

North Dakota State Assessment for Science

2020–2021

Volume 4: Evidence of Reliability and Validity



**NORTH DAKOTA DEPARTMENT OF
PUBLIC INSTRUCTION**

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1. INTRODUCTION AND OVERVIEW OF RELIABILITY AND VALIDITY EVIDENCE

The new North Dakota Science Content Standards were adopted by the North Dakota Department of Public Instruction (NDDPI) in February 2019. As a result, the first operational administration of the North Dakota State Assessment (NDSA) for Science in grades 4, 8, and 10 occurred during the 2020–2021 school year, and the assessment was based upon the 2019 Standards. The NDSA for Science is administered online for grades 4, 8, and 10 using an adaptive test design. Accommodated Braille versions and designated-support Spanish-language versions are available for each grade. For the 2020–2021 school year, remote testing forms were constructed to allow for assessing science among students taking the test remotely. However, before the testing window opened, NDDPI decided not to use these remote forms; please refer to Volume 2, Appendix L for form construction procedures for the unused remote test forms. Table 1 shows the complete list of summative tests for the first year of operational test administration in 2020–2021.

Table 1. 2020–2021 Operational Assessment Modes

| Language/Format | Assessment Mode | Grade |
|-----------------|-----------------|--------------|
| English | Online | 4, 8, and 10 |
| Spanish | Online | 4, 8, and 10 |
| Braille | Paper | 4, 8, and 10 |

Given the intended uses of these tests, both reliability evidence and validity evidence are necessary to support appropriate inferences of student academic achievement based on the NDSA for Science scores. The analyses to support reliability and validity evidence that are reported in this volume were conducted based on test results for students whose scores were reported, including those taking the standard version and the accommodated versions of the NDSA for Science.

The purpose of this report is to provide empirical evidence that supports a validity argument for the uses of and inferences from the NDSA for Science. This volume addresses the following five topics:

1. **Reliability.** The reliability estimates are presented by grade and demographic subgroups. This section also includes Conditional Standard Error of Measurement (CSEM), classification accuracy (CA), and classification consistency (CC) results by grade.
2. **Content validity.** This section presents evidence showing that test forms were constructed to measure the three-dimensional 2019 North Dakota Science Content Standards with a sufficient number of items targeting each area of the test blueprint.
3. **Internal structure validity.** This section provides evidence regarding the internal relationships among the subscale scores to support their use and to justify the item response theory (IRT) measurement model. This type of evidence includes observed and disattenuated Pearson correlations among discipline scores per grade. The IRT model is a multidimensional model with an overall dimension representing proficiency in science and nuisance dimensions that consider within-item local dependencies among scoring assertions (refer to Volume 1, Section 5.1, Annual Technical Report).

In this volume, the evidence is provided for the presence of item cluster effects. Additionally, confirmatory factor analysis was used to evaluate the fit of the IRT model and to compare it to alternative models, including models with a simpler internal structure (i.e., unidimensional models) and models with a more elaborate internal structure.

4. **Relationship of test scores to external variables.** Evidence of convergent and discriminant validity is provided using observed and disattenuated subscore correlations both within and across subjects.
5. **Test fairness.** Fairness is an explicit concern during item development. Items are developed following the principles of universal design. Universal design removes barriers to provide access for the widest range of students possible. Test fairness is further statistically monitored using differential item functioning (DIF) analysis in tandem with content reviews by specialists.

1.1 RELIABILITY

Reliability refers to consistency in test scores and can be defined as the degree to which individuals' deviation scores remain relatively consistent over repeated administrations of the same test or alternate test forms (Crocker & Algina, 1986). For example, if a person takes the same or parallel tests repeatedly, he or she should receive consistent results. The *reliability coefficient* refers to the ratio of true score variance to observed score variance:

$$\rho_{XX'} = \frac{\sigma_T^2}{\sigma_X^2}$$

Another way to view reliability is to consider its relationship with the Standard Error of Measurement (SEM)—the smaller the standard error, the higher the precision of the test scores. For example, classical test theory assumes that an observed score (X) of an individual can be expressed as a true score (T) plus some error (E), $X = T + E$. The variance of X can be shown to be the sum of two orthogonal variance components:

$$\sigma_X^2 = \sigma_T^2 + \sigma_E^2.$$

Returning to the definition of reliability as the ratio of true score variance to observed score variance, we can arrive at the following theorem:

$$\rho_{XX'} = \frac{\sigma_T^2}{\sigma_X^2} = \frac{\sigma_X^2 - \sigma_E^2}{\sigma_X^2} = 1 - \frac{\sigma_E^2}{\sigma_X^2}.$$

As the fraction of error variance to observed score variance tends to zero, the reliability then tends to 1. The classical test theory SEM, which assumes a homoscedastic error, is derived from the classical notion expressed above as $\sigma_X \sqrt{1 - \rho_{XX'}}$, where σ_X is the standard deviation of the scaled score, and $\rho_{XX'}$ is a reliability coefficient. Based on the definition of reliability, this formula can be derived as follows:

$$\rho_{XX'} = 1 - \frac{\sigma_E^2}{\sigma_X^2},$$

$$\begin{aligned}\frac{\sigma_E^2}{\sigma_X^2} &= 1 - \rho_{XX'}, \\ \sigma_E^2 &= \sigma_X^2(1 - \rho_{XX'}), \\ \sigma_E &= \sigma_X\sqrt{(1 - \rho_{XX'})}.\end{aligned}$$

In general, the SEM is relatively constant across samples, as the group dependent term, σ_X , can be shown to cancel out:

$$\sigma_E = \sigma_X\sqrt{(1 - \rho_{XX'})} = \sigma_X\sqrt{(1 - (1 - \frac{\sigma_E^2}{\sigma_X^2}))} = \sigma_X\sqrt{\frac{\sigma_E^2}{\sigma_X^2}} = \sigma_X \times \frac{\sigma_E}{\sigma_X} = \sigma_E.$$

This shows that the SEM in the classical test theory is assumed to be a homoscedastic error, irrespective of the standard deviation of a group.

In contrast, the SEM in IRT vary over the ability continuum. These heterogeneous errors are a function of a test information function (TIF) that provides different information about test takers depending on their estimated abilities.

Because the TIF indicates the amount of information provided by the test at different points along the ability scale, its inverse indicates the lack of information at different points along the ability scale. This lack of information is the uncertainty, or the measurement error, of the cut score at various cut score points. Refer to Section 3.3, Precision at Cut Scores, for the derivation of heterogeneous measurement errors in IRT, and how these errors are aggregated over the cut score distribution to obtain a single, marginal, IRT-based reliability coefficient.

1.2 VALIDITY

Validity refers to the degree to which “evidence and theory support the interpretations of test scores entailed by proposed uses of tests” (American Educational Research Association [AERA], American Psychological Association [APA], & National Council on Measurement in Education [NCME], 2014). Messick (1989) defines validity as “an integrated evaluative judgment of the degree to which empirical evidence and theoretical rationales support the adequacy and appropriateness of inferences and actions based on test scores and other modes of assessment.” Both definitions emphasize the need for evidence and theory to support inferences and interpretations of test scores.

The *Standards for Educational and Psychological Testing* (AERA, APA, & NCME, 2014) suggest five sources of validity evidence that can be used in evaluating a proposed interpretation of test scores. When validating test scores, these sources of evidence should be carefully considered.

The first source of evidence for validity is the relationship between the test content and the intended test construct (see Section 4, Evidence of Content Validity). For test score inferences to support a validity claim, the items should be representative of the content domain, and the content domain should be relevant to the proposed interpretation of test scores. To determine content representativeness, diverse panels of content experts conduct alignment studies, in which experts review individual items and rate them based on how well they match the test specifications or cognitive skills required for a construct (refer to Section 4.2, Independent Alignment Study, for

the results of an independent alignment study; refer to Volume 2, Test Development, for details on the item development process).

Technology-enhanced items should be examined to ensure that no construct-irrelevant variance is introduced. If some aspect of the technology impedes or advantages a student in his or her responses to items, this could affect item responses and inferences regarding abilities on the measured construct (see Volume 2, Test Development).

The second source of validity evidence is based on “the fit between the construct and the detailed nature of performance or response actually engaged in by examinees” (AERA et al., 2014). This evidence is collected by surveying test takers about their performance strategies or responses to specific items. Because items are developed to measure specific constructs and intellectual processes, evidence that test takers have engaged in relevant performance strategies to correctly answer the items supports the validity of the test scores.

The third source of evidence for validity is based on *internal structure*, defined as the degree to which the relationships among test items and test components relate to the construct on which the proposed test scores are interpreted. Dimensionality assessment, goodness-of-model-fit to data, and reliability analysis are possible analyses to examine internal structure (refer to Section 3, Reliability, and Section 5, Evidence of Internal-External Structure). It is important to assess to which degree the statistical relation between items and test components is invariant across groups. DIF analysis can be used to assess whether specific items function differently for subgroups of test takers (see Volume 1, Section 4.4, Annual Technical Report).

The fourth source of evidence for validity is the relationship of test scores to external variables. The *Standards for Educational and Psychological Testing* (AERA et al., 2014) divides this source of evidence into three parts: (1) convergent and discriminant evidence; (2) test-criterion relationships; and (3) validity generalization. Convergent evidence supports the relationship between the test and other measures intended to assess similar constructs. Conversely, discriminant evidence delineates the test from other measures intended to assess different constructs. To analyze both convergent and discriminant evidence, a multitrait-multimethod matrix can be used. Additionally, test-criterion relationships indicate how accurately test scores predict criterion performance. The degree of accuracy mainly depends on the test’s purpose, such as classification, diagnosis, or selection. Test-criterion evidence is also used to investigate predictions of favoring different groups. Due to construct underrepresentation or construct-irrelevant components, the relation of test scores to a relevant criterion may differ from one group to another. Furthermore, validity generalization is related to whether the evidence is situation-specific or can be generalized across different settings and times. For example, sampling errors or range restrictions may need to be considered to determine whether the conclusions of a test can be assumed for the larger population.

The fifth source of validity evidence is the fact that intended and unintended consequences of test use should be included in the test-validation process. Determining the validity of the test should depend upon evidence directly related to the test; this process should not be influenced by external factors. For example, if an employer administers a test to determine hiring rates for different groups of people, an unequal distribution of skills related to the measurement construct does not necessarily imply a lack of validity for the test; however, if the unequal distribution of scores is in

fact due to an unintended, confounding aspect of the test, this would interfere with the test's validity. Test use should align with the intended purpose of the test.

