	1	0	1	0	1
5-PS1-3: Structure and Properties of Matter	0	1	0	1	0	1

Grade 5	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
5-PS1-4: Structure and Properties of Matter	0	1	0	1	0	1
Discipline—Life Sciences, PE Total = 12	**2**	**2**	**4**	**4**	**6**	**6**
DCI—From Molecules to Organisms: Structure and Function	**0**	**1**	**0**	**2**	**0**	**3**
3-LS1-1: Inheritance	0	1	0	1	0	1
4-LS1-1: Structure, Function, Information Processing	0	1	0	1	0	1
4-LS1-2: Structure, Function, Information Processing	0	1	0	1	0	1
5-LS1-1: Matter and Energy	0	1	0	1	0	1
DCI—Ecosystems: Interactions, Energy, and Dynamics	**0**	**1**	**0**	**2**	**0**	**3**
3-LS2-1: Ecosystems	0	1	0	1	0	1
5-LS2-1: Matter and Energy	0	1	0	1	0	1
DCI—Inheritance and Variation of Traits	**0**	**1**	**0**	**2**	**0**	**3**
3-LS3-1: Inheritance	0	1	0	1	0	1
3-LS3-2: Inheritance	0	1	0	1	0	1
DCI—Biological Evolution: Unity and Diversity	**0**	**1**	**0**	**2**	**0**	**3**
3-LS4-1: Ecosystems	0	1	0	1	0	1
3-LS4-2: Inheritance	0	1	0	1	0	1
3-LS4-3: Ecosystems	0	1	0	1	0	1
3-LS4-4: Ecosystems*	0	1	0	1	0	1
Discipline—Earth and Space Sciences, PE Total = 13	**2**	**2**	**4**	**4**	**6**	**6**
DCI—Earth's Systems	**0**	**1**	**0**	**2**	**0**	**3**
3-ESS2-1: Weather and Climate	0	1	0	1	0	1
3-ESS2-2: Weather and Climate	0	1	0	1	0	1
4-ESS2-1: Earth's Systems and Processes	0	1	0	1	0	1

Grade 5	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
4-ESS2-2: Earth's Systems and Processes	0	1	0	1	0	1
5-ESS2-1: Earth's Systems	0	1	0	1	0	1
5-ESS2-2: Earth's Systems	0	1	0	1	0	1
DCI—Earth and Human Activity	**0**	**1**	**0**	**1**	**0**	**2**
3-ESS3-1: Weather and Climate*	0	1	0	1	0	1
4-ESS3-2: Earth's Systems and Processes*	0	1	0	1	0	1
4-ESS3-1: Energy	0	1	0	1	0	1
5-ESS3-1: Earth's Systems	0	1	0	1	0	1
DCI – Earth's Place in the Universe	**0**	**1**	**0**	**1**	**0**	**2**
4-ESS1-1: Earth's Systems and Processes	0	1	0	1	0	1
5-ESS1-1: Space Systems	0	1	0	1	0	1
5-ESS1-2: Space Systems	0	1	0	1	0	1
PE Total = 42	**6**	**6**	**12**	**12**	**18**	**18**

Note. *These PEs have an engineering component.

Table 26. Science Test Blueprint, Grade 8

Grade 8	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
Discipline—Physical Sciences, PE Total = 19	**2**	**2**	**4**	**4**	**6**	**6**
DCI—Matter and Its Interactions	**0**	**1**	**0**	**2**	**0**	**3**
MS-PS1-1: Structure and Properties of Matter	0	1	0	1	0	1
MS-PS1-2: Chemical Reactions	0	1	0	1	0	1
MS-PS1-3: Structure and Properties of Matter	0	1	0	1	0	1
MS-PS1-4: Structure and Properties of Matter	0	1	0	1	0	1
MS-PS1-5: Chemical Reactions	0	1	0	1	0	1
MS-PS1-6: Chemical Reactions*	0	1	0	1	0	1
DCI—Motion and Stability: Forces and Interactions	**0**	**1**	**0**	**2**	**0**	**3**
MS-PS2-1: Forces and Interactions*	0	1	0	1	0	1
MS-PS2-2: Forces and Interactions	0	1	0	1	0	1
MS-PS2-3: Forces and Interactions	0	1	0	1	0	1
MS-PS2-4: Forces and Interactions	0	1	0	1	0	1
MS-PS2-5: Forces and Interactions	0	1	0	1	0	1
DCI—Energy	**0**	**1**	**0**	**2**	**0**	**3**
MS-PS3-1: Energy	0	1	0	1	0	1
MS-PS3-2: Energy	0	1	0	1	0	1
MS-PS3-3: Energy*	0	1	0	1	0	1
MS-PS3-4: Energy	0	1	0	1	0	1
MS-PS3-5: Energy	0	1	0	1	0	1
DCI—Waves and Their Applications in Technologies for Information Transfer	**0**	**1**	**0**	**2**	**0**	**3**
MS-PS4-1: Waves and Electromagnetic Radiation	0	1	0	1	0	1

Grade 8	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
MS-PS4-2: Waves and Electromagnetic Radiation	0	1	0	1	0	1
MS-PS4-3: Waves and Electromagnetic Radiation	0	1	0	1	0	1
Discipline—Life Sciences, PE Total = 21	**2**	**2**	**4**	**4**	**6**	**6**
DCI—From Molecules to Organisms: Structures and Processes	**0**	**1**	**0**	**2**	**0**	**3**
MS-LS1-1: Structure, Function, Information Processing	0	1	0	1	0	1
MS-LS1-2: Structure, Function, Information Processing	0	1	0	1	0	1
MS-LS1-3: Structure, Function, Information Processing	0	1	0	1	0	1
MS-LS1-4: Growth, Development, Reproduction	0	1	0	1	0	1
MS-LS1-5: Growth, Development, Reproduction	0	1	0	1	0	1
MS-LS1-6: Matter and Energy	0	1	0	1	0	1
MS-LS1-7: Matter and Energy	0	1	0	1	0	1
MS-LS1-8: Structure, Function, Information Processing	0	1	0	1	0	1
DCI—Ecosystems: Interactions, Energy, and Dynamics	**0**	**1**	**0**	**2**	**0**	**3**
MS-LS2-1: Matter and Energy	0	1	0	1	0	1
MS-LS2-2: Interdependent Relationships in Ecosystems	0	1	0	1	0	1
MS-LS2-3: Matter and Energy	0	1	0	1	0	1
MS-LS2-4: Matter and Energy	0	1	0	1	0	1
MS-LS2-5: Interdependent Relationships in Ecosystems*	0	1	0	1	0	1
DCI—Heredity: Inheritance and Variation of Traits	**0**	**1**	**0**	**2**	**0**	**3**
MS-LS3-1: Growth, Development, Reproduction	0	1	0	1	0	1
MS-LS3-2: Growth, Development, Reproduction	0	1	0	1	0	1

Grade 8	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
DCI—Biological Evolution: Unity and Diversity	**0**	**1**	**0**	**2**	**0**	**3**
MS-LS4-1: Natural Selection and Adaptation	0	1	0	1	0	1
MS-LS4-2: Natural Selection and Adaptation	0	1	0	1	0	1
MS-LS4-3: Natural Selection and Adaptation	0	1	0	1	0	1
MS-LS4-4: Natural Selection and Adaptation	0	1	0	1	0	1
MS-LS4-5: Growth, Development, Reproduction	0	1	0	1	0	1
MS-LS4-6: Natural Selection and Adaptation	0	1	0	1	0	1
Discipline—Earth and Space Sciences, PE Total = 15	**2**	**2**	**4**	**4**	**6**	**6**
DCI—Earth's Place in the Universe	**0**	**1**	**0**	**1**	**0**	**2**
MS-ESS1-1: Space Systems	0	1	0	1	0	1
MS-ESS1-2: Space Systems	0	1	0	1	0	1
MS-ESS1-3: Space Systems	0	1	0	1	0	1
MS-ESS1-4: History of Earth	0	1	0	1	0	1
DCI—Earth's Systems	**0**	**1**	**0**	**2**	**0**	**3**
MS-ESS2-1: Earth's Systems	0	1	0	1	0	1
MS-ESS2-2: History of Earth	0	1	0	1	0	1
MS-ESS2-3: History of Earth	0	1	0	1	0	1
MS-ESS2-4: Earth's Systems	0	1	0	1	0	1
MS-ESS2-5: Weather and Climate	0	1	0	1	0	1
MS-ESS2-6: Weather and Climate	0	1	0	1	0	1
DCI—Earth and Human Activity	**0**	**1**	**0**	**1**	**0**	**2**
MS-ESS3-1: Earth's Systems	0	1	0	1	0	1
MS-ESS3-2: Human Impacts	0	1	0	1	0	1
MS-ESS3-3: Human Impacts*	0	1	0	1	0	1

Grade 8	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
MS-ESS3-4: Human Impacts	0	1	0	1	0	1
MS-ESS3-5: Weather and Climate	0	1	0	1	0	1
PE Total = 55	**6**	**6**	**12**	**12**	**18**	**18**

Note. *These PEs have an engineering component.

Table 27. Science Test Blueprint, Grade 11

Grade 11	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
Discipline—Physical Sciences, PE Total = 24	**2**	**2**	**4**	**4**	**6**	**6**
DCI—Matter and Its Interactions	**0**	**1**	**0**	**2**	**0**	**3**
HS-PS1-1: Structure and Properties of Matter	0	1	0	1	0	1
HS-PS1-2: Structure and Properties of Matter	0	1	0	1	0	1
HS-PS1-3: Structure and Properties of Matter	0	1	0	1	0	1
HS-PS1-4: Chemical Reactions	0	1	0	1	0	1
HS-PS1-5: Chemical Reactions	0	1	0	1	0	1
HS-PS1-6: Chemical Reactions*	0	1	0	1	0	1
HS-PS1-7: Chemical Reactions	0	1	0	1	0	1
HS-PS1-8: Nuclear Processes	0	1	0	1	0	1
DCI—Motion and Stability: Forces and Interactions	**0**	**0**	**0**	**2**	**0**	**2**
HS-PS2-1: Forces and Motion	0	0	0	1	0	1
HS-PS2-2: Forces and Motion	0	0	0	1	0	1
HS-PS2-3: Forces and Motion*	0	0	0	1	0	1
HS-PS2-4: Types of Interactions	0	0	0	1	0	1
HS-PS2-5: Types of Interactions	0	0	0	1	0	1
HS-PS2-6: Chemical Reactions*	0	0	0	1	0	1
DCI—Energy	**0**	**1**	**0**	**2**	**0**	**3**
HS-PS3-1: Energy	0	1	0	1	0	1
HS-PS3-2: Energy	0	1	0	1	0	1
HS-PS3-3: Energy*	0	1	0	1	0	1
HS-PS3-4: Energy	0	1	0	1	0	1
HS-PS3-5: Energy	0	1	0	1	0	1

Grade 11	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
DCI—Waves and Their Applications in Technologies for Information Transfer	**0**	**0**	**0**	**2**	**0**	**2**
HS-PS4-1: Wave Properties	0	0	0	1	0	1
HS-PS4-2: Wave Properties	0	0	0	1	0	1
HS-PS4-3: Wave Properties/Electromagnetic Radiation	0	0	0	1	0	1
HS-PS4-4: Electromagnetic Radiation	0	0	0	1	0	1
HS-PS4-5: Electromagnetic Radiation*	0	0	0	1	0	1
Discipline—Life Sciences, PE Total = 24	**2**	**2**	**4**	**4**	**6**	**6**
DCI—From Molecules to Organisms: Structures and Processes	**0**	**1**	**0**	**2**	**0**	**3**
HS-LS1-1: Structure and Function	0	1	0	1	0	1
HS-LS1-2: Structure and Function	0	1	0	1	0	1
HS-LS1-3: Structure and Function	0	1	0	1	0	1
HS-LS1-4: Growth and Development of Organisms	0	1	0	1	0	1
HS-LS1-5: Organization for Matter and Energy Flow in Organisms	0	1	0	1	0	1
HS-LS1-6: Organization for Matter and Energy Flow in Organisms	0	1	0	1	0	1
HS-LS1-7: Organization for Matter and Energy Flow in Organisms	0	1	0	1	0	1
DCI—Ecosystems: Interactions, Energy, and Dynamics	**0**	**1**	**0**	**2**	**0**	**3**
HS-LS2-1: Interdependent Relationships in Ecosystems	0	1	0	1	0	1
HS-LS2-2: Interdependent Relationships in Ecosystems	0	1	0	1	0	1
HS-LS2-3: Cycles of Matter and Energy Transfer in Ecosystems	0	1	0	1	0	1

Grade 11	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
HS-LS2-4: Cycles of Matter and Energy Transfer in Ecosystems	0	1	0	1	0	1
HS-LS2-5: Cycles of Matter and Energy Transfer in Ecosystems	0	1	0	1	0	1
HS-LS2-6: Ecosystem Dynamics, Functioning, and Resilience	0	1	0	1	0	1
HS-LS2-7: Ecosystem Dynamics, Functioning, and Resilience*	0	1	0	1	0	1
HS-LS2-8: Social Interactions and Group Behavior	0	1	0	1	0	1
DCI—Heredity: Inheritance and Variation of Traits	**0**	**1**	**0**	**1**	**0**	**2**
HS-LS3-1: Structure and Function	0	1	0	1	0	1
HS-LS3-2: Variation of Traits	0	1	0	1	0	1
HS-LS3-3: Variation of Traits	0	1	0	1	0	1
DCI—Biological Evolution: Unity and Diversity	**0**	**1**	**0**	**2**	**0**	**3**
HS-LS4-1: Evidence of Common Ancestry and Diversity	0	1	0	1	0	1
HS-LS4-2: Natural Selection	0	1	0	1	0	1
HS-LS4-3: Natural Selection	0	1	0	1	0	1
HS-LS4-4: Adaptation	0	1	0	1	0	1
HS-LS4-5: Adaptation	0	1	0	1	0	1
HS-LS4-6: Adaptation*	0	1	0	1	0	1
Discipline—Earth and Space Sciences, PE Total = 19	**2**	**2**	**4**	**4**	**6**	**6**
DCI—Earth's Place in the Universe	**0**	**0**	**0**	**1**	**0**	**1**
HS-ESS1-1: The Universe and Its Stars	0	0	0	1	0	1
HS-ESS1-2: The Universe and Its Stars	0	0	0	1	0	1
HS-ESS1-3: The Universe and Its Stars	0	0	0	1	0	1

Grade 11	Min Item Clusters	Max Item Clusters	Min Stand-Alone Items	Max Stand-Alone Items	Min Item Clusters + Min Stand-Alone Items	Max Item Clusters + Max Stand-Alone Items
HS-ESS1-4: Earth and the Solar System	0	0	0	1	0	1
HS-ESS1-5: The History of Planet Earth	0	0	0	1	0	1
HS-ESS1-6: The History of Planet Earth	0	0	0	1	0	1
DCI—Earth's Systems	**0**	**1**	**0**	**2**	**0**	**3**
HS-ESS2-1: Earth Materials and Systems	0	1	0	1	0	1
HS-ESS2-2: Earth Materials and Systems	0	1	0	1	0	1
HS-ESS2-3: Earth Materials and Systems	0	1	0	1	0	1
HS-ESS2-4: Weather and Climate	0	1	0	1	0	1
HS-ESS2-5: The Roles of Water in Earth's Surface Processes	0	1	0	1	0	1
HS-ESS2-6: Weather and Climate	0	1	0	1	0	1
HS-ESS2-7: Weather and Climate	0	1	0	1	0	1
DCI—Earth and Human Activity	**0**	**1**	**0**	**2**	**0**	**3**
HS-ESS3-1: Natural Resources	0	1	0	1	0	1
HS-ESS3-2: Natural Resources*	0	1	0	1	0	1
HS-ESS3-3: Human Impacts on Earth Systems	0	1	0	1	0	1
HS-ESS3-4: Human Impacts on Earth Systems*	0	1	0	1	0	1
HS-ESS3-5: Global Climate Change	0	1	0	1	0	1
HS-ESS3-6: Global Climate Change*	0	1	0	1	0	1
PE Total = 67	**6**	**6**	**12**	**12**	**18**	**18**

Note. *These PEs have an engineering component.

The main characteristics of the blueprint were that any performance expectation (PE) could be tested only once (indicated by the values of 0 and 1 for the minimum and maximum values of the individual PEs in Table 25 through Table 27). In general, no more than one item cluster or two stand-alone items could be sampled from the same Disciplinary Core Idea (DCI), and no more than three total items could be sampled from the same DCI (as indicated by the minimum and maximum values in the rows representing DCIs). Some specific constraints for the Connecticut NGSS Assessment blueprint were that for grades 5 and 8, students would get two stand-alone items from the Earth Systems DCI (rather than one for other DCIs in the Earth and Space Sciences discipline) because it had the most PEs and was rated the highest in the district responses. In addition, three DCIs in grade 11—Motion and Stability, Waves, and Earth's Place in the Universe—were constrained to not receive an item cluster due to low content priority ratings from districts.

A segmented test design was used for the 2018 independent field test; items were administered grouped by science discipline. In 2019, a non-segmented test design was used for the first operational test administration; items were no longer grouped by science discipline. Instead, students received items from different disciplines in random order. Embedded field-test items were randomly positioned in the test and randomly distributed across students. Every student received either one item cluster or five stand-alone items as field-test items throughout the test. In 2021, a similar non-segmented test design with embedded field-test items was used. The only difference in 2021 was that every student received either one item cluster or four stand-alone items as field-test items throughout the test.

4. FIELD-TEST CLASSICAL ANALYSIS OVERVIEW

As explained in Section 3, Item Bank and Test Design, science items administered as field-test items underwent rubric validation and data review. Items were flagged for data review based on business rules defined on classical item statistics. Except for response times, the classical item statistics are computed for individual assertions, whereas the business rules for flagging are defined at the item level. In general, item statistics used to flag items for data review were computed using the student responses of the state that owned the items. However, for ICCR items, the flagging rules were defined on the item statistics computed from the combined data of states that used ICCR items and administered either an independent or operational test. In 2021, those states were Connecticut, Hawaii, Idaho, Montana, New Hampshire, North Dakota, South Dakota, Rhode Island, Utah, Vermont, and West Virginia. Furthermore, to compute the DIF statistics for the field-test items, the data from all states with an operational or independent field test were combined to obtain enough students for each demographic group. The criteria for flagging and reviewing items are provided in Table 28, and the statistics are described below in Section 4.1, Item Discrimination, through Section 4.4, Differential Item Functioning Analysis. Items flagged for data review were reviewed by a committee, as explained in Section 3, Item Bank and Test Design.

Table 28. Thresholds for Flagging in Classical Item Analysis

Analysis Type	Flagging Criteria
Item Discrimination	Average biserial correlation < 0.25 (across the assertions within an item)
	One or more assertions with a biserial correlation < 0.05
Item Difficulty (Clusters)	Average *p*-value < 0.30 or > 0.85 (across the assertions within a cluster)
Item Difficulty (Stand-Alone Items)	Average *p*-value < 0.15 or > 0.95 (across the assertions within a stand-alone item)
Timing (Clusters)	Percentile 80* > 15 minutes
Timing (Stand-Alone Items)	Percentile 80* > 3 minutes
Timing	Assertions per minute < 0.5
DIF (Clusters)	Two or more assertions show "C" DIF in the same direction
DIF (Stand-Alone Items)	One or more assertions show "C" DIF in the same direction

Note. *A percentile 80 of *x* minutes: 80% of the students spent *x* minutes or less on the item.

4.1 ITEM DISCRIMINATION

The item discrimination index indicates the extent to which each item differentiated between those test takers who possessed the skills being measured and those who did not. Generally, the higher the value, the better the item was able to differentiate between high- and low-achieving students.

For each assertion within an item, the discrimination index was calculated as the biserial correlation between the assertion score and the ability estimate for students. The average biserial correlation was then calculated across the assertions within an item.

4.2 ITEM DIFFICULTY

Items that are either very difficult or very easy are flagged for review but are not necessarily removed from the item bank if they are grade-level appropriate and aligned with the test specifications. Both the *p*-value for individual assertions and the average across all assertions of an item are calculated. Acceptable item *p*-values are summarized in Table 28.

4.3 RESPONSE TIME

Given that the science item clusters consisted of multiple student interactions, they required more time for students to complete. Item response time was recorded and analyzed to ensure a good balance between the amount of information an item provides and the time students spent on the item. Specifically, the statistic "percentile 80" was computed for each item. A percentile 80 of *x* minutes means that 80% of the students spent *x* minutes or fewer on the item. An item was flagged for review when the

- percentile 80 > 15 minutes, if the item is an item cluster;
- percentile 80 > 3 minutes, if the item is a stand-alone item; or

- assertions per (percentile 80) minute < 0.5.

4.4 DIFFERENTIAL ITEM FUNCTIONING ANALYSIS

DIF refers to items that appear to function differently across identifiable groups, typically across different demographic groups. Identifying DIF is important because it provides a statistical indicator that an item may contain cultural or other biases. DIF-flagged items are further examined by content experts who are asked to re-examine each flagged item to decide whether the item should be excluded from the pool due to bias. Not all items that exhibit DIF are biased, and various characteristics of the educational system may also lead to DIF.

CAI uses a generalized Mantel-Haenszel (MH) procedure to calculate DIF. The generalizations include adaptation to polytomous items and improved variance estimators to render the test statistics valid under complex sample designs. With this procedure, each student's estimated theta score on the operational items on a given test is used as the ability-matching variable. That score is divided into 10 intervals to compute the $MH\chi^2$ DIF statistics for balancing the stability and sensitivity of the DIF scoring category selection. The analysis program computes the $MH\chi^2$ value, the conditional odds ratio, and the MH-delta for dichotomous items; the $GMH\chi^2$ and the standardized mean difference (SMD [Dorans & Schmitt, 1991]) are computed for polytomous items.

The MH chi-square statistic (Holland & Thayer, 1988) is calculated as:

$$MH\chi^2 = \frac{(|\sum_k n_{R1k} - \sum_k E(n_{R1k})| - 0.5)^2}{\sum_k var(n_{R1k})},$$

where $k = \{1, 2, \ldots K\}$ for the strata, n_{R1k} is the number of correct responses for the reference group in stratum k, and 0.5 is a continuity correction. The expected value is calculated as

$$E(n_{R1k}) = \frac{n_{+1k} n_{R+k}}{n_{++k}},$$

where n_{+1k} is the total number of correct responses, n_{R+k} is the number of students in the reference group, and n_{++k} is the number of students in stratum k. The variance is calculated as

$$var(n_{R1k}) = \frac{n_{R+k} n_{F+k} n_{+1k} n_{+0k}}{n_{++k}^2 (n_{++k} - 1)},$$

where n_{F+k} is the number of students in the focal group, n_{+1k} is the number of students with correct responses, and n_{+0k} is the number of students with incorrect responses in stratum k.