Supporting a validity argument requires multiple sources of validity evidence. This enables one to evaluate if sufficient evidence has been presented to support the intended uses and interpretations of the test scores. Thus, determining the validity of a test first requires an explicit statement regarding the intended uses of the test scores, and, subsequently, evidence that the scores can be used to support these inferences.

2. PURPOSE OF THE NORTH DAKOTA STATE ASSESSMENT FOR SCIENCE

The primary purpose of the North Dakota State Assessment (NDSA) for Science is to yield accurate information on students' achievement of North Dakota's Science Content Standards. The NDSA for Science measures the science knowledge and skills of North Dakota students in grades 4, 8, and 10. The North Dakota Department of Public Instruction (NDDPI) provides an overview of the NDSA for Science at: www.nd.gov/dpi/districtschools/assessment/nds. Information about the 2019 North Dakota Science Content Standards is available at: www.nd.gov/dpi/districtschools/k-12-education-content-standards.

The NDSA for Science supports instruction and student learning by measuring growth in student achievement. Assessments can be used as indicators to determine whether students in North Dakota are ready with the knowledge and skills that are essential for college education and careers.

North Dakota's educational assessments also provide evidence for the requirements of state and federal accountability systems. Test scores can be employed to evaluate students' learning progress and to help teachers to improve their instruction, which in turn has a positive effect on students' learning over time.

The assessments are constructed to measure student proficiency on the *Standards for Educational and Psychological Testing* (AERA, APA, & NCME, 2014). The NDSA for Science was developed in adherence to the principles of universal design to ensure that all students have access to the test content (refer to Volume 2, Test Development, for a description of the NDSA for Science standards and test blueprints in more detail; see Section 4, Evidence of Content Validity, for additional evidence of content validity). The NDSA for Science test scores are useful indicators for understanding individual students' academic achievement of the 2019 North Dakota Science Content Standards and evaluating whether students are progressing in their performance over time. Additionally, both individual and aggregated scores can be used to for measuring the reliability of the test (see Section 3, Reliability, for the reliability of the test scores).

The NDSA for Science is a criterion-referenced test that is designed to measure students' performance on the three-dimensional science standards in North Dakota schools. As a comparison, norm-referenced tests are designed to compare or rank all students with one another (see Volume 2, Test Development, for the NDSA for Science standards and test blueprints).

The scale score and relative strengths and weaknesses at the discipline level are provided for each student to indicate student strengths and weaknesses in different content areas of the test, relative to the other areas and to the district and state. These scores serve as useful feedback that teachers can use to tailor their instruction. To support their practical use across the state, we must examine the reliability coefficients for and the validity of these test scores.

3. RELIABILITY

Classical test theory-based reliability indices are not appropriate for science for two reasons. First, in spring 2021, the North Dakota State Assessment (NDSA) for Science was administered using an adaptive test design. Each student could potentially get a unique set of items, whereas classical test theory-based reliability indices require that the same set of items be administered to a (large) group of students. Second, since item response theory (IRT) methods are used for calibration and scoring, the measurement error of ability estimates is not constant across the ability range, even for the same set of items. The reliability of science is computed as follows:

$$\bar{\rho} = [\sigma^2 - \left(\frac{\sum_{i=1}^N CSEM_i^2}{N}\right)]/\sigma^2,$$

where N is the number of students; $CSEM_i$ is the Conditional Standard Error of Measurement (CSEM) of the overall ability estimate for student i ; and σ^2 is the variance of the overall ability estimates. The higher the reliability coefficient, the greater the precision of the test.

The marginal reliability of science for the overall sample is reported by grade in Table 2. The overall reliability ranges from 0.82 to 0.85. Due to the new structure of the test, Cambium Assessment, Inc. (CAI) has explored the relationships between reliability and other important factors, such as the effect of nuisance dimensions (refer to Volume 1, Section 5, Annual Technical Report). It was found that if the local dependencies among assertions pertaining to the same item were ignored, the marginal reliability would increase. Ignoring local dependencies can be achieved either by computing the maximum likelihood estimates (MLE) ability estimates under the unidimensional Rasch model or by setting the variance parameters to zero for all item clusters when computing the marginal maximum likelihood estimation (MMLE) ability estimates under the one-parameter logistic (1PL) bifactor model (see Volume 1, Section 6, Annual Technical Report); therefore, by ignoring the local dependencies, which are substantial for many item clusters, the reliability coefficient is overestimating the true reliability of the test. Note, however, that local dependencies are also present to some degree in traditional assessments that make use of item groups (e.g., a set of items relating to the same reading passage). Local dependencies are typically not accounted for by traditional assessments and hence reported reliability coefficients may be overestimating to some degree the true reliability for these tests. The reliability coefficients are also reported for demographics subgroups and reporting categories in Appendix A, Student Demographics and Reliability Coefficients for NDSA Science.

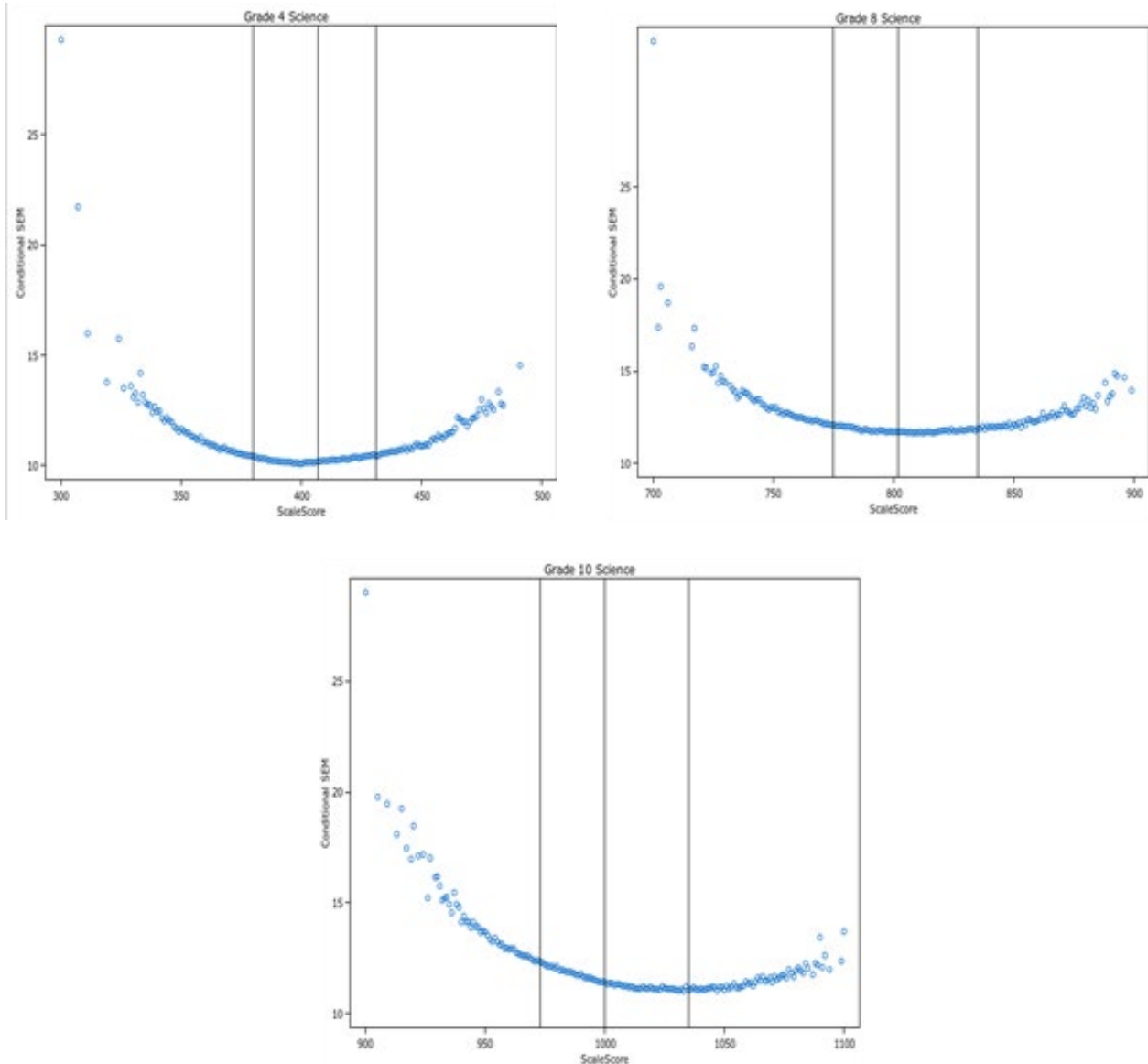
Table 2. Marginal Reliability Coefficients

| Grade | <i>N</i> | Reliability |
|--------------|-----------------|--------------------|
| 4 | 8,524 | 0.85 |
| 8 | 8,326 | 0.82 |
| 10 | 7,148 | 0.82 |

3.1 STANDARD ERROR OF MEASUREMENT

The computation method of CSEM has been described in Volume 1, Section 6.4, Annual Technical Report. Figure 1 presents the average CSEM for each scale score. The lowest standard errors are observed near the proficiency cut score (the middle vertical line) for grades 4 and 8, which is a desirable test property. The CSEM at each scale score is reported in Appendix B, Conditional Standard Error of Measurement for NDSA Science.

Figure 1. Conditional Standard Errors of Measurement



3.2 RELIABILITY OF ACHIEVEMENT CLASSIFICATION

When student achievement is reported in terms of achievement levels, the reliability of classifying students into a specific level can be computed in terms of the likelihood of accurate and consistent classification as specified in Standard 2.16 in the *Standards for Educational and Psychological Testing* (AERA, APA, & NCME, 2014).

The reliability of achievement classification can be examined in terms of the classification accuracy (CA) and classification consistency (CC). CA refers to the agreement between the classifications based on the form taken and the classifications that would be made based on the students' true scores if hypothetically they could be obtained. CC refers to the agreement between the classifications based on the form taken and the classifications that would be made based on an alternate, equivalently constructed test form.

In reality, students' true abilities are unknown, and students are not administered an alternate, equivalent form. Therefore, CA and CC are estimated based on students' item scores, the item parameters, and the assumed latent ability distribution as described in the following sections. The true score is an expected value of the test score with measurement error.

For student j , the student's estimated ability is $\hat{\theta}_j$ with a Standard Error of Measurement (SEM) of $se(\hat{\theta}_j)$, and the estimated ability is distributed as $\hat{\theta}_j \sim N(\theta_j, se^2(\hat{\theta}_j))$, assuming a normal distribution, where θ_j is the unknown true ability of student j . The probability of the true score at achievement level l ($l = 1, \dots, L$) is estimated as

$$\begin{aligned} p_{jl} &= p(c_{Ll} \leq \theta_j < c_{Ul}) = p\left(\frac{c_{Ll} - \hat{\theta}_j}{se(\hat{\theta}_j)} \leq \frac{\theta_j - \hat{\theta}_j}{se(\hat{\theta}_j)} < \frac{c_{Ul} - \hat{\theta}_j}{se(\hat{\theta}_j)}\right) \\ &= p\left(\frac{\hat{\theta}_j - c_{Ul}}{se(\hat{\theta}_j)} < \frac{\hat{\theta}_j - \theta_j}{se(\hat{\theta}_j)} \leq \frac{\hat{\theta}_j - c_{Ll}}{se(\hat{\theta}_j)}\right) = \Phi\left(\frac{\hat{\theta}_j - c_{Ll}}{se(\hat{\theta}_j)}\right) - \Phi\left(\frac{\hat{\theta}_j - c_{Ul}}{se(\hat{\theta}_j)}\right), \end{aligned}$$

where c_{Ll} and c_{Ul} denote the score corresponding to the lower and upper limits of the achievement level l , respectively.

3.2.1 Classification Accuracy

Using p_{jl} , an $L \times L$ matrix E_A can be calculated. Each element E_{Akl} of matrix E_A represents the expected number of students at level l (based on their true scores) given students from observed level k , and can be calculated as

$$E_{Akl} = \sum_{p|_j \in k} p_{jl},$$

where $p|_j$ is the j th student's observed achievement level. The CA at level l is estimated by

$$CA_l = \frac{E_{Akl}}{N_k},$$

where N_k is the observed number of students scoring in achievement level k .

The CA for the p th cut is estimated by forming square partitioned blocks of the matrix E_A and taking the summation over all elements within the block as follows:

$$CAC = (\sum_{k=1}^p \sum_{l=1}^p E_{Akl} + \sum_{k=p+1}^L \sum_{l=p+1}^L E_{Akl})/N,$$

where N is the total number of students.

The overall CA is estimated from the diagonal elements of the matrix:

$$CA = \frac{tr(E_A)}{N}.$$

Table 3 provides the CA for the individual cut scores. The overall CA of the test ranges from 72.54–73.57%. The individual cut score accuracy rates are high across all grades and forms, with the minimum value being 87.29% for grade 8. It denotes that more than 87% of the time, we can accurately differentiate students between adjacent achievement levels in the 2020–2021 NDSA for Science. The CA for demographic subgroups is presented in Appendix C, Classification Accuracy and Consistency Index by Subgroups for NDSA Science.

Table 3. Classification Accuracy Index

| Grade | Overall Accuracy (%) | Cut Score Accuracy (%) | | |
|-------|----------------------|------------------------|-------------|-------------|
| | | Cut Score 1 | Cut Score 2 | Cut Score 3 |
| 4 | 73.57 | 90.66 | 89.53 | 93.28 |
| 8 | 72.54 | 91.62 | 87.29 | 93.50 |
| 10 | 72.88 | 90.86 | 87.64 | 94.26 |

3.2.2 Classification Consistency

Assuming the test is administered twice independently to the same group of students, similarly to accuracy, a $L \times L$ matrix E_C can be constructed. The element of E_C is populated by

$$E_{Ckl} = \sum_{j=1}^N p_{jl} p_{jk},$$

where p_{jl} is the probability of the true score at achievement level l in test one, and p_{jk} is the probability of the true score at achievement level k in test two for the j th student. The classification consistency index for the cuts (CCC) and overall CC were estimated in a way similar to CAC and CA.

$$CCC = (\sum_{k=1}^p \sum_{l=1}^p E_{Ckl} + \sum_{k=p+1}^L \sum_{l=p+1}^L E_{Ckl})/N,$$

and

$$CC = \frac{tr(E_C)}{N}.$$

Table 4 provides the CC for the cut scores. The overall CC of the test ranges from 62.44–63.92%. The individual cut score consistency rates are high across all grades and forms, with the minimum value being 82.34% for grade 8. In all achievement levels, CA is slightly higher than CC. CC rates can be lower than CA; the consistency is based on two tests with measurement errors, but the accuracy is based on one test with a measurement error and the true score. The CC for demographic subgroups is presented in Appendix C, Classification Accuracy and Consistency Index by Subgroups for NDSA Science.

Table 4. Classification Consistency Index

| Grade | Overall Consistency (%) | Cut Score Consistency (%) | | |
|-------|-------------------------|---------------------------|-------------|-------------|
| | | Cut Score 1 | Cut Score 2 | Cut Score 3 |
| 4 | 63.92 | 86.93 | 85.34 | 90.53 |
| 8 | 62.44 | 88.21 | 82.34 | 90.70 |
| 10 | 62.85 | 87.20 | 82.69 | 91.86 |

3.3 PRECISION AT CUT SCORES

Table 5 presents the mean CSEM at each achievement level by grade and includes achievement-level cut scores and associated CSEM. The CSEM at each scale score is reported in Appendix B, Conditional Standard Error of Measurement for NDSA Science.

Table 5. Achievement Levels and Associated Conditional Standard Error of Measurement

| Grade | Achievement Level | Mean CSEM | Cut Score (Scale Score) | CSEM at Cut Score |
|-------|----------------------|-----------|-------------------------|-------------------|
| 4 | Novice | 11.00 | - | - |
| | Partially Proficient | 10.19 | 380 | 10.40 |
| | Proficient | 10.30 | 407 | 10.18 |
| | Advanced | 10.81 | 431 | 10.42 |
| 8 | Novice | 12.74 | - | - |
| | Partially Proficient | 11.83 | 775 | 12.07 |
| | Proficient | 11.72 | 802 | 11.69 |
| | Advanced | 12.12 | 835 | 11.89 |
| 10 | Novice | 13.21 | - | - |
| | Partially Proficient | 11.83 | 973 | 12.34 |
| | Proficient | 11.21 | 1,000 | 11.43 |
| | Advanced | 11.28 | 1,035 | 11.07 |

4. EVIDENCE OF CONTENT VALIDITY

The knowledge and skills assessed by the North Dakota State Assessment (NDSA) for Science are representative of the content standards of the larger knowledge domain. We describe the content standards for the NDSA for Science and discuss the test development process and mapping NDSA for Science tests to the *Standards for Educational and Psychological Testing* (AERA, APA, & NCME, 2014). A complete description of the test development process can be found in Volume 2, Test Development.

4.1 CONTENT STANDARDS

The NDSA for Science was aligned to the new three-dimensional North Dakota Science Content Standards, adopted by North Dakota in 2019. The 2019 North Dakota Science Content Standards are available for review at: www.nd.gov/dpi/districtschools/k-12-education-content-standards. Test blueprints were developed to ensure that the test and the items were aligned to the prioritized standards that they were intended to measure. A complete description of the blueprint and test construction process can be found in Volume 2, Test Development.

Table 6 presents the disciplines by grade, as well as the number of operational items administered to measure each discipline.

Table 6. Number of Items for Each Discipline

| Grade | Discipline | Item Clusters | Stand-Alone Items |
|-------|--------------------------------|---------------|-------------------|
| 4 | Earth and Space Sciences (ESS) | 7 | 6 |
| | Life Sciences (LS) | 9 | 15 |
| | Physical Sciences (PS) | 5 | 13 |
| 8 | Earth and Space Sciences (ESS) | 8 | 15 |
| | Life Sciences (LS) | 6 | 19 |
| | Physical Sciences (PS) | 10 | 10 |
| 10 | Life Sciences (LS) | 14 | 31 |
| | Physical Sciences (PS) | 5 | 5 |

4.2 INDEPENDENT ALIGNMENT STUDY

While it is critically important to develop and strictly enforce an item development process that works to ensure the alignment of test items to content standards, it is also important to independently verify the alignment of test items to content standards. EdMetric LLC served as an external evaluator and conducted an alignment study in October 2021. The purpose of the study was to examine the extent to which the NDSA for Science item pool represented the North Dakota Science Content Standards as represented by the test blueprints in terms of range, complexity, depth, and breadth.

The results of the alignment study are presented in Appendix F, Independent Alignment Study Report.

5. EVIDENCE OF INTERNAL-EXTERNAL STRUCTURE

In this section, the internal structure of the assessment is explored using the scores provided at the discipline level. The relationship between the discipline scores is just one indicator of test dimensionality. The North Dakota State Assessment (NDSA) for Science is modeled with the Rasch testlet model (Wang & Wilson, 2005). The item response theory (IRT) model is a high-dimensional model, incorporating a nuisance dimension for each item cluster (and stand-alone items with four or more assertions), in addition to an overall dimension representing the overall proficiency. This approach is innovative and quite different from the traditional approach of ignoring local dependencies. Validity evidence on the internal structure will focus on the presence of cluster effects and how substantial they are. Additionally, confirmatory factor analysis is used to evaluate the fit of the IRT model and to compare the model to alternative models, including models with a simpler internal structure (i.e., unidimensional models without cluster effects) and models with a more elaborate internal structure.

Another pathway is to explore observed correlations between the discipline scores; however, as each discipline is measured with a small number of items, the standard errors of the observed scores within each discipline are typically larger than the standard error of the total test score. Disattenuating for measurement error could offer some insight into the theoretical true score correlations. Both observed correlations and disattenuated correlations are provided in the following subsection.

5.1 CORRELATIONS AMONG DISCIPLINE SCORES

Table 7 presents the observed and disattenuated correlation matrix of the discipline scores. The observed correlations range from 0.58 to 0.64, and disattenuated correlations range from 0.96 to 1.00.

In some instances, the observed correlations were lower than one might expect. However, as previously noted, the correlations were subject to a large amount of measurement error at the discipline level, given the limited number of items from which the scores were derived. Consequently, over-interpretation of these correlations as either high or low should be made cautiously. After correcting for measurement error, the correlations between the discipline scores become very high. The disattenuated correlations are close to 1, supporting the use of a psychometric model that does not include a separate dimension for each of the three disciplines.

Table 7. Correlations Among Disciplines

| Grade | Discipline | Earth and Space Sciences (ESS) | Life Sciences (LS) | Physical Sciences (PS) |
|-------|--------------------------|--------------------------------|--------------------|------------------------|
| 4 | Earth and Space Sciences | 0.68* | 0.96 | 0.96 |
| | Life Sciences | 0.64 | 0.66* | 0.96 |
| | Physical Sciences | 0.64 | 0.63 | 0.66* |
| 8 | Earth and Space Sciences | 0.62* | 0.98 | 1.00 |
| | Life Sciences | 0.62 | 0.63* | 1.00 |
| | Physical Sciences | 0.59 | 0.58 | 0.53* |
| 10 | Life Sciences | NA | 0.79* | 1.00 |
| | Physical Sciences | NA | 0.64 | 0.48* |

Note. *The values for cells shaded on the diagonal are marginal reliabilities for each discipline. Below the cells shaded on the diagonal are the observed correlations, and above the cells shaded on the diagonal are the disattenuated correlations. The disattenuated correlations larger than 1 were truncated to 1.