The MH conditional odds ratio is calculated as

$$\alpha_{MH} = \frac{\sum_k n_{R1k} n_{F0k} / n_{++k}}{\sum_k n_{R0k} n_{F1k} / n_{++k}}.$$

The MH-delta (Δ_{MH} [Holland & Thayer, 1988]) is then defined as

$$\Delta_{MH} = -2.35 \ln(\alpha_{MH}).$$

The generalized MH statistic generalizes the MH statistic to polytomous items (Somes, 1986), and is defined as

$$GMH\chi^2 = (\sum_k \boldsymbol{a}_k - \sum_k E(\boldsymbol{a}_k))'(\sum_k var(\boldsymbol{a}_k))^{-1}(\sum_k \boldsymbol{a}_k - \sum_k E(\boldsymbol{a}_k)),$$

where $\boldsymbol{a}_k$ is a $(T-1)\ X\ 1$ vector of item response scores, corresponding to the T response categories of a polytomous item (excluding one response). $E(\boldsymbol{a}_k)$ and $var(\boldsymbol{a}_k)$, a $(T-1) \times (T-1)$ variance matrix, are calculated analogously to the corresponding elements in $MH\chi^2$ in stratum k.

The SMD (Dorans & Schmitt, 1991) is defined as

$$SMD = \sum_k p_{FK} m_{FK} - \sum_k p_{FK} m_{RK},$$

where

$$p_{FK} = \frac{n_{F+k}}{n_{F++}}$$

is the proportion of the focal group students in stratum k,

$$m_{FK} = \frac{1}{n_{F+k}}\left(\sum_t a_t n_{Ftk}\right)$$

is the mean item score for the focal group in stratum k, and

$$m_{RK} = \frac{1}{n_{R+k}}\left(\sum_t a_t n_{Rtk}\right)$$

is the mean item score for the reference group in stratum k.

DIF analysis was conducted for all field-test items with at least 200 responses per item in each subgroup (Zwick, 2012) to detect potential item bias for major demographic groups. Student responses from multiple states were combined to minimize the number of items with insufficient sample sizes for one or more demographic groups.

DIF statistics were calculated at the assertion level and were performed for the following groups (some items had insufficient sample sizes for DIF analyses in some groups):

- Female vs. Male
- American Indian/Alaskan Native vs. White
- Asian vs. White
- African American vs. White
- Hawaiian/Pacific Islander vs. White
- Hispanic vs. White

- Multi-Racial vs. White
- English Learner (EL) vs. Non-EL
- Special Education (SPED) vs. Non-SPED
- Economically Disadvantaged vs. Non-Economically Disadvantaged

Similar to how the general MH statistic is used to classify items on traditional tests, assertions were classified into three categories (i.e., A, B, or C) for DIF, ranging from "no evidence of DIF" to "severe DIF." The classification rules are shown in Table 29. Furthermore, assertions were categorized positively (i.e., +A, +B, or +C), signifying that an item favored the focal group (e.g., African American/Black, Hispanic, female), or negatively (i.e., –A, –B, or –C), signifying that an item favored the reference group (e.g., white or male).

An item was flagged for data review according to the following criteria:

- **Item Clusters.** Two or more assertions showed "C" DIF in the same direction.
- **Stand-Alone Items.** One or more assertions showed "C" DIF in the same direction.

Table 29. DIF Classification Rules

Assertions

Category	*Rule*
C	MH_{X^2} is significant and $\lvert SMD\rvert/\lvert SD\rvert \geq 0.25$
B	MH_{X^2} is significant and $\lvert SMD\rvert/\lvert SD\rvert < 0.25$
A	MH_{X^2} is not significant

Note that, for the 2018 field test, a slightly less strict criterion was used for item clusters with 10 or more assertions (i.e., three or more assertions with "C" DIF in the same direction). The change was made taking into consideration the feedback received from several Technical Advisory Committees (TACs) and modified such that the rate of flagging items for DIF was similar for item clusters and stand-alone items (based on the flagging rates computed on items field-tested in 2018).

4.5 Classical Analysis Results

This section presents a summary of results from classical item analysis of the field-test items administered in 2021. Table 30 and Table 31 provide the summary of the *p*-values and biserial correlations for the science field-test items administered in Connecticut in 2021. The statistics were computed using Connecticut data only. The average values across the assertions within an item were used to compute percentiles and ranges.

Table 30. Distribution of p-*Values for Field-Test Items, Spring 2021*

Grade	Total FT Items	Min	5th Percentile	25th Percentile	50th Percentile	75th Percentile	95th Percentile	Max
5	36	0.20	0.25	0.33	0.45	0.56	0.63	0.71
8	27	0.06	0.10	0.24	0.39	0.48	0.57	0.68
11	47	0.04	0.10	0.24	0.35	0.48	0.59	0.63

Table 31. Distribution of Item Biserial Correlations for Field-Test Items, Spring 2021

Grade	Total FT Items	Min	5th Percentile	25th Percentile	50th Percentile	75th Percentile	95th Percentile	Max
5	36	0.15	0.16	0.40	0.45	0.53	0.62	0.75
8	27	0.13	0.21	0.34	0.43	0.52	0.59	0.66
11	47	0.10	0.15	0.33	0.43	0.53	0.65	0.74

Table 32 presents the summary of the response times by item type (item cluster or stand-alone item) for field-test items administered in 2021.

Table 32. Summary of Response Times for Field-Test Items, Spring 2021

Grade	Item Type	Total FT Items	Min	25th Percentile	50th Percentile	75th Percentile	Max
5	Cluster	16	7.90	8.38	9.30	11.70	14.00
	Stand-Alone	20	1.80	2.48	2.90	3.93	4.60
8	Cluster	12	7.10	9.05	9.70	9.98	13.90
	Stand-Alone	15	2.20	2.55	3.00	3.65	5.00
11	Cluster	9	6.10	7.20	10.40	11.50	13.10
	Stand-Alone	38	1.60	2.40	2.90	3.58	8.60

Table 33 presents the number of field-test items flagged for DIF for each item type and demographic group included in the DIF analyses in 2021.

Table 33. Differential Item Functioning Classifications for Field-Test Items, Spring 2021

DIF Flag	Item Type	Female/ Male	American Indian[a]/ White	Asian/ White	African American / White	Hawaiian [b]/ White	Hispanic/ White	Multi-Racial/ White	EL/ Non-EL	SPED/ Non-SPED	Low Income/ Non-Low Income[c]
Grade 5											
Items Evaluated	Cluster	16	0	0	1	0	16	0	13	16	16
	Stand-Alone	20	0	0	11	0	20	0	16	20	20
Items Flagged C	Cluster	0	-	-	0	-	0	-	0	0	0
	Stand-Alone	0	-	-	0	-	0	-	0	0	0
% Items Flagged C	Cluster	0	-	-	0	-	0	-	0	0	0
	Stand-Alone	0	-	-	0	-	0	-	0	0	0
Grade 8											
Items Evaluated	Cluster	12	0	0	9	0	12	1	10	12	12
	Stand-Alone	15	1	0	9	0	15	0	12	15	15
Items Flagged C	Cluster	0	-	-	0	-	0	0	0	0	0
	Stand-Alone	0	0	-	0	-	0	-	0	0	0
% Items Flagged C	Cluster	0	-	-	0	-	0	0	0	0	0
	Stand-Alone	0	0	-	0	-	0	-	0	0	0
Grade 11											
Items Evaluated	Cluster	9	0	0	0	0	9	0	0	8	9
	Stand-Alone	38	0	0	2	0	38	0	17	34	38
Items Flagged C	Cluster	0	-	-	-	-	0	-	-	0	0
	Stand-Alone	1	-	-	0	-	0	-	0	0	0
	Cluster	0	-	-	-	-	0	-	-	0	0

DIF Flag	Item Type	Female/ Male	American Indian[a]/ White	Asian/ White	African American / White	Hawaiian [b]/ White	Hispanic/ White	Multi-Racial/ White	EL/ Non-EL	SPED/ Non-SPED	Low Income/ Non-Low Income[c]
% Items Flagged C	Stand-Alone	3	-	-	0	-	0	-	0	0	0

Note. Full DIF group names: [a]American Indian/Alaskan Native; [b]Hawaiian/Pacific Islander; [c]Economically Disadvantaged vs. Non-Economically Disadvantaged

In 2021, 118 field-test items were administered in Connecticut; 110 passed rubric validation. Among these 110 items, 13 were flagged for item discrimination, 16 items were flagged for *p*-value, 48 items were flagged for response time, and one item was flagged for DIF according to the criteria used in 2021 (as described in Section 4.1, Item Discrimination, through Section 4.4, Differential Item Functioning Analysis). Some items were flagged for multiple reasons. Flagged field-test items were reviewed by educators during data review. The total number of field-test items flagged and the total number of field-test items that passed item data review in 2021 were summarized in Table 23.

5. ITEM CALIBRATION

5.1 MODEL DESCRIPTION

In discussing item response theory (IRT) models for Connecticut, we distinguish between the underlying latent structure of a model and the parameterization of the item response function conditional on that assumed latent structure. Subsequently, we discuss how group effects are considered.

5.1.1 Latent Structure

Most operational assessment programs rely on a unidimensional IRT model for item calibration and computing scores for students. These models assume a single underlying trait and that items are independent given that underlying trait. In other words, the models assume that given the value of the underlying trait, knowing the response to one item provides no information about responses to other items. This assumption of conditional independence implies that the conditional probability of a pattern of I item responses takes the relatively simple form of a product over items for a single student, as shown below:

$$P(\boldsymbol{z_j}|\theta_j) = \prod_{i=1}^{I} P(z_{ij}|\theta_j) \quad (1)$$

where z_{ij} represents the scored response of student j $(j = 1, \ldots, N)$ to item i $(I = 1, \ldots, I)$, $\boldsymbol{z}_j$ represents the pattern of scored item responses for student j, and θ_j represents student j's proficiency. Unidimensional IRT models differ with respect to the functional relation between the proficiency θ_j and the probability of obtaining a score z_{ij} on item i.

Connecticut NGSS Assessment items are more complex than traditional item types. A single item may contain multiple parts, and each part may contain multiple student interactions. For example, a student may be asked to select a term from a set of terms at several places in a single item. Instead of receiving a single score for each item, multiple inferences are made about the knowledge and skills that a student has demonstrated based on specific features of the student's responses to the item. These scoring units are called *assertions* and are the basic unit of analysis in our IRT analysis. That is, they fulfill the role of items in traditional assessments; however, for the Connecticut NGSS

Assessment items, multiple assertions are typically developed around a single item so that assertions are clustered within items.

One approach is to apply one of the traditional IRT models to the scored assertions; however, a substantial complexity that arises from using this new item type is that local dependencies exist between assertions pertaining to the same stimulus (i.e., item or item cluster). The local dependencies between the assertions pertaining to the same stimulus constitute a violation of the assumption that a single latent trait can explain all dependencies between assertions. Fitting a unidimensional model in the presence of local dependencies may result in biased item parameters and standard errors of measurement (SEMs). In particular, it is well documented that ignoring local item dependencies leads to an overestimation of the amount of information conveyed by a set of responses and an underestimation of the SEM (e.g., Sireci, Thissen, & Wainer, 1991; Yen, 1993).

The effects of groups of assertions developed around a common stimulus can be accounted for by including additional dimensions corresponding to those groupings in the IRT model. These dimensions are considered to be nuisance dimensions[1]. Whereas traditional unidimensional IRT models assume that all assertions (the basic units of analysis) are independent given a single underlying trait θ, we now assume the conditional independence of assertions, given the underlying latent trait θ and all nuisance dimensions:

$$P(\boldsymbol{z_j}|\theta_j, \mathbf{u}_j) = \prod_{i \in \mathrm{SA}} P(z_{ij}|\theta_j) \prod_{g=1}^{G} \prod_{i \in g} P(z_{ij}|\theta_j, u_{jg}) \qquad (2)$$

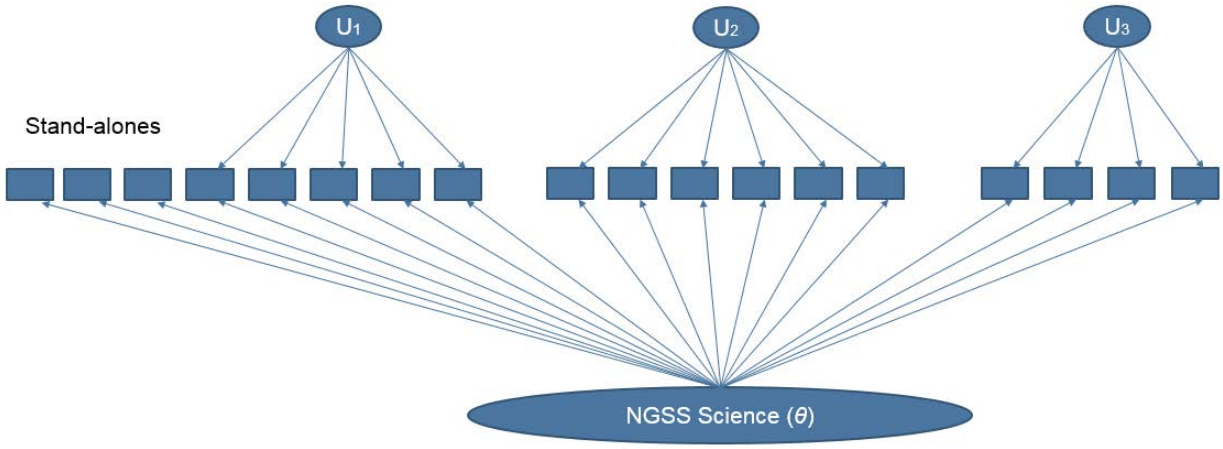
where SA indicates stand-alone item assertions, u_g indicates the nuisance dimension for assertion group g (with the position of student j on that dimension denoted as u_{jg}), and $\mathbf{u}$ is the vector of all G nuisance dimensions. It can be seen that the conditional probability $P(z_{ij}|\theta_j, u_{jg})$ becomes a function of two latent variables: the latent trait θ, representing a student's proficiency in science (the underlying trait of interest), and the nuisance dimension u_g, accounting for the conditional dependencies between assertions of the same group. Furthermore, we assume that the nuisance dimensions are all uncorrelated with one another and with the general dimension. It is important to point out that even though every group of assertions introduces an additional dimension, models with this latent structure do not suffer from the complications of dimensionality like other multidimensional IRT models because one can take advantage of this special structure during model calibration (Gibbons & Hedeker, 1992). In this regard, Rijmen (2010) showed that it is unnecessary to assume all nuisance dimensions are uncorrelated; instead, it is sufficient that they are independent, given the general dimension θ.

The model structure of the IRT model for science is illustrated in Figure 1. Note that stand-alone items can be scored with more than one assertion. The assertions of stand-alone items with more than one assertion, but fewer than four assertions, were also modeled as stand-alone item assertions.

[1] The term *nuisance dimension* here pertains to within-item local dependencies among scoring assertions and should not be confused with the three dimensions of the NGSS Framework.

Even though these assertions are likely to exhibit conditional dependencies, the variance of the nuisance dimension cannot be reliably estimated if it is based on a very small number of assertions. The few stand-alone items with four or more assertions were treated as item clusters to take into account the conditional dependencies.

Figure 1. Directed Graph of the Science IRT Model



5.1.2 Item Response Function

The item response functions of the stand-alone item assertions are modeled with a unidimensional model. For the grouped assertions, like in unidimensional models, different parametric forms can be assumed for the conditional probability of obtaining a score of z_{ij}. The Rasch testlet model is adopted as the IRT model for the Connecticut NGSS Assessment (Wang & Wilson, 2005). For binary data, the Rasch testlet model is defined as:

$$P\left(z_{ij}|\theta_j, u_{jg}; b_i\right) = \frac{\exp\left(\theta_j + u_{jg} - b_i\right)}{1 + \exp\left(\theta_j + u_{jg} - b_i\right)} \quad (3)$$

The item response function of the Rasch testlet model models the probability of a correct answer (i.e., a true assertion), as a function of the overall proficiency θ, the nuisance dimension u_g, and the item (i.e., assertion) difficulty b_i. The Rasch testlet model does not include item discrimination parameters; however, the same model structure as presented in Figure 1 could be employed with discrimination parameters included in Equations (2) and (3). Furthermore, only models for binary data are considered. Assertions are always binary because they are either true or false. Nevertheless, the model could easily accommodate polytomous responses by using the same response function incorporated in unidimensional models for polytomous data.

5.1.3 Multigroup Model

The Shared Science Assessment Item Bank was calibrated concurrently using all the items administered in any state that collaborates with CAI on their new science assessments. In the calibration, each state was treated as a population of students or a group. Overall group differences were taken into account by allowing a group-specific distribution of the overall proficiency variable θ. Specifically, for every student j belonging to group k, $k = 1, \ldots, K$, a normal distribution was assumed,

$$\theta_j \sim N(\mu_k, \sigma_k^2),$$

where μ_k and σ_k^2 are the mean and variance of a normal distribution. The mean of the reference distribution ($k = 1$) was set to 1 to identify the model. For each of the nuisance variables u_g, a common variance parameter across groups was assumed, and the means were set to 0 in order to identify the model,

$$u_{jg} \sim N\left(0, \sigma_{u_g}^2\right).$$

5.2 ITEM CALIBRATION

5.2.1 Estimation

A separate IRT model was fit for each grade band. The parameters of the IRT model were estimated using the marginal maximum likelihood (MML) method. In the MML method, the latent proficiency variable θ_j and the vector of nuisance parameters $\boldsymbol{u}_j$ for each student j are treated as random effects and integrated out to obtain the marginal log likelihood corresponding to the observed response pattern $\boldsymbol{z}_j$ for student j,

$$\ell_j = \log \int \int P\left(\boldsymbol{z}_j | \theta_j, \boldsymbol{u}_j\right) N\left(\theta_j | \mu_k, \sigma_k^2\right) N\left(\boldsymbol{u}_j | \boldsymbol{0}, \boldsymbol{\Sigma}\right) d\boldsymbol{u}_j d\theta_j,$$

where $\boldsymbol{\Sigma}$ is a diagonal matrix with diagonal elements $\sigma_{u_k}^2$. Across all students and groups, the overall log likelihood to be maximized with respect to the vector $\boldsymbol{\gamma}$ of all model parameters (i.e., item difficulty parameters and the mean and variance parameters of the latent variables) is

$$\ell(\boldsymbol{\gamma}) = \sum_k \sum_{j \in k} \ell_j.$$

Even though the number of latent variables in the equation above is very high, issues with dimensionality can be avoided because the integration over the high-dimensional latent $(\theta, \boldsymbol{u})$ space can be carried out as a sequence of computations in two-dimensional space $(\theta, \boldsymbol{u_g})$ (Gibbons & Hedeker, 1992; Rijmen, 2010).

The Shared Science Assessment Item Bank was calibrated in 2018 after the 2018 science test administrations concluded, and it was recalibrated in 2019 following the 2019 test administrations. The scores reported in 2019 were computed using the 2019 parameters because Connecticut reports scores after the testing window closes (with no immediate score reporting). The 2019

parameters were used for the 2021 test administration. Because the calibration sequence was somewhat different between 2018 and 2019, the calibration sequences are presented in detail for both years.

In 2018 and 2019, the IRT models were fitted using the Bayesian networks with logistic regression (BNL) suite of Matlab functions (Rijmen, 2006) and flexMIRT (Cai, 2017). The resulting parameters from BNL were used as starting values for flexMIRT to reduce the estimation time for flexMIRT. The flexMIRT estimates were taken to be the operational parameters, except for the middle school items calibrated in 2018 during the core calibration (refer to Section 5.2.2, 2018 Calibration Sequence). For the 2018 core calibration of middle-school items, flexMIRT did not converge after several weeks, and the estimates obtained from BNL were used as operational parameters. Note that the parameters estimates were very similar across software packages.

In 2021, field-test items were calibrated with one multigroup calibration per grade band. In each calibration, the parameters of the operational items were fixed to their bank values (anchor items), and the item parameters of the field-test items as well as the mean and variance of each group were estimated using the MML method. Because the estimation time in flexMIRT became prohibitive, CAIRT (Cambium Assessment IRT) was used. CAIRT was specifically developed by CAI to calibrate the multigroup Rasch model on very large data sets. It relies on the same estimation methods as BNL. CAI has cross-validated parameter estimates from CAIRT with BNL and flexMIRT under various scenarios (Rijmen, Liao, & Lin, 2021).

5.2.2 2018 Calibration Sequence

Table 34 provides an overview of the groups per grade band for the 2018 calibration.

Table 34. Groups Per Grade Band for the Spring 2018 Core Calibration

Group	Elementary School	Middle School	High School
Connecticut	X	X	X
Hawaii	X	X	X
New Hampshire	X	X	X
Rhode Island	X	X	X
Utah Grade 6		X	
Utah Grade 7		X	
Utah Grade 8		X	
Vermont	X	X	X
West Virginia	X	X	

Items were calibrated in three steps for two reasons. First, the rubric validations for some states took place at a later date, and the student responses for the items owned by those states could not be included in the first round of calibrations without jeopardizing the reporting schedule of the two states with operational field tests (i.e., those two states did not have any of the items with late

rubric validation in their item pool). Second, to divide the large set of items and assertions into more manageable pieces, a separate calibration was conducted for two states with many items administered in those states only. Specifically, the following sequence of calibrations was conducted:

1. **Core Calibration.** The core calibration was performed on the following:
    a. All item responses for New Hampshire and West Virginia. These states administered items from the following sources (as described in the state-sharing matrix in Table 35):
        i. ICCR item bank
        ii. Connecticut
        iii. Hawaii
        iv. Rhode Island
        v. Vermont
        vi. Utah
        vii. West Virginia

        A more detailed overlap of the common items at the time of the 2018 calibration was given in Section 3.2.1, 2018 Field Test (see Table 8 through Table 10).
    b. All item responses from Connecticut, Rhode Island, and Vermont except for the responses to Oregon and Wyoming items. These states administered items from the following sources:
        i. ICCR item bank
        ii. Connecticut
        iii. Hawaii
        iv. Rhode Island
        v. Vermont
        vi. Utah
        vii. West Virginia
        viii. Wyoming (items were treated as "not administered;" responses were replaced by missing code)
        ix. Oregon (items were treated as "not administered;" responses were replaced by missing code)
    c. Item responses from Hawaii to items also administered in another state (Hawaii items were used in Hawaii, Connecticut, Rhode Island, Vermont, and West Virginia).

d. Item responses from Utah to items also administered in another state (Utah items were used in Utah, Connecticut, Rhode Island, Vermont, and West Virginia). Utah tested only middle school students but included every grade in middle school. One-third of students were selected at random to balance the large population size for Utah.