5.2 CONVERGENT AND DISCRIMINANT VALIDITY

According to Standard 1.16 of the *Standards for Educational and Psychological Testing* (AERA et al., 2014), it is necessary to provide evidence of convergent and discriminant validity evidence. It is a part of validity evidence demonstrating that assessment scores are related as expected with criteria and other variables for all student groups. However, a second, independent test measuring the same science construct as the NDSA for Science, which could easily permit for a cross-test set of correlations, was not available. Alternatively, the correlations between subscores were examined. The *a priori* expectation is that subscores within the same subject (e.g., correlations of science disciplines within science) will correlate more positively than subscores correlations across subjects (e.g., correlation of science disciplines with reporting categories within mathematics). These correlations are based on a small number of items; consequently, the observed score correlations will be smaller in magnitude as a result of the larger measurement error at the subscore level. For this reason, both the observed score and the disattenuated correlations are provided.

Observed and disattenuated subscore correlations were calculated both within and across subjects. The pattern is generally consistent with the *a priori* expectation that subscores within a test have higher correlations than correlations between tests measuring a different construct. The correlations between reporting categories from science, English language arts (ELA), and mathematics are presented in Table 8 through Table 10. The cells shaded on the diagonal show the reliability coefficient of the reporting category.

Table 8. Correlations Across Subjects, Grade 4

| Subject | Number of Students | Reporting Category | Science | | | ELA | | | Mathematics | | | |
|-------------|--------------------|--|---------|-------|-------|-------|-------|-------|-------------|-------|-------|-------|
| | | | Cat1 | Cat2 | Cat3 | Cat1 | Cat2 | Cat3 | Cat1 | Cat2 | Cat3 | Cat4 |
| Science | 8,473 | Earth and Space Sciences (ESS) (Cat1) | 0.68* | 0.96 | 0.96 | 0.72 | 0.77 | 0.68 | 0.75 | 0.70 | 0.74 | 0.76 |
| | | Life Sciences (LS) (Cat2) | 0.64 | 0.66* | 0.96 | 0.76 | 0.83 | 0.73 | 0.76 | 0.73 | 0.74 | 0.78 |
| | | Physical Sciences (PS) (Cat3) | 0.64 | 0.63 | 0.66* | 0.72 | 0.78 | 0.72 | 0.79 | 0.74 | 0.77 | 0.80 |
| ELA | | Reading Standards for Informational/Nonfiction Text (Cat1) | 0.49 | 0.51 | 0.49 | 0.69* | 0.77 | 0.66 | 0.62 | 0.60 | 0.60 | 0.65 |
| | | Reading Standards for Literature/Fiction (Cat2) | 0.55 | 0.59 | 0.55 | 0.55 | 0.75* | 0.72 | 0.66 | 0.62 | 0.63 | 0.68 |
| | | Writing and Language Standards (Cat3) | 0.49 | 0.53 | 0.51 | 0.49 | 0.55 | 0.78* | 0.64 | 0.66 | 0.63 | 0.69 |
| Mathematics | | Measurement, Data, and Geometry (Cat1) | 0.54 | 0.54 | 0.56 | 0.45 | 0.50 | 0.49 | 0.76* | 0.84 | 0.84 | 0.87 |
| | | Number and Operations in Base Ten (Cat2) | 0.50 | 0.51 | 0.52 | 0.43 | 0.47 | 0.50 | 0.64 | 0.75* | 0.84 | 0.91 |
| | | Number and Operations - Fractions (Cat3) | 0.53 | 0.53 | 0.55 | 0.44 | 0.48 | 0.50 | 0.65 | 0.64 | 0.78* | 0.86 |
| | | Operations and Algebraic Thinking (Cat4) | 0.54 | 0.55 | 0.57 | 0.47 | 0.51 | 0.53 | 0.66 | 0.69 | 0.66 | 0.77* |

Note. *Cells shaded on the diagonal represent the reliability coefficient of the reporting category. Observed correlations are below the cells shaded on the diagonal; disattenuated correlations are above. The disattenuated correlations larger than 1 were truncated to 1.

Table 9. Correlations Across Subjects, Grade 8

| Subject | Number of Students | Reporting Category | Science | | | ELA | | | Mathematics | | | |
|-------------|--------------------|--|---------|-------|-------|-------|-------|-------|-------------|-------|-------|-------|
| | | | Cat1 | Cat2 | Cat3 | Cat1 | Cat2 | Cat3 | Cat1 | Cat2 | Cat3 | Cat4 |
| Science | 8,234 | Earth and Space Sciences (ESS) (Cat1) | 0.62* | 0.99 | 1.00 | 0.76 | 0.75 | 0.71 | 0.81 | 0.78 | 0.68 | 0.80 |
| | | Life Sciences (LS) (Cat2) | 0.62 | 0.63* | 1.00 | 0.80 | 0.80 | 0.73 | 0.83 | 0.79 | 0.72 | 0.81 |
| | | Physical Sciences (PS) (Cat3) | 0.59 | 0.58 | 0.53* | 0.82 | 0.81 | 0.75 | 0.85 | 0.82 | 0.73 | 0.82 |
| ELA | | Reading Standards for Informational/Nonfiction Text (Cat1) | 0.50 | 0.53 | 0.50 | 0.70* | 0.83 | 0.73 | 0.69 | 0.72 | 0.58 | 0.70 |
| | | Reading Standards for Literature/Fiction (Cat2) | 0.50 | 0.53 | 0.49 | 0.58 | 0.70* | 0.71 | 0.69 | 0.69 | 0.58 | 0.68 |
| | | Writing and Language Standards (Cat3) | 0.50 | 0.52 | 0.49 | 0.55 | 0.54 | 0.81* | 0.72 | 0.70 | 0.61 | 0.71 |
| Mathematics | | Expressions and Equations and Number Systems (Cat1) | 0.55 | 0.57 | 0.53 | 0.50 | 0.50 | 0.56 | 0.75* | 0.89 | 0.82 | 0.91 |
| | | Functions (Cat2) | 0.49 | 0.50 | 0.47 | 0.48 | 0.46 | 0.50 | 0.62 | 0.64* | 0.74 | 0.85 |
| | | Geometry (Cat3) | 0.44 | 0.47 | 0.44 | 0.41 | 0.40 | 0.46 | 0.59 | 0.49 | 0.69* | 0.75 |
| | | Statistics and Probability (Cat4) | 0.54 | 0.55 | 0.51 | 0.50 | 0.49 | 0.55 | 0.68 | 0.58 | 0.53 | 0.73* |

Note. *Cells shaded on the diagonal represent the reliability coefficient of the reporting category. Observed correlations are below the cells shaded on the diagonal; disattenuated correlations are above. The disattenuated correlations larger than 1 were truncated to 1.

Table 10. Correlations Across Subjects, Grade 10

| Subject | Number of Students | Reporting Category | Science | | ELA | | | Mathematics | | | |
|-------------|--------------------|--|---------|-------|-------|-------|-------|-------------|-------|-------|-------|
| | | | Cat2 | Cat3 | Cat1 | Cat2 | Cat3 | Cat1 | Cat2 | Cat3 | Cat4 |
| Science | 2,905 | Life Sciences (LS) (Cat2) | 0.78* | 1.00 | 0.86 | 0.83 | 0.77 | 0.78 | 0.80 | 0.81 | 0.75 |
| | | Physical Sciences (PS) (Cat3) | 0.65 | 0.47* | 0.86 | 0.81 | 0.77 | 0.83 | 0.83 | 0.82 | 0.77 |
| ELA | | Reading Standards for Informational/Nonfiction Text (Cat1) | 0.63 | 0.50 | 0.70* | 0.89 | 0.79 | 0.71 | 0.71 | 0.72 | 0.66 |
| | | Reading Standards for Literature/Fiction (Cat2) | 0.59 | 0.45 | 0.60 | 0.66* | 0.76 | 0.68 | 0.67 | 0.69 | 0.63 |
| | | Writing and Language Standards (Cat3) | 0.61 | 0.48 | 0.59 | 0.55 | 0.82* | 0.68 | 0.66 | 0.69 | 0.63 |
| Mathematics | | Algebra (Cat1) | 0.59 | 0.49 | 0.51 | 0.47 | 0.52 | 0.73* | 0.82 | 0.82 | 0.75 |
| | | Functions (Cat2) | 0.55 | 0.45 | 0.46 | 0.43 | 0.47 | 0.55 | 0.61* | 0.81 | 0.73 |
| | | Geometry (Cat3) | 0.61 | 0.48 | 0.51 | 0.48 | 0.53 | 0.60 | 0.54 | 0.73* | 0.77 |
| | | Statistics and Probability (Cat4) | 0.56 | 0.45 | 0.46 | 0.43 | 0.48 | 0.54 | 0.48 | 0.55 | 0.70* |

Note. *Cells shaded on the diagonal represent the reliability coefficient of the reporting category. Observed correlations are below the cells shaded on the diagonal; disattenuated correlations are above. The disattenuated correlations larger than 1 were truncated to 1.

Additionally, the correlation was computed among the overall scores for the three tested subjects: ELA, mathematics, and science as shown in Table 11.

*Table 11. Correlations Across Spring 2021
English Language Arts, Mathematics, and Science Scores*

| Grade | N | ELA & Mathematics | ELA & Science | Mathematics & Science |
|-------|-------|-------------------|---------------|-----------------------|
| 4 | 8,473 | 0.69 | 0.73 | 0.72 |
| 8 | 8,234 | 0.72 | 0.71 | 0.72 |
| 10 | 2,905 | 0.70 | 0.73 | 0.72 |

5.3 CLUSTER EFFECTS

The NDSA for Science is modeled with the Rasch testlet model (Wang & Wilson, 2005). The IRT model is a high-dimensional model that incorporates a nuisance dimension for each item cluster in addition to an overall dimension representing overall proficiency. Section 5.1, Model Description, of Volume 1, Annual Technical Report, presents a detailed description of the IRT model. The internal (latent) structure of the model is presented in Figure 7 of this volume. The psychometric approach for the assessment is innovative and quite different from the traditional approach of ignoring local dependencies. The validity evidence on the internal structure presented in this section relates to the presence of cluster effects and how substantial they are.