Table 35. Spring 2018 State-Sharing Matrix

Source Bank	CT	HI	MSSA	NH	OR	UT	WV	WY
ICCR	X	X	X	X	X		X	X
Connecticut	X		X				X	
Hawaii	X	X	X				X	
MSSA[a]	X		X				X	
Oregon	X		X		X			
Utah	X		X			X	X	
West Virginia	X		X				X	
Wyoming	X		X					X

Note. The core calibration provided parameters for all items used in New Hampshire and West Virginia.
[a]MSSA = Rhode Island and Vermont's Multi-State Science Assessment

2. **Calibration of State-Specific Items.** Both Hawaii and Utah had a substantial proportion of items that were only administered in Hawaii and Utah, respectively. Hawaii has both Hawaii and ICCR items in common with the states of the core calibration (Hawaii administered only Hawaii and ICCR items); Utah has only Utah items in common (Utah only administered Utah items). The parameters for the unique Hawaii items depended only on responses from Hawaii students, and the parameters for the unique Utah items depended only on responses from Utah students. For both states, the state-specific items were calibrated through a separate calibration based on the state data only, with the items in common with the core states mentioned in Step 1 anchored to the estimates from Step 1. These calibrations were done separately for each group under a single-group IRT model. The mean and variance of the groups were fixed to the estimated mean and variance from the core calibration.

3. **Calibration of States with Late Rubric Validation.** Oregon and Wyoming items were administered in some of the states from the core calibration (Connecticut, Rhode Island, and Vermont) but could not be calibrated in Step 1 because of their late rubric validation dates. In a later stage, items from Oregon and Wyoming were calibrated by

    a. adding Oregon and Wyoming student responses to the core calibration;

    b. keeping the responses from Connecticut, Rhode Island, and Vermont to Wyoming and Oregon items (as opposed to treating them as missing in Step 1);

    c. removing the responses from Hawaii, Utah, New Hampshire, and West Virginia, who did not administer Oregon or Wyoming items (as the item parameters for the Oregon and Wyoming items did not depend on the students from these states); and

d. fixing the parameters of all other items to the values obtained in Step 1 and the group means and standard deviations that were estimated in Step 1.

5.2.3 2019 Calibration Sequence

Calibration was performed in two steps. First, CAI calibrated all items in operational use in 2019, for which 1,000 or more student responses were observed (among these, there were 1,500 or more student responses for all but three items). In this step, only the data from states with an operational test were included. Table 36 provides an overview of the groups per grade band for this first calibration. All students who attempted the test were included in the calibration. The assertions of skipped items were scored as incorrect. Note that only Rhode Island allowed students to skip items. There were nine items administered as operational items in 2019, for which the sample size was smaller than 1,000, out of a total of 438 items.

Table 37 through Table 39 present the number of operational item clusters and stand-alone items that were shared between the item pools of any two states. The numbers below the shaded diagonal elements represent the number of all the operational items administered, and the numbers above the shaded diagonal elements represent the number of common operational items at the time of the 2019 calibration. The shaded diagonal elements represent the number of operational items administered only in the given state (the number of unique operational items at the time of calibration are provided in parentheses). Since the items that were administered but not calibrated were only administered in one state, the numbers above the diagonal are the same as the numbers below the diagonal.

Table 37 presents the results for elementary schools, Table 38 presents the results for middle schools, and Table 39 presents the results for high schools. The numbers at operational administration are slightly different from the numbers at calibration because items with sample sizes smaller than 1,000 were excluded from the calibration.

Table 36. Groups Per Grade Band for the Spring 2019 Calibration of Operational Items

Group	Elementary School	Middle School	High School
Connecticut	X	X	X
New Hampshire	X	X	X
Oregon	X	X	X
Rhode Island	X	X	X
Vermont	X	X	X
West Virginia	X	X	

Table 37. Common Elementary School Operational Items Administered and Calibrated, Spring 2019

	State	CT	MSSA[a]	NH	OR	WV
Cluster	CT	**1 (1)**	44	24	42	55
	MSSA	44	**0 (0)**	17	37	41
	NH	24	17	**0 (0)**	14	27
	OR	42	37	14	**0 (0)**	41
	WV	55	41	27	41	**1 (1)**
Stand-Alone	CT	**3 (3)**	34	26	30	47
	MSSA	34	**0 (0)**	20	23	32
	NH	26	20	**0 (0)**	14	25
	OR	30	23	14	**0 (0)**	25
	WV	47	32	25	25	**1 (1)**
Grade Band Total	CT	**4 (4)**	78	50	72	102
	MSSA	78	**0 (0)**	37	60	73
	NH	50	37	**0 (0)**	28	52
	OR	72	60	28	**0 (0)**	66
	WV	102	73	52	66	**2 (2)**

Note. [a]MSSA = Rhode Island and Vermont's Multi-State Science Assessment

Table 38. Common Middle School Operational Items Administered and Calibrated, Spring 2019

	State	CT	MSSA[a]	NH	OR	WV
Cluster	CT	**3 (3)**	26	24	54	92
	MSSA	26	**0 (0)**	11	14	21
	NH	24	11	**1 (1)**	9	18
	OR	54	14	9	**2 (2)**	56
	WV	92	21	18	56	**12 (4)**
Stand-Alone	CT	**0 (0)**	42	26	34	50
	MSSA	42	**0 (0)**	25	30	37
	NH	26	25	**0 (0)**	16	21
	OR	34	30	16	**1 (0)**	29
	WV	50	37	21	29	**0 (0)**
Grade Band Total	CT	**3 (3)**	68	50	88	142
	MSSA	68	**0 (0)**	36	44	58
	NH	50	36	**1 (1)**	25	39
	OR	88	44	25	**3 (2)**	85
	WV	142	58	39	85	**12 (4)**

Note. [a]MSSA = Rhode Island and Vermont's Multi-State Science Assessment

Table 39. Common High School Operational Items Administered and Calibrated, Spring 2019

	State	CT	MSSA[a]	NH	OR	WV
Cluster	CT	**5 (5)**	33	22	30	–
	MSSA	33	**0 (0)**	20	31	–
	NH	22	20	**2 (2)**	15	–
	OR	30	31	15	**1 (1)**	–
	WV	–	–	–	–	**–**
Stand-Alone	CT	**0 (0)**	39	27	40	–
	MSSA	39	**2 (2)**	23	32	–
	NH	27	23	**0 (0)**	20	–
	OR	40	32	20	**4 (4)**	–
	WV	–	–	–	–	**–**
Grade Band Total	CT	**5 (5)**	72	49	70	–
	MSSA	72	**2 (2)**	43	63	–
	NH	49	43	**2 (2)**	35	–
	OR	70	63	35	**5 (5)**	–
	WV	–	–	–	–	**–**

Note. [a]MSSA = Rhode Island and Vermont's Multi-State Science Assessment

In Step 2, the field-test items were calibrated. The calibration included the operational items that were calibrated in Step 1 and the field-test items across all states in which they were administered. All students who attempted at least one field-test item were included in the calibration. Table 40 provides an overview of the groups per grade band for calibration of the field-test items.

Table 40. Groups Per Grade Band for the Spring 2019 Calibration of Field-Test Items

Group	Elementary School	Middle School	High School
Connecticut	X	X	X
Hawaii	X	X	X
Idaho	X	X	
New Hampshire	X	X	X
Oregon	X	X	X
Rhode Island	X	X	X
Vermont	X	X	X
West Virginia	X	X	
Wyoming	X	X	X

5.2.4 Linking the 2018 Scale to the 2019 Scale

The item parameter estimates obtained from the 2018 student responses were highly correlated with the item parameters obtained from the 2019 student responses. For the item difficulties, the correlation between the 2018 and 2019 estimates was 0.993 for elementary school, 0.986 for middle school, and 0.994 for high school. For the standard deviations of the clusters, these correlations were 0.971 for elementary school, 0.972 for middle school, and 0.964 for high school. These high correlations indicate that items functioned similarly in 2018 and 2019. Nevertheless, item parameters from separate calibrations cannot be directly compared because the scale of an IRT model is not determined. In the multigroup Rasch testlet model, the only scale indeterminacy is the origin of the scale. The models can be identified by setting the mean of the overall proficiency variable θ to zero for the reference distribution. As a result, the 2018 and 2019 variable θ and item parameters were on the same scale except for an overall shift parameter *B*. Specifically, the 2018 scale can be linked to the 2019 scale as follows:

$$P\left(z_{ij}|\theta_{j\,2018}, u_{jg}; b_{i\,2018}\right) = \frac{\exp\left(\theta_{j\,2018} + u_{jg} - b_{i\,2018}\right)}{1 + \exp\left(\theta_{j\,2018} + u_{jg} - b_{i\,2018}\right)}$$

$$= \frac{exp\left(\theta_{j\,2018}+B+u_{jg}-b_{i\,2018}-B\right)}{1+exp\left(\theta_{j\,2018}+B+u_{jg}-b_{i\,2018}-B\right)}$$

$$= \frac{exp\left(\theta_{j\,2019}+u_{jg}-b_{i\,2019}\right)}{1+exp\left(\theta_{j\,2019}+u_{jg}-b_{i\,2019}\right)}.$$

Because $\theta_{j\,2019} = \theta_{j\,2018} + B$, the population means of θ must be transformed accordingly,

$$\theta_{j\,2019} \sim N\left(\mu_{k\,2018} + B, \sigma_k^2\right)$$

$$\theta_{j\,2018} \sim N\left(\mu_{k\,2018}, \sigma_k^2\right).$$

Item parameters based on 2018 student responses can be expressed on the 2019 scale by adding the constant *B* to the 2018 item parameter. The 2018 parameters were expressed on the 2019 scale for items that were part of the pool in both 2018 and 2019 but not administered in any states in 2019 (13 items), and for items that were administered in 2019 but the number of student responses from the 2019 assessments was lower than 1,000 (nine items). Therefore, the linking process was performed for 22 items only.

All items that were operational in 2019 were also administered in 2018. Therefore, the shift parameter *B* can be estimated from a separate calibration of the items operational in 2019 using the 2019 student responses (of the six operational states), but with the item parameters fixed to the estimates obtained from the 2018 calibrations. By fixing a subset of the item parameters, the model is identified so that the means and variances of θ can be estimated for all groups. Parameter *B* can be obtained by equating the overall mean of θ across all groups for the 2019 student response data from the free calibration (i.e., the 2019 overall mean expressed on the 2019 scale) to the overall mean of θ across all groups for the 2019 student response data from the calibration with items anchored to their 2018 parameters values (2019 overall mean expressed on the 2018 scale):

$$\frac{1}{K}\sum_{k=1}^{K}\mu_{k\ 2019} = \frac{1}{K}\sum_{k=1}^{K}(\mu_{k\ 2018} + B).$$

Therefore, an estimate of parameter *B* can be obtained as

$$\hat{B} = \frac{1}{K}\sum_{k=1}^{K}(\hat{\mu}_{k\ 2019} - \hat{\mu}_{k\ 2018}).$$

Table 41 presents the estimated means of θ under both the free and anchored calibrations and the number of students per state. Table 41 also presents the overall means and estimated shift in parameter *B*. Note that the parameters for three items were not anchored but freely estimated together with the means and variances in the anchored calibration. The reason for not treating these items as common items across the 2018 and 2019 administrations was that they had an omit rate of 4% or higher for the last item interaction in the 2018 administration in at least one state. In 2019, these interactions could no longer be omitted because all interactions of an item needed to be responded to in states where skipping was not allowed (all states except Rhode Island). Therefore, these three items were not anchored to their 2018 parameter values out of an abundance of caution.