Simulation studies conducted by Rijmen, Jiang, & Turhan (2018) confirmed that both the item difficulty parameters and the cluster variances are recovered well for the Rasch testlet model (Wang & Wilson, 2005) under a variety of conditions. Cluster effects with a range of magnitudes were recovered well. The results obtained by Rijmen et al. (2018) confirmed earlier findings reported in the literature under conditions that were chosen to closely resemble the assessment (e.g., Bradlow, Wainer, & Wang, 1999). For example, in one of the studies, the item location parameters and cluster variances used to simulate data were based on the results of a pilot study.

Cambium Assessment, Inc. (CAI) examined the distribution of cluster variances obtained from the 2019 IRT calibrations for the entire Independent College and Career Readiness (ICCR) item bank. For elementary school, the estimated value of the cluster variances of all operational, scored items ranged from 0 to 5.13, with a median value of 0.38 and a mean value of 0.78. As a comparison, the estimated variance parameter of the overall dimension for North Dakota elementary school in 2021 was $\hat{\sigma}_{\theta ND}^2 = 0.67$.

For middle school, the estimated value of the cluster variances of all operational, scored items ranged from 0 to 2.47, with a median value of 0.43 and a mean value of 0.57. The estimated variance parameter of the overall dimension for North Dakota middle school in 2021 was $\hat{\sigma}_{\theta ND}^2 = 0.42$.

For high school, the estimated value of the cluster variances of all operational, scored items ranged from 0.07 to 2.58, with a median value of 0.43 and a mean value of 0.52. The estimated variance parameter of the overall dimension for North Dakota high school in 2021 was $\hat{\sigma}_{\theta ND}^2 = 0.48$.

Figure 2 through Figure 4 present the histograms of the cluster variances expressed as the proportion of the systematic variance due to the cluster variance for each cluster (computed as $\eta_g = \frac{\sigma_g^2}{\sigma_{\theta_{ND}}^2 + \sigma_g^2}$), where $\sigma_{\theta_{ND}}^2$ is the variance estimate of the overall proficiency of North Dakota students.

For all three grade bands, a wide range of cluster variances was observed. These results indicate that, for all grades, cluster effects can be substantial and provide evidence for the appropriateness of a psychometric model that explicitly takes local dependencies among the assertions of an item cluster into account.

Figure 2. Cluster Variance Proportion for Operational Items in Elementary School

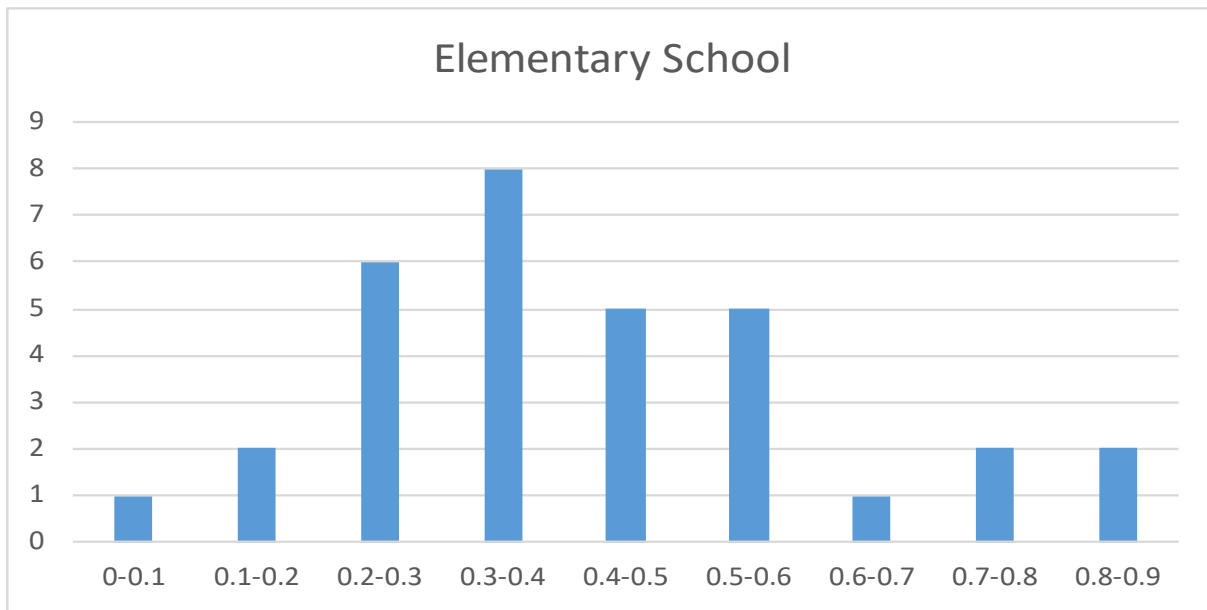


Figure 3. Cluster Variance Proportion for Operational Items in Middle School

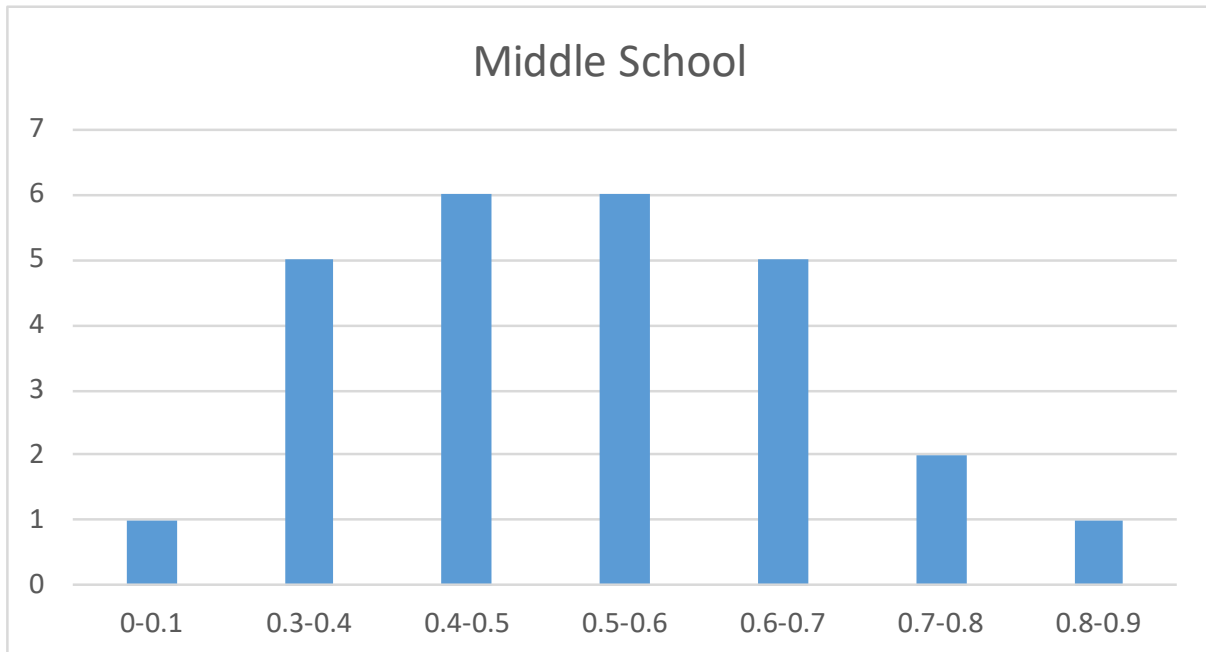
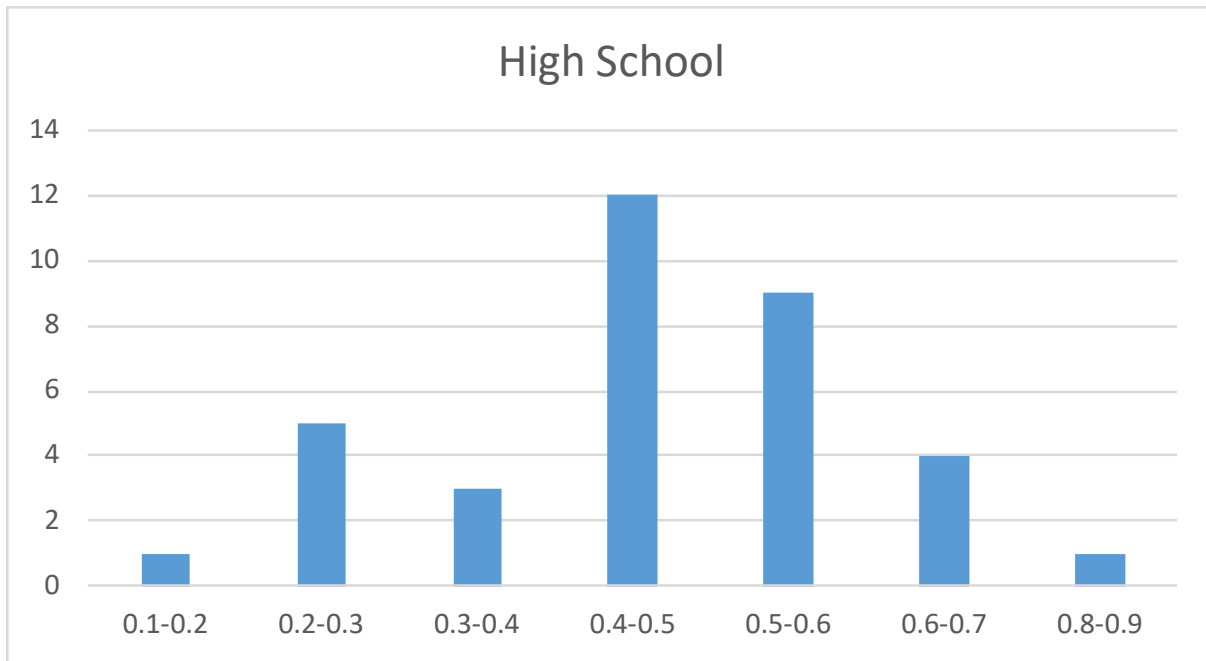


Figure 4. Cluster Variance Proportion for Operational Items in High School



5.4 CONFIRMATORY FACTOR ANALYSIS

In Section 5.3, Cluster Effects, evidence is presented for the existence of substantial cluster effects. In this section, the internal structure of the IRT model used for calibrating the item parameters is further evaluated using confirmatory factor analysis. In addition, alternative models are considered, including models with a simpler internal structure (e.g., unidimensional models) and models with a more elaborate internal structure.

Estimation methods for confirmatory factor analysis for discrete observed variables are not well suited for incomplete data collection designs where each case has data only on a subset of the set of observed variables. The linear-on-the-fly (LOFT) test design results in sparse data matrices. Every student is responding to only a small number of items relative to the size of the item pool, so data are missing on most of the manifest variables for any given student. In 2018 and 2019, a LOFT test design was used for all operational science assessments inspired by a three-dimensional science framework, except for Utah. As a result, the student responses of these other states are not readily amenable for the application of confirmatory factor analysis techniques.

The 2018 Utah science operational field test made use of a set of fixed-form tests for each grade. Therefore, the data for each fixed-form test are complete, and the fixed-form tests are amenable to confirmatory factor analysis. The Utah science standards, even though the standards are grade-specific for middle school, were developed under a framework similar to the one developed for the Next Generation Science Standards (NGSS), and a crosswalk is available between both sets of standards. Utah is part of the Memorandum of Understanding (MOU), and many of the other states that take part in the MOU also use the middle school items developed for and owned by Utah. Taken together, analyzing the science fixed-form tests that were administered in Utah in 2018 can provide evidence with respect to the internal structure of the NDSA for Science.

In 2018, Utah’s science assessments comprised a set of fixed-form tests per grade, and all items in these forms were item clusters. The number of fixed-form tests varied by grade, but within each grade the total number of item clusters was the same across forms. However, some items were rejected during the rubric validation or data review and were removed from this analysis. All students with a “completed” status were included in the factor analysis. The percentage of students per grade that had a status other than “completed” was less than 0.85%. Table 12 summarizes the number of forms included in this analysis, the number of item clusters per discipline (range across forms), the number of assertions (range across forms), and the number of students (range across forms) for each one of the grades.

Table 12. Number of Forms, Clusters per Discipline (Range Across Forms), Number of Assertions per Form (Range Across Forms), and Number of Students per Form (Range Across Forms)

| Grade | Number of Fixed Forms | Number of Item Clusters per Discipline in Each Form | | | Number of Assertions per Form | Number of Students per Form |
|----------|-----------------------|---|----------------------|--------------------------|-------------------------------|-----------------------------|
| | | <i>Earth and Space Sciences</i> | <i>Life Sciences</i> | <i>Physical Sciences</i> | | |
| 6 | 3 | 2–3 | 2–3 | 2 | 74–83 | 6,804–6,881 |
| 7 | 6 | 2 | 5 | 2 | 83–89 | 3,822–3,890 |
| 8 | 3 | 2 | 2 | 6–7 | 93–100 | 5,061–5,104 |

The factor structure of a testlet model, which is the model used for calibration, is formally equivalent to a second-order model. Specifically, the testlet model is the model obtained after a Schmid Leiman transformation of the second-order model (Li, Bolt, & Fu, 2006; Rijmen, 2009; Yung, Thissen, & McLeod, 1999). In the corresponding second-order model, the group of assertions related to an item cluster are indicators of the item cluster, and each item cluster is an indicator of overall science achievement. Because assertions are not pure indicators of a specific factor, each assertion has a corresponding error component. Similarly, item clusters include an error component indicating that they are not pure indicators of the overall science achievement.

CAI used confirmatory factor analysis to evaluate the fit of the second-order model described above to student data from spring 2018. Three additional structural models were included in the analysis, as well. In the first model, there is only one factor representing overall science achievement. All assertions are indicators of this overall proficiency factor. The first model is a testlet model where all cluster variances are zero. In the second model, assertions are indicators of the corresponding science discipline, and each discipline is an indicator of the overall science achievement. This is a second-order model with science disciplines rather than item clusters as first-order factors. This model does not take the cluster effects into account. In the last, most general model, assertions are indicators of the corresponding item cluster, and item clusters are indicators of the corresponding science discipline, with disciplines being indicators of the overall science achievement. For the sake of simplicity, the models in the analysis are here referred to as:

- Model 1–Assertions-Overall Science (one-factor model)
- Model 2–Assertions-Disciplines-Overall Science (second-order model)
- Model 3–Assertions-Clusters-Overall Science (second-order model)
- Model 4–Assertions-Clusters-Disciplines-Overall Science (third-order model)

Figure 5 to Figure 8 illustrate these four structural models. Model 1 is nested within Models 2, 3, and 4. Also, Models 2 and 3 are nested within Model 4. The paths from the factors to the assertions represent the first-order factor loadings. Note that all four models include factor loadings for the assertions, which is different from the calibration model for which all the discrimination parameters of the assertions were set to 1.

Figure 5. One-Factor Structural Model (Assertions-Overall Science): “Model 1”

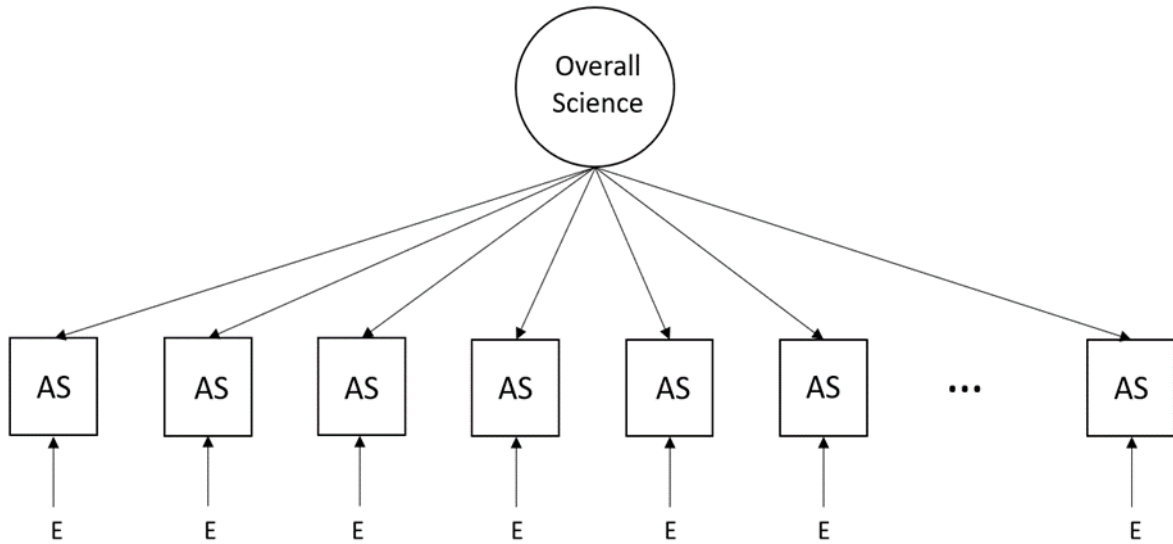


Figure 6. Second-Order Structural Model (Assertions-Disciplines-Overall Science): “Model 2”

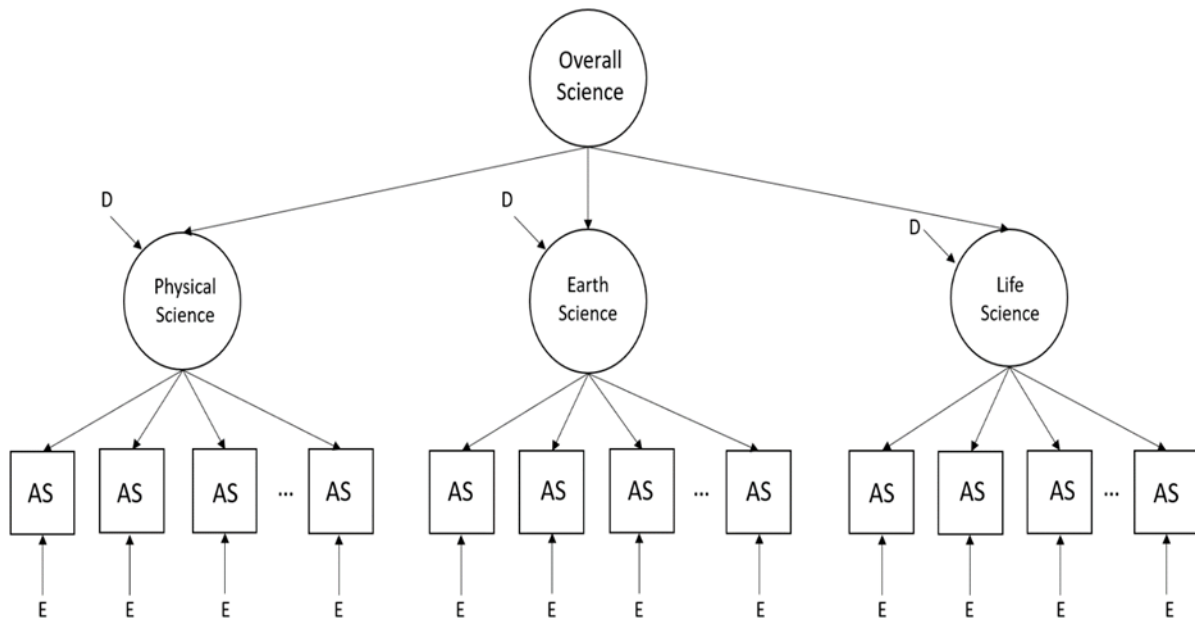


Figure 7. Second-Order Structural Model (Assertions-Clusters-Overall Science): “Model 3”