Table 41. Estimated Latent Means and Number of Students Per State

Group	Elementary School			Middle School			High School		
	$\hat{\mu}_{k\ 2019}$	$\hat{\mu}_{k\ 2018}$	*N*	$\hat{\mu}_{k\ 2019}$	$\hat{\mu}_{k\ 2018}$	*N*	$\hat{\mu}_{k\ 2019}$	$\hat{\mu}_{k\ 2018}$	*N*
Connecticut	0.0000	0.0518	38,549	0.0000	0.0234	39,347	0.0000	0.1443	37,616
New Hampshire	0.0631	0.1083	13,187	0.0940	0.1108	12,060	0.0798	0.2278	11,385
Oregon	-0.0101	0.0096	44,989	0.0028	0.0156	42,043	-0.0383	0.1030	41,630
Rhode Island	-0.0312	0.0142	10,751	-0.1044	-0.0692	10,306	-0.2261	-0.0879	9,612
Vermont	0.1069	0.1504	6,017	0.0781	0.1133	5,894	0.0179	0.1545	5,332
West Virginia	-0.1970	-0.1529	19,540	-0.3012	-0.2783	19,043	–	–	–
	$\frac{1}{K}\sum_{k=1}^{K}\hat{\mu}_{k\ 2019}$	$\frac{1}{K}\sum_{k=1}^{K}\hat{\mu}_{k\ 2018}$	$\hat{B}$	$\frac{1}{K}\sum_{k=1}^{K}\hat{\mu}_{k\ 2019}$	$\frac{1}{K}\sum_{k=1}^{K}\hat{\mu}_{k\ 2018}$	$\hat{B}$	$\frac{1}{K}\sum_{k=1}^{K}\hat{\mu}_{k\ 2019}$	$\frac{1}{K}\sum_{k=1}^{K}\hat{\mu}_{k\ 2018}$	$\hat{B}$
Overall	-0.0114	0.0303	-0.0416	-0.0385	-0.0141	-0.0244	-0.0333	0.1083	-0.1417

5.2.5 Calibration of 2021 Field-Test Items

In 2021, the calibration was completed in one step in which the field-test items were calibrated. The calibration included the field-test items across all states in which they were administered. All students who attempted at least one field-test item were included in the calibration. Table 42 provides an overview of the groups per grade band for calibration of the field-test items.

Table 42. Groups Per Grade Band for the Spring 2021 Calibration of Field-Test Items

Group	Elementary School	Middle School	High School
Connecticut	X	X	X
Hawaii	X	X	X
Idaho	X	X	X
Montana	X	X	
North Dakota	X	X	X
New Hampshire	X	X	X
Rhode Island	X	X	X
South Dakota	X	X	X
Utah	X	X	
Vermont	X	X	X
West Virginia	X	X	
Wyoming	X	X	X

5.2.6 Overview of the Operational Item Bank

Figure 2, Figure 3, and Figure 4 display the histogram of the difficulty parameters for grades 5, 8, and 11, respectively, for all items that are part of the Connecticut NGSS Assessment operational pool. The figures also display the student proficiency distributions. The grade 5 items are slightly easier compared to the student proficiency level. The distribution of the difficulty parameter overlaps well with the proficiency distribution in grade 8. The grade 11 items are slightly more difficult than the student proficiency in general.

Figure 2. Connecticut NGSS Assessment Item Difficulty and Student Proficiency Distributions, Grade 5

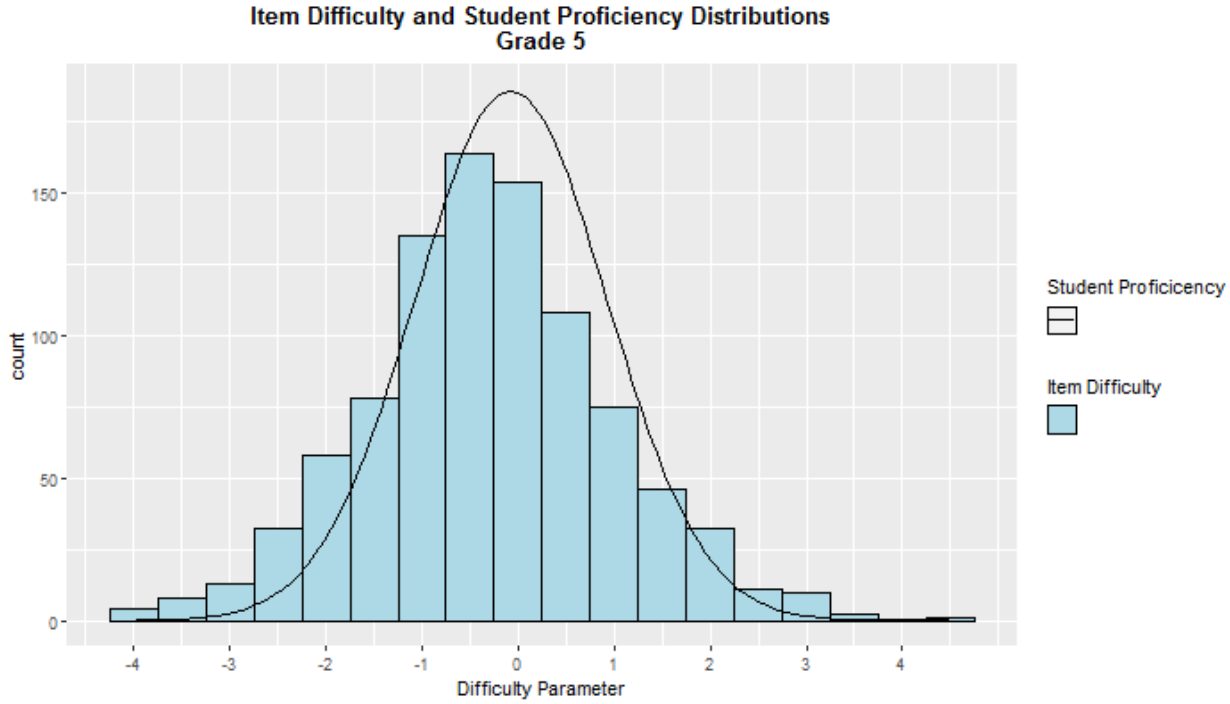


Figure 3. Connecticut NGSS Assessment Item Difficulty and Student Proficiency Distributions, Grade 8

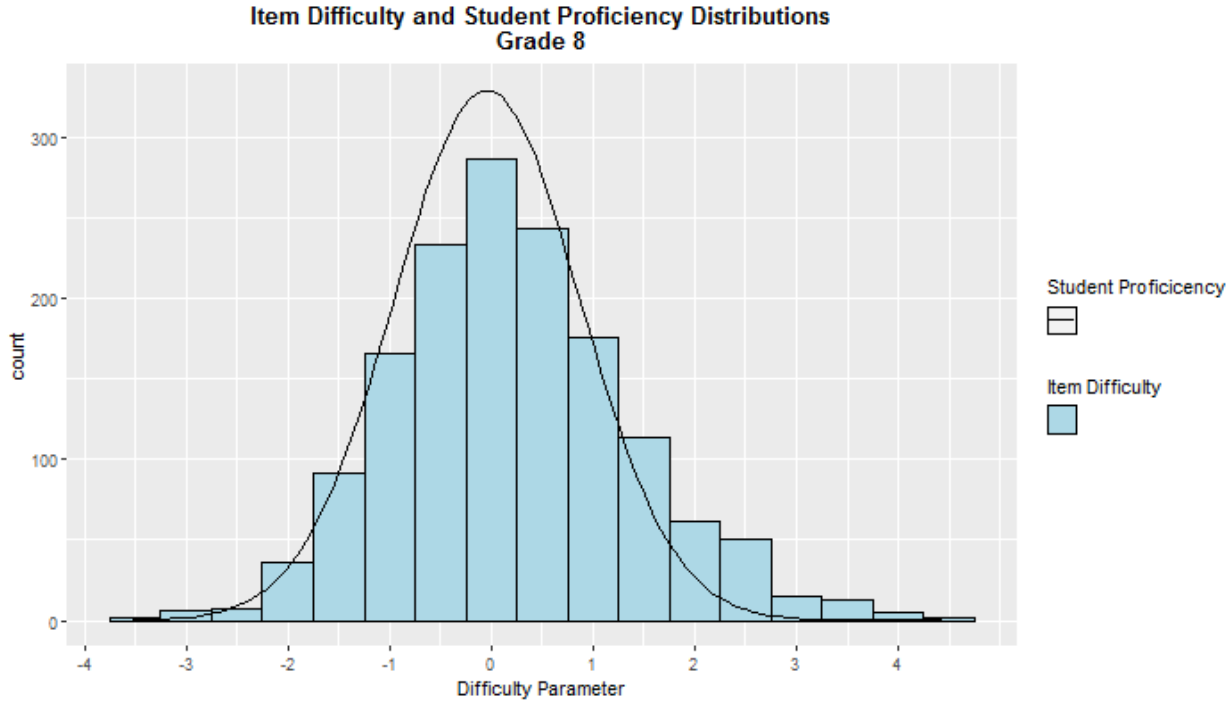
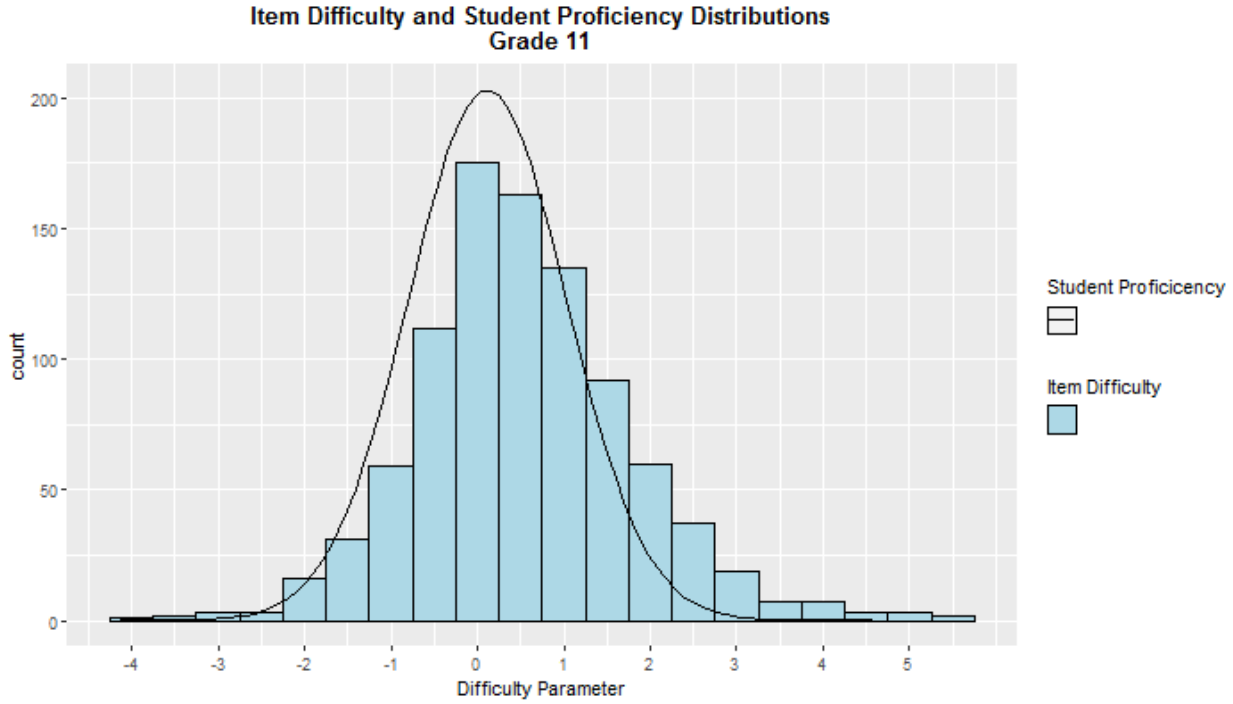


Figure 4. Connecticut NGSS Assessment Item Difficulty and Student Proficiency Distributions, Grade 11



6. SCORING

6.1 MAXIMUM LIKELIHOOD FUNCTION

Student scores are obtained by marginalizing out the nuisance dimensions $\boldsymbol{u}_j$ from the likelihood of the observed response pattern $\boldsymbol{z}_j$ for student j,

$$\ell_i(\theta_j) = log \int_{\boldsymbol{u}_j} P(\boldsymbol{z}_j|\theta_j, \boldsymbol{u}_j)\, N(\boldsymbol{u}_j|\boldsymbol{0}, \boldsymbol{\Sigma}) d\boldsymbol{u}_j,$$

and maximizing this marginalized likelihood function for θ_j. The marginal maximum likelihood estimation (MMLE) estimator is a hybrid between the expected a posteriori (EAP) estimator (by marginalizing out the nuisance dimensions) and the MLE estimator (by maximizing the resulting marginal likelihood for θ). The marginal likelihood is maximized with respect to θ using the Newton Raphson method.