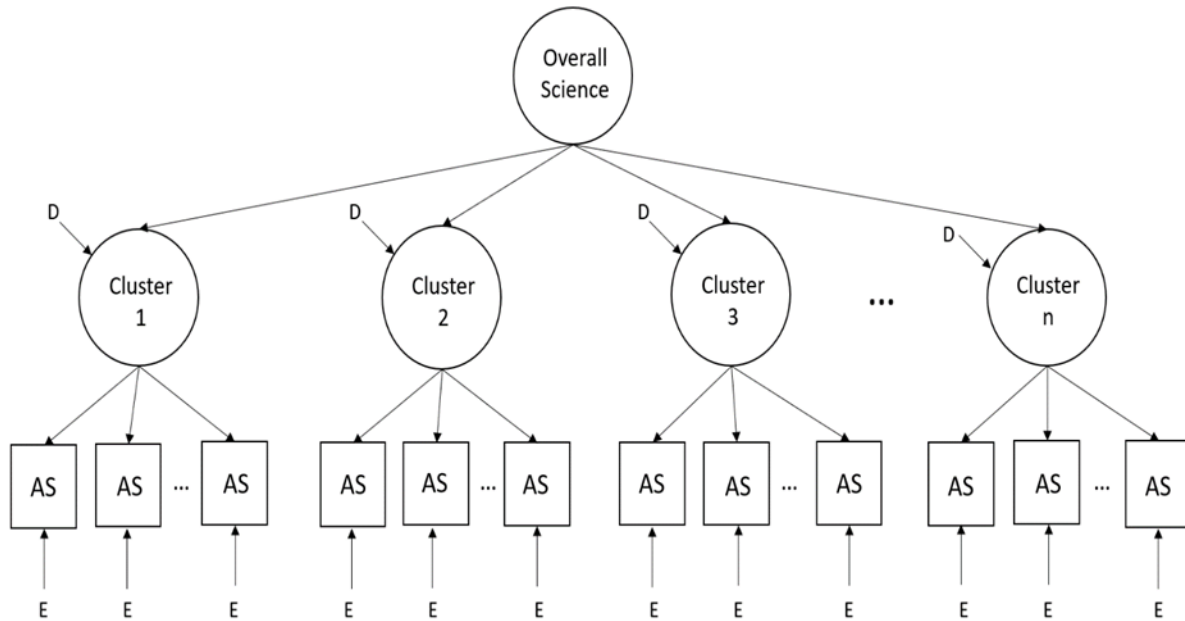
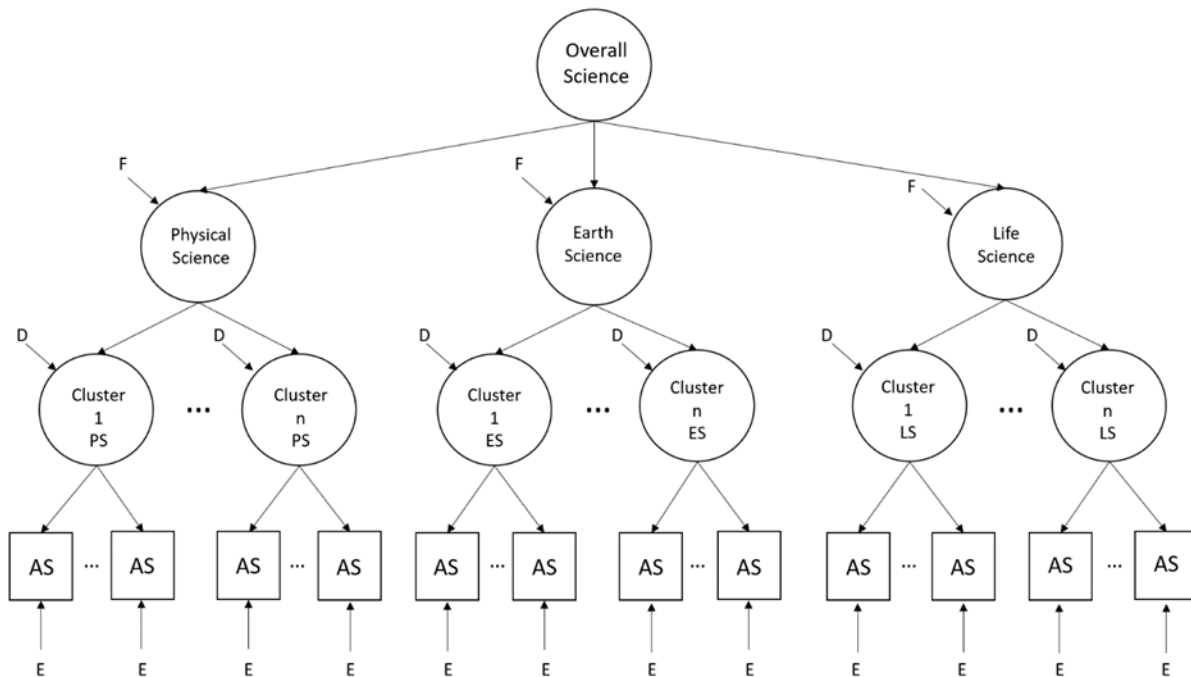


Figure 8. Third-Order Structural Model (Assertions-Clusters-Disciplines-Overall Science): “Model 4”



5.4.1 Results

For each test form, fit measures were computed for each of the four models. The fit measures used to evaluate goodness-of-fit were the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), the Root Mean Square Error of Approximation (RMSEA), and the Standardized Root Mean Residual (SRMR). CFI and TLI are relative fit indices, meaning they evaluate model fit by comparing the model of interest to a baseline model. RMSEA and SRMR are indices of absolute fit. Table 13 provides a list of these measures along with the corresponding thresholds indicating a good fit.

*Table 13. Guidelines for Evaluating Goodness-of-Fit**

| Goodness-of-Fit Measure | Indication of Good Fit |
|-------------------------|------------------------|
| CFI | ≥ 0.95 |
| TLI | ≥ 0.95 |
| RMSEA | ≤ 0.06 |
| SRMR | ≤ 0.08 |

Note. *Brown, 2015; Hu & Bentler, 1999

Table 14 through Table 16 show the goodness-of-fit statistics for grades 6–8, respectively.¹ Numbers in bold indicate those indices that did not meet the criteria established in Table 13. Across all grades and models, the following conclusions can be drawn:

- Model 1 shows the most misfit across grades and forms.
- Across forms, Model 3 generally shows more improvement in model fit relative to Model 1 than Model 2 does (i.e., higher values for CFI and TLI and lower values for RMSEA and SRMR). This means that accounting for the clusters resulted in a higher improvement in model fit over a single factor model than accounting for disciplines.
- Model 4 does not show improvement in model fit over Model 3. Fit measures remained the same (or had a difference of 0.001 or smaller in very few cases) across forms for Models 3 and 4. Hence, including the disciplines into the model (when clusters are taken into account) did not improve model fit.
- Overall model fit for Models 3 and 4 decreases with decreasing grades. For grade 8, all fit indices for Models 3 and 4 indicate good model fit for all three forms. For grade 7, all fit indices for Models 3 and 4 indicate good fit for two out of the six forms, and the degree of misfit for the other four forms is small. For grade 6, all three forms have fit indices above the threshold values for at least one of the absolute fit indices for Models 3 and 4.

¹ For very few assertions per form and models, some error variances for the assertions were slightly below 0. For grade 6, 1–2 assertions per form and model had error variance below 0, with the lowest error variance being -0.027 . For grade 7, Forms 1, 2, 5, and 6 each had one negative error variance for one assertion in Models 3 and 4, with the lowest error variance being -0.099 . Form 4 had 1–2 assertions with negative error variance in each model, and the lowest error variance was -0.102 . For grade 8, there were no assertions with negative error variances for any of the forms or models.

The amount of misfit is small for the RMSEA but more substantial for the SRMR for two out of the three forms.

Table 14. Fit Measures per Model and Form, Grade 6

| Model | Form | CFI | TLI | RMSEA | SRMR |
|---|------|-------|-------|--------------|--------------|
| Model 1 Assertions-Overall Science (one-factor model) | 1 | 0.995 | 0.995 | 0.106 | 0.163 |
| | 2 | 0.997 | 0.997 | 0.093 | 0.148 |
| | 3 | 0.995 | 0.995 | 0.109 | 0.161 |
| Model 2 Assertions-Disciplines-Overall Science (second-order model) | 1 | 0.996 | 0.996 | 0.089 | 0.144 |
| | 2 | 0.998 | 0.998 | 0.078 | 0.128 |
| | 3 | 0.997 | 0.997 | 0.087 | 0.135 |
| Model 3 Assertions-Clusters-Overall Science (second-order model) | 1 | 0.998 | 0.998 | 0.065 | 0.107 |
| | 2 | 0.999 | 0.999 | 0.056 | 0.095 |
| | 3 | 0.998 | 0.998 | 0.067 | 0.104 |
| Model 4 Assertions-Clusters-Disciplines-Overall Science (third-order model) | 1 | 0.998 | 0.998 | 0.065 | 0.107 |
| | 2 | 0.999 | 0.999 | 0.056 | 0.095 |
| | 3 | 0.998 | 0.998 | 0.067 | 0.104 |

Note. Numbers in bold do not meet the criteria for goodness-of-fit.

Table 15. Fit Measures per Model and Form, Grade 7

| Model | Form | CFI | TLI | RMSEA | SRMR |
|---|------|--------------|--------------|--------------|--------------|
| Model 1 Assertions-Overall Science (one-factor model) | 1 | 0.892 | 0.889 | 0.060 | 0.074 |
| | 2 | 0.938 | 0.936 | 0.083 | 0.109 |
| | 3 | 0.940 | 0.939 | 0.052 | 0.065 |
| | 4 | 0.937 | 0.936 | 0.068 | 0.114 |
| | 5 | 0.939 | 0.937 | 0.093 | 0.119 |
| | 6 | 0.898 | 0.895 | 0.056 | 0.071 |
| Model 2 Assertions-Disciplines-Overall Science (second-order model) | 1 | 0.908 | 0.906 | 0.055 | 0.073 |
| | 2 | 0.962 | 0.961 | 0.065 | 0.088 |
| | 3 | 0.950 | 0.949 | 0.048 | 0.063 |
| | 4 | 0.955 | 0.954 | 0.058 | 0.094 |
| | 5 | 0.959 | 0.957 | 0.077 | 0.103 |
| | 6 | 0.906 | 0.903 | 0.054 | 0.070 |
| Model 3 Assertions-Clusters-Overall Science (second-order model) | 1 | 0.938 | 0.937 | 0.046 | 0.072 |
| | 2 | 0.974 | 0.973 | 0.054 | 0.082 |
| | 3 | 0.967 | 0.966 | 0.039 | 0.055 |
| | 4 | 0.977 | 0.976 | 0.041 | 0.072 |

| Model | Form | CFI | TLI | RMSEA | SRMR |
|--|----------|--------------|--------------|-------|--------------|
| | 5 | 0.975 | 0.974 | 0.060 | 0.089 |
| | 6 | 0.932 | 0.930 | 0.046 | 0.072 |
| Model 4 Assertions-Clusters-Disciplines-Overall Science (third-order model) | 1 | 0.939 | 0.937 | 0.045 | 0.072 |
| | 2 | 0.974 | 0.973 | 0.054 | 0.082 |
| | 3 | 0.967 | 0.966 | 0.039 | 0.055 |
| | 4 | 0.977 | 0.976 | 0.041 | 0.072 |
| | 5 | 0.975 | 0.974 | 0.060 | 0.089 |
| | 6 | 0.932 | 0.930 | 0.046 | 0.072 |

Note. Numbers in bold do not meet the criteria for goodness-of-fit.