The proposed model reduces to the unidimensional Rasch model when the nuisance variances are zero for all g. Likewise, the proposed MMLE is equivalent to the MLE of the unidimensional Rasch model when all the nuisance variances are zero. This can be shown by using the variable transformation $\mathbf{v} = \boldsymbol{\Sigma}^{-\frac{1}{2}}\mathbf{u}$. Then we have

$$\int_{\boldsymbol{u}_j} P\left(\boldsymbol{z}_j \middle| \theta_j, \boldsymbol{u}_j\right) N\left(\boldsymbol{u}_j \middle| \boldsymbol{0}, \boldsymbol{\Sigma}\right) d\boldsymbol{u}_j = \int_{\boldsymbol{v}_j} P\left(\boldsymbol{z}_j \middle| \theta_j, \boldsymbol{\Sigma}^{\frac{1}{2}} \boldsymbol{v}_j\right) N\left(\boldsymbol{v}_j \middle| \boldsymbol{0}, \boldsymbol{I}\right) d\boldsymbol{v}_j.$$

If $\sigma_{u_g}^2 = 0$ for all g, then

$$\int_{\boldsymbol{u}_j} P\left(\boldsymbol{z}_j \middle| \theta_j, \boldsymbol{u}_j\right) N\left(\boldsymbol{u}_j \middle| \boldsymbol{0}, \boldsymbol{\Sigma}\right) d\boldsymbol{u}_j = P\left(\boldsymbol{z}_j \middle| \theta_j\right),$$

which is the likelihood under the unidimensional Rasch model.

6.2 DERIVATIVE

The marginal log likelihood function based on the item response theory (IRT) model with one overall dimension and one nuisance dimension for each grouping of assertions can be written as

$$l(\theta) = \sum_{i \in \mathrm{SA}} \log\left(P(z_i|\theta)\right) + \sum_{g=1}^{G} \log\left\{ \int \mathrm{Exp}\left[\sum_{i \in g} \log\left(P\left(z_{ig}|\theta, u_g\right)\right)\right] N\left(u_g \middle| 0, \sigma_{u_g}^2\right) du_g \right\}.$$

The first derivative of the marginal log likelihood function with respect to θ is

$$\frac{dl(\theta)}{d\theta} = \sum_{i \in \mathrm{SA}} \frac{\frac{dP(z_i|\theta)}{d\theta}}{P(z_i|\theta)} + \sum_{g=1}^{G} \frac{\int \left\{ \mathrm{Exp}\left[\sum_{i \in g} \log\left(P\left(z_{ig}|\theta, u_g\right)\right)\right] \left(\sum_{i \in g} \frac{\frac{dP\left(z_{ig}|\theta, u_g\right)}{d\theta}}{P\left(z_{ig}|\theta, u_g\right)} \right) N\left(u_g \middle| 0, \sigma_{u_g}^2\right) \right\} du_g}{\int \left\{ \mathrm{Exp}\left[\sum_{i \in g} \log\left(P\left(z_{ig}|\theta, u_g\right)\right)\right] N\left(u_g \middle| 0, \sigma_{u_g}^2\right) \right\} du_g}$$

and the second derivative of the marginal log likelihood function with respect to θ is

$$\frac{d^2 l(\theta)}{d\theta^2}$$
$$= \sum_{i \in \mathrm{SA}} \left[\frac{\frac{d^2 P(z_i|\theta)}{d\theta^2}}{P(z_i|\theta)} - \left(\frac{\frac{d P(z_i|\theta)}{d\theta}}{P(z_i|\theta)} \right)^2 \right]$$
$$+ \sum_{g=1}^{G} \frac{\int \mathrm{Exp}\left[\sum_{i \in g} \log\left(P\left(z_{ig}|\theta, u_g\right)\right)\right] \left(\sum_{i \in g} \frac{\frac{d P\left(z_{ig}|\theta, u_g\right)}{d\theta}}{P\left(z_{ig}|\theta, u_g\right)} \right)^2 N\left(u_g \middle| 0, \sigma_{u_g}^2\right) du_g}{\int \left\{ \mathrm{Exp}\left[\sum_{i \in g} \log\left(P\left(z_{ig}|\theta, u_g\right)\right)\right] N\left(u_g \middle| 0, \sigma_{u_g}^2\right) \right\} du_g}$$
$$+ \sum_{g=1}^{G} \frac{\int \mathrm{Exp}\left[\sum_{i \in g} \log\left(P\left(z_{ig}|\theta, u_g\right)\right)\right] \left(\sum_{i \in g} \left[\frac{\frac{d^2 P\left(z_{ig}|\theta, u_g\right)}{d\theta^2}}{P\left(z_{ig}|\theta, u_g\right)} - \left(\frac{\frac{d P\left(z_{ig}|\theta, u_g\right)}{d\theta}}{P\left(z_{ig}|\theta, u_g\right)} \right)^2 \right] \right) N\left(u_g \middle| 0, \sigma_{u_g}^2\right) du_g}{\int \left\{ \mathrm{Exp}\left[\sum_{i \in g} \log\left(P\left(z_{ig}|\theta, u_g\right)\right)\right] N\left(u_g \middle| 0, \sigma_{u_g}^2\right) \right\} du_g}$$
$$- \sum_{g=1}^{G} \left\{ \frac{\int \mathrm{Exp}\left[\sum_{i \in g} \log\left(P\left(z_{ig}|\theta, u_g\right)\right)\right] \left(\sum_{i \in g} \frac{\frac{d P\left(z_{ig}|\theta, u_g\right)}{d\theta}}{P\left(z_{ig}|\theta, u_g\right)} \right) N\left(u_g \middle| 0, \sigma_{u_g}^2\right) du_g}{\int \left\{ \mathrm{Exp}\left[\sum_{i \in g} \log\left(P\left(z_{ig}|\theta, u_g\right)\right)\right] N\left(u_g \middle| 0, \sigma_{u_g}^2\right) \right\} du_g} \right\}^2.$$

Based on the above equations, we only need to define the ratios of the first and second derivatives of the item response probabilities with respect to θ to the response probabilities. For the Rasch testlet model, these are obtained as

$$p_i = P(z_i = 1|\theta) = \frac{\mathrm{Exp}(\theta - b_i)}{1 + \mathrm{Exp}(\theta - b_i)}, q_i = P(z_i = 0|\theta) = 1 - p_i,$$

and

$$p_{ig} = P\left(z_{ig} = 1|\theta, u_g\right) = \frac{\mathrm{Exp}\left(\theta + u_g - b_i\right)}{1 + \mathrm{Exp}\left(\theta + u_g - b_i\right)}, q_{ig} = P\left(z_{ig} = 0|\theta, u_g\right) = 1 - p_{ig}.$$

Therefore, we have,

$$\frac{\frac{dp_i}{d\theta}}{p_i} = q_i \ , \ \frac{\frac{dq_i}{d\theta}}{q_i} = -p_i,$$

$$\frac{\frac{dp_{ig}}{d\theta}}{p_{ig}} = q_{ig} \ , \ \frac{\frac{dq_{ig}}{d\theta}}{q_{ig}} = -p_{ig},$$

$$\frac{\frac{d^2 p_i}{d\theta^2}}{p_i} - \left(\frac{\frac{d p_i}{d\theta}}{p_i}\right)^2 = -p_i q_i,$$

$$\frac{\frac{d^2 q_i}{d\theta^2}}{q_i} - \left(\frac{\frac{d q_i}{d\theta}}{q_i}\right)^2 = -p_i q_i,$$

$$\frac{\frac{d^2 p_{ig}}{d\theta^2}}{p_{ig}} - \left(\frac{\frac{d p_{ig}}{d\theta}}{p_{ig}}\right)^2 = -p_{ig} q_{ig}, \text{ and}$$

$$\frac{\frac{d^2 q_{ig}}{d\theta^2}}{q_{ig}} - \left(\frac{\frac{d q_{ig}}{d\theta}}{q_{ig}}\right)^2 = -p_{ig} q_{ig}.$$

6.3 Extreme Case Handling

As with the MLE, the MMLE is not defined for zero and perfect scores. These cases are handled by assigning the lowest obtainable theta (LOT) scores and highest obtainable theta (HOT) scores, respectively. Table 43 contains the LOT and HOT values for each grade.

6.4 Standard Error of Measurement

The standard error of measurement (SEM) of the MMLE score estimate is:

$$SEM(\hat{\theta}_{MMLE}) = \frac{1}{\sqrt{I(\hat{\theta}_{MMLE})}}$$

where $I(\hat{\theta}_{MMLE})$ is the observed information evaluated at $\hat{\theta}_{MMLE}$. The observed information is calculated as $I(\theta^2) = -\frac{d^2 l(\theta)}{d\theta^2}$ where $\frac{d^2 l(\theta)}{d\theta^2}$ is defined in Section 6.2, Derivative. Note that the calculation of the SEM depends on the unique set of items that each student answers and their estimate of θ. Different students have different SEM, even if they have the same raw score and/or theta estimate. Standard errors are truncated at 1 for the overall science scores and truncated at 1.4 for the discipline scores.

Standard errors for MMLE estimates truncated at the LOT (HOT) are computed by evaluating the observed information at the MMLE before truncation. For all incorrect or all correct answers, the reported SEM is set at the truncation value for the standard error.

6.5 Scoring Incomplete Tests

The Connecticut NGSS Assessment is assembled on-the-fly using a matrix design. For science, tests are considered complete if students respond to all of the operational items. Otherwise, the tests are "incomplete." Tests that are incomplete but attempted (Attempt=Y) are scored. A student must have attempted the corresponding discipline of the test in order to receive a discipline score (e.g., Life Sciences, Physical Sciences, Earth and Space Sciences). The MMLE is used to score

the attempted incomplete tests counting unanswered items as incorrect. If the identities of the unanswered items are unknown due to the test being assembled on-the-fly, the item parameters for a "typical" item are used. If a missing item is an item cluster, the simulated item parameters of the missing item are the item parameters of item cluster 4482 for grade 5, 3781 for grade 8, and 4350 for grade 11, which are operational item clusters that are typical for the Connecticut NGSS Assessment item pool used in Connecticut in terms of the number of assertions and estimated parameters. Likewise, if a missing item is a stand-alone item, the simulated item parameters of the missing item are the item parameters of stand-alone item 4047 for grade 5, 4529 for grade 8, and 4555 for grade 11, which are operational stand-alone items that are typical for the Connecticut NGSS Assessment item pool used in Connecticut.

If the identity of items that have not been answered are known because they have already been lined up through the pre-fetch process, the item parameters of the lined-up items will be used. Similarly, for the accommodated forms that are fixed-forms, the item parameters of the unanswered items on the form will be used.

6.6 STUDENT-LEVEL SCALE SCORE

At the student level, scale scores are computed for

1. Overall Science;
2. Life Sciences;
3. Physical Sciences; and
4. Earth and Space Sciences.

Scores are computed using the MMLE method outlined in this report, with all items from overall science or only items within the given discipline. Scores are truncated on the "theta" scale at the LOT and HOT values specified in Table 43, which correspond to values of the estimated mean minus/plus four times the estimated standard deviation of θ.

The reporting scales will be a linear transformation of the theta scales

$$SS = a * \hat{\theta}_{MMLE} + b$$

where a and b are the slope and intercept of the linear transformation that transforms $\hat{\theta}_{MMLE}$ to the reporting scale (refer to Table 43). The SEM for the estimated scale score is obtained as

$$SEM_{SS} = a * SEM_{\hat{\theta}_{MMLE}}.$$

In 2019, the slope a and intercept b were chosen so that the reporting scale of each grade (500, 800, and 1100, respectively) is centered at the grade mean of the 2019 base-year and has a standard deviation of 28. Furthermore, for each grade, the reporting scale ranges approximately from the base-year mean minus 3.5 times the standard deviation to the base-year mean plus 3.5 times the standard deviation. Specifically, for grade 5, the slope and intercept were obtained as

$$SS = 28\theta^* + 500$$

$$= 28\frac{\theta - \hat{\mu}_\theta}{\hat{\sigma}_\theta} + 500$$
$$= \frac{28}{\hat{\sigma}_\theta}\theta + \left(500 - \frac{28\hat{\mu}_\theta}{\hat{\sigma}_\theta}\right),$$

where the second line stems from standardizing theta, $\theta^* = \frac{\theta - \hat{\mu}_\theta}{\hat{\sigma}_\theta}$. For grades 8 and 11, the slope and intercept can also be derived similarly.

Table 43 presents the intercept and slope and the LOT, HOT, lowest obtainable scale score (LOSS), and highest obtainable scale score (HOSS) values used for the 2019 reporting scale. The scale score distribution is reported for overall science in Appendix A, Distribution of Scale Scores and Performance Levels. The scale score distribution is reported for the science disciplines ~~for overall science, and~~ in Appendix B, Distribution of Scale Scores by Science Discipline.

Table 43. Science Reporting Scale Linear Transformation Constants, Theta, and Corresponding Scaled-Score Limits for Extreme Ability Estimates (for 2019 θ Scale)

Grade	Slope	Intercept	Lowest of Theta (LOT)	Highest of Theta (HOT)	Lowest of Scale Score (LOSS)	Highest of Scale Score (HOSS)
5	31.684	500	–3.15	3.12	400	599
8	31.766	800	–3.14	3.11	700	899
11	30.792	1100	–3.24	3.21	1000	1199

6.7 Rules for Calculating Performance Levels

Performance levels and corresponding cut scores were set during standard setting in summer 2019. Students are classified into one of four performance levels, based on their total score. The distribution of performance levels is summarized in Appendix A, Distribution of Scale Scores and Performance Levels. Further, the distribution of scale scores and performance levels for subgroups described in Section 4.4, Differential Item Functioning Analysis, are presented in Appendix C, Distribution of Scale Scores and Performance Levels by Subgroup.

Table 44 lists the cut scores on the reporting scale metrics for each grade.

Table 44. Performance-Level Cut Scores

Grade	Cut 1	Cut 2	Cut 3
5	468	498	535
8	772	798	842
11	1073	1099	1141

6.7.1 Strengths and Weaknesses for Disciplines Relative to Proficiency Cut Score

Discipline-level classifications are computed to classify student performance levels for each of the science disciplines/areas of science. The following are the classification rules:

- if $\left(\hat{\theta}_{discipline} < \theta_{proficient} - 1.5 * SEM\left(\hat{\theta}_{discipline}\right)\right)$, then performance is classified as *Below Standard*;
- if $\left(\theta_{proficient} - 1.5 * SEM\left(\hat{\theta}_{discipline}\right) \leq \hat{\theta}_{discipline} < \theta_{proficient} + 1.5 * SEM\left(\hat{\theta}_{discipline}\right)\right)$, then performance is classified as *Approaching Standard*; and
- if $\left(\hat{\theta}_{discipline} \geq \theta_{proficient} + 1.5 * SEM\left(\hat{\theta}_{discipline}\right)\right)$, then performance is classified as *Above Standard*,

where $\theta_{Proficient}$ is the proficiency cut score of the overall test. Standard errors are truncated at 1.4. The LOT is always classified as *Below Standard*, and the HOT is always classified as *Above Standard*.

6.8 DISCIPLINARY CORE IDEA-LEVEL REPORTING

6.8.1 Relative to Overall Performance

For aggregated units (i.e., classrooms, schools, districts), there is reporting at levels below the science discipline level. In 2020–2021, reports were provided at the level of Disciplinary Core Ideas (DCI). The method for reporting at levels below the science discipline level is based on the use of residuals. The equations are presented first for DCIs.

For each assertion i, the residual between the observed and expected score for each student j is defined as

$$\delta_{ij} = z_{ij} - E\left(z_{ij}\right).$$

The expected score is computed for a student's estimated overall ability. For the assertions clustered within an item, the expected score is marginalized over the nuisance dimensions for the assertions clustered within an item,

$$E\left(z_{ijg} = 1; \theta_{j,overall}, \boldsymbol{\tau}_i\right) = \int P\left(z_{ijg} = 1 | u_{jg};\ \theta_{j,overall}, \boldsymbol{\tau}_i\right) N\left(u_{jg}\right) du_{jg},$$

where $\boldsymbol{\tau}_i$ is the vector of parameters for assertion i (e.g., for the Rasch testlet model, $\boldsymbol{\tau}_i = b_i$), and $P\left(z_{ijg} = 1 | u_{jg};\ \theta_{j,overall}, \boldsymbol{\tau}_i\right)$ is defined in Section 6.2, Derivative. Next, residuals are aggregated over assertions within students,

$$\delta_{jDCI} = \frac{\sum_{i \in DCI} \delta_{ij}}{n_{jDCI}},$$

and over students of the group on which is reported,

$$\bar{\delta}_{DCIg} = \frac{1}{n_g}\sum_{j\in g}\delta_{jDCI},$$

where n_{jDCI} is the number of assertions related to the DCI for student j, and n_g is the number of students in a group assessed on the DCI. If a student did not see any items on a DCI, the student is not included in the n_g count for the aggregate. The standard error of the average residual is computed as

$$SEM(\bar{\delta}_{DCIg}) = \sqrt{\frac{1}{n_g(n_g-1)}\sum_{j\in g}\left(\delta_{jDCI} - \bar{\delta}_{PDCIg}\right)^2}.$$

A statistically significant difference from zero in these aggregates is evidence that a class, teacher, school, or district is more effective (if $\bar{\delta}_{DCIg}$ is positive) or less effective (negative $\bar{\delta}_{DCIg}$) in teaching a given DCI.

We do not suggest direct reporting of the statistic $\bar{\delta}_{DCIg}$; instead, we recommend reporting in the aggregate whether a group of students performs better, worse, or as expected on this DCI. It will also be indicated that, in some cases, sufficient information is not available.

For target-level strengths/weakness, the following is reported:

- If $\bar{\delta}_{DCIg} \leq -1.5 * SEM\left(\bar{\delta}_{DCIg}\right)$, then performance is *worse than* on the overall test.
- If $\bar{\delta}_{DCIg} \geq 1.5 * SEM(\bar{\delta}_{DCIg})$, then performance is *better than* on the overall test.
- Otherwise, performance is *similar to* on the overall test.
- If $SEM\left(\bar{\delta}_{DCIg}\right) > 0.2$, data are insufficient.

6.8.2 Relative to Proficiency Cut Score

DCI-level scores for aggregated units can be computed using the same method as outlined in Section 6.8.1, Relative to Overall Performance, but with the expected score computed at the theta value corresponding to the proficiency cut score:

$$E\left(z_{ijg} = 1; \theta_{proficiency}, \boldsymbol{\tau}_i\right) = \int P\left(z_{ijg} = 1 | u_{jg};\ \theta_{proficiency}, \boldsymbol{\tau}_i\right) N\left(u_{jg}\right) du_{jg}.$$

The following is reported for DCIs for aggregate units:

- If $\bar{\delta}_{DCIg} \leq -1.5 * SEM\left(\bar{\delta}_{DCIg}\right)$, then performance is *below* the proficiency cut score.
- If $\bar{\delta}_{DCIg} \geq 1.5 *\ SEM\left(\bar{\delta}_{DCIg}\right)$, then performance is *above* the proficiency cut score.
- Otherwise, performance is *approaching* the proficiency cut score.
- If $SEM\left(\bar{\delta}_{DCIg}\right) > 0.2$, data are insufficient.

7. QUALITY CONTROL PROCEDURES

CAI's quality assurance (QA) procedures are built on two key principles: (1) automation and (2) replication. Certain procedures can be automated, which removes the potential for human error. Procedures that cannot be reasonably automated are replicated by two independent analysts at CAI.

Although the quality of any test is monitored as an ongoing activity, several sources of CAI's quality control system are described here. First, QA reports are routinely generated and evaluated throughout the testing window to ensure that each test performs as anticipated. Second, the quality of scores is ensured by employing a second independent scoring verification system.

7.1 QUALITY ASSURANCE REPORTS

Test monitoring occurs while tests are administered in a live environment to ensure that item behavior is consistent with expectations. This is accomplished using CAI's Quality Monitoring System that yields item statistics, blueprint match rates, and item exposure rate reports.

7.1.1 Item Analysis

The item analysis report is a key check for the early detection of potential problems with item scoring, including the incorrect designation of a keyed response or other scoring errors and potential breaches of test security that may be indicated by changes in the difficulty of test items. To examine the performance of test items, this report generates classical item analysis indicators of difficulty and discrimination, including proportion correct, biserial/polyserial correlation, and item fit statistics based on the IRT. The report is configurable and can be produced to flag only items with statistics that fall outside a specified range or to generate reports based on all items in the pool. For science, statistics reports at the assertion level (which are the units of analysis for science) are currently not yet available; however, CAI psychometricians compute and monitor classical item statistics at the end of the testing window.

7.1.2 Blueprint Match

The QA system generates Blueprint Match reports at the content-standards level and for other content requirements, such as strand and affinity group for science. For each blueprint element, the report indicates the minimum and maximum number of items specified in the blueprint, the number of test administrations in which those specifications were met, the number of administrations in which the blueprint requirements were not met, and, for administrations in which specifications were not met, the number of items by which the requirement was not met.

For all three grades, every test met the blueprint specifications at the level of the science disciplines, which is the lowest content level at which scores for individual students are reported. A few violations did occur at lower content levels for the Spanish tests due to the limited number of items for which a Spanish version is available. Blueprint match is discussed in detail in Volume 2, Test Development, for both simulated and operational test administrations.

7.1.3 Item Exposure Rates

The QA system also generates item exposure reports that allow test items to be monitored for unexpectedly large exposure rates or unusually low item-pool usage throughout the testing window. As with other reports, it is possible to examine the exposure rate for all items or flagged items with exposure rates that exceed an acceptable range. Often, item overexposure indicates a blueprint element or combination of blueprint elements that are underrepresented in the item pool and should be targeted for future item development. Such item overexposure is also usually anticipated in the simulation studies used to configure the adaptive algorithm. A total of 3.52% of the items in grade 5, 3.67% of items in grade 8, and 12.58% of items in grade 11 were administered to 20% or more test takers at that grade. More details are discussed in Volume 2, Test Development.

7.2 SCORING QUALITY CHECK

All student test scores are produced using CAI's scoring engine. Before releasing any scores, a second score verification system is used to verify that all test scores match with 100% agreement in all tested grades. The second system is independently constructed and maintained from the main scoring engine and separately estimates scores using the procedures described within this report.

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