Table 16. Fit Measures per Model and Form, Grade 8

| Model | Form | CFI | TLI | RMSEA | SRMR |
|--|----------|--------------|--------------|-------|-------|
| Model 1 Assertions-Overall Science (one-factor model) | 1 | 0.929 | 0.927 | 0.043 | 0.060 |
| | 2 | 0.959 | 0.958 | 0.042 | 0.056 |
| | 3 | 0.943 | 0.941 | 0.052 | 0.074 |
| Model 2 Assertions-Disciplines-Overall Science (second-order model) | 1 | 0.934 | 0.932 | 0.041 | 0.060 |
| | 2 | 0.963 | 0.963 | 0.040 | 0.056 |
| | 3 | 0.950 | 0.949 | 0.049 | 0.072 |
| Model 3 Assertions-Clusters-Overall Science (second-order model) | 1 | 0.953 | 0.952 | 0.034 | 0.057 |
| | 2 | 0.974 | 0.973 | 0.034 | 0.054 |
| | 3 | 0.970 | 0.969 | 0.038 | 0.064 |
| Model 4 Assertions-Clusters-Disciplines-Overall Science (third-order model) | 1 | 0.953 | 0.952 | 0.034 | 0.057 |
| | 2 | 0.974 | 0.974 | 0.033 | 0.053 |
| | 3 | 0.970 | 0.969 | 0.038 | 0.064 |

Note. Numbers in bold do not meet the criteria for goodness-of-fit.

For Models 3 and 4, grade 6 showed some degree of misfit across all three forms according to the measures of absolute model fit, especially for the SRMR. Further examination indicated that the lack of fit could be attributed to a single item that was common to all three grade 6 forms that were part of this factor analysis study. After removing that item, there were only two forms that had two or more clusters per discipline. The fit for both forms improved drastically in Models 3 and 4, with all fit measures except the SRMR for one form meeting the criteria for model fit. The SRMR value that exceeded the threshold value did so barely, with a value of 0.083. Table 17 shows the fit measures for grade 6 after removal of the item causing misfit. Note that, unlike Models 3 and 4, Models 1 and 2 still did not meet the criteria of model fit after removing the item.

Table 17. Fit Measures per Model and Form – Grade 6 – One Cluster Removed²

| Model | Form | CFI | TLI | RMSEA | SRMR |
|---|----------|-------|-------|--------------|--------------|
| Model 1 Assertions-Overall Science (one-factor model) | 1 | 0.977 | 0.976 | 0.094 | 0.130 |
| | 2 | 0.974 | 0.973 | 0.082 | 0.118 |
| Model 2 Assertions-Disciplines-Overall Science (second-order model) | 1 | 0.986 | 0.986 | 0.072 | 0.106 |
| | 2 | 0.985 | 0.984 | 0.062 | 0.094 |
| Model 3 Assertions-Clusters-Overall Science (second-order model) | 1 | 0.992 | 0.991 | 0.057 | 0.083 |
| | 2 | 0.991 | 0.991 | 0.048 | 0.072 |
| Model 4 Assertions-Clusters-Disciplines-Overall Science (third-order model) | 1 | 0.992 | 0.991 | 0.057 | 0.083 |
| | 2 | 0.991 | 0.991 | 0.048 | 0.072 |

Note. Numbers in bold do not meet the criteria for goodness-of-fit.

Table 18 shows the estimated correlations among disciplines for Model 4 (third-order model). The correlations are all very high, ranging between 0.913 and 1. The high correlations between the disciplines in Model 4 indicate that, after considering the cluster effects, the disciplines do not add much to the model. This may explain why Model 4 did not show an improvement in fit compared to Model 3. Overall, the findings support the IRT model used for calibration.

Table 18. Model Implied Correlations per Form for the Disciplines in Model 4

| Grade | Form | Discipline | Earth and Space Sciences (ESS) | Life Sciences (LS) |
|-------|------|--------------------------------|--------------------------------|--------------------|
| 6 | 1 | Physical Sciences (PS) | 0.999 | 0.941 |
| | | Earth and Space Sciences (ESS) | – | 0.940 |
| | 2 | Physical Sciences (PS) | 1.000 | 0.964 |
| | | Earth and Space Sciences (ESS) | – | 0.964 |
| | 3 | Physical Sciences (PS) | 0.975 | 0.923 |
| | | Earth and Space Sciences (ESS) | – | 0.947 |
| 7 | 1 | Physical Sciences (PS) | 0.983 | 0.947 |
| | | Earth and Space Sciences (ESS) | – | 0.937 |
| | 2 | Physical Sciences (PS) | 0.978 | 0.972 |
| | | Earth and Space Sciences (ESS) | – | 0.951 |
| | 3 | Physical Sciences (PS) | 0.955 | 0.936 |
| | | Earth and Space Sciences (ESS) | – | 0.966 |
| | 4 | Physical Sciences (PS) | 0.938 | 0.913 |
| | | Earth and Space Sciences (ESS) | – | 0.973 |

² One assertion per model in form 1 and one assertion on three of the models in form 2 had error variance below 0, with the lowest error variance being –0.027.

| Grade | Form | Discipline | Earth and Space Sciences (ESS) | Life Sciences (LS) |
|-------|------|--------------------------------|--------------------------------|--------------------|
| | 5 | Physical Sciences (PS) | 0.931 | 0.944 |
| | | Earth and Space Sciences (ESS) | – | 0.965 |
| | 6 | Physical Sciences (PS) | 0.941 | 0.928 |
| | | Earth and Space Sciences (ESS) | – | 0.967 |
| 8 | 1 | Physical Sciences (PS) | 0.971 | 0.971 |
| | | Earth and Space Sciences (ESS) | – | 0.970 |
| | 2 | Physical Sciences (PS) | 0.956 | 0.958 |
| | | Earth and Space Sciences (ESS) | – | 0.935 |
| | 3 | Physical Sciences (PS) | 0.966 | 0.978 |
| | | Earth and Space Sciences (ESS) | – | 0.988 |

6. FAIRNESS IN CONTENT

The principles of universal design of assessments provide guidelines for test design to minimize the impact of construct-irrelevant factors in assessing student achievement. Universal design removes barriers to provide access for the widest range of students possible. The following seven principles of universal design are applied in the process of test development (Thompson, Johnstone, & Thurlow, 2002):

1. Inclusive assessment population
2. Precisely defined constructs
3. Accessible, non-biased items
4. Amenable to accommodations
5. Simple, clear, and intuitive instructions and procedures
6. Maximum readability and comprehensibility
7. Maximum legibility

Test development specialists have received extensive training on the principles of universal design and apply these principles in the development of all test materials. In the review process, adherence to the principles of universal design is verified by North Dakota educators and stakeholders.

6.1 COGNITIVE LABORATORY STUDIES

In 2017, when the development of item clusters for the states that are part of the Memorandum of Understanding (MOU) started, cognitive lab studies were carried out to evaluate and refine the process of developing item clusters aligned to three-dimensional science standards. Results of the

cognitive lab studies confirmed the feasibility of the approach. Item clusters were completed within 12 minutes on average, and students reported being familiar with the format conventions and online tools used in the item clusters. They appeared to easily navigate the item clusters' interactive features and response formats. In general, students who received credit on a given item displayed a reasoning process that aligned with the skills that the item was intended to measure.

A second set of cognitive lab studies was carried out in 2018 and 2019 to determine if students using braille could understand the task demands of selected accommodated three-dimensional science-aligned item clusters and navigate the interactive features of these item clusters in a manner that allows 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. The item clusters were clearly different from (and more complex than) other tests with which the students were familiar; however, the study recommended that students should be given adequate time to practice with at least one sample item cluster before taking the summative test. The study's findings also proposed tool-specific recommendations for accessibility for visually impaired students. The reports for both cognitive laboratory studies are presented in Appendix D, Science Clusters Cognitive Lab Report, and Appendix E, Braille Cognitive Lab Report.

6.2 STATISTICAL FAIRNESS IN ITEM STATISTICS

Differential item functioning (DIF) analysis was conducted with other states that field tested the items for the initial item bank. A thorough content review was performed in those states. The details surrounding this review of items for bias is further described in Volume 1, Section 4.4, Annual Technical Report, along with the DIF analysis process for the North Dakota State Assessment (NDSA) for Science.

7. SUMMARY

This report is intended to provide a collection of reliability and validity evidence to support appropriate inferences from the observed test scores. The overall results can be summarized as follows:

- **Reliability.** Various measures of reliability are provided at the aggregate and subgroup levels, showing that the reliability of all tests is in line with acceptable industry standards.
- **Content validity.** Evidence is provided to support the assertion that content coverage on each test was consistent with the test specifications of the blueprint across testing modes.
- **Internal structural validity.** Evidence is provided to support the selection of the measurement model, the tenability of model assumptions, and the reporting of an overall score and subscores at the reporting category levels.
- **Relationship of test scores to external variables.** Evidence of convergent and discriminant validity is provided to support the relationship between the test and other measures intended to assess similar and different constructs.

- ***Test fairness.*** Items are developed following the principles of universal design, which removes barriers to provide access for the widest range of students possible. Evidence of test fairness is provided statistically using DIF analysis in tandem with content reviews by specialists.

8. REFERENCES

- American Educational Research Association, American Psychological Association, & National Council on Measurement in Education. (2014). *Standards for educational and psychological testing*. Washington, DC: AERA.
- Bradlow, E. T., Wainer, H., & Wang, X. (1999). A Bayesian random effects model for testlets. *Psychometrika*, *64*, 153–168.
- Brown, T. A. (2015). *Confirmatory factor analysis for applied research* (2nd ed.). New York: The Guilford Press.
- Crocker, L., & Algina, J. (1986). *Introduction to classical and modern test theory*. New York: Holt, Rinehart, and Winston.
- Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1–55.
- Li, Y., Bolt, D. M., & Fu, J. (2006). A comparison of alternative models for testlets. *Applied Psychological Measurement*, *30*, 3–21.
- Messick, S. (1989). Validity. In R. L. Linn (Ed.), *Educational measurement* (3rd ed., pp. 13–103). New York: Macmillan.
- Rijmen, F. (2009). *Three multidimensional models for testlet-based tests: Formal relations and an empirical comparison*. Educational Testing Service (ETS) Research Rep. No. RR–09–37, Princeton, NJ: ETS.
- Rijmen, F., Jiang, T., & Turhan, A. (2018, April). *An item response theory model for new science assessments*. Paper presented at the annual meeting of the National Council on Measurement in Education, New York, NY.
- Thompson, S. J., Johnstone, C. J., & Thurlow, M. L. (2002). *Universal design applied to large scale assessments* (Synthesis Report 44). Minneapolis: University of Minnesota, National Center on Educational Outcomes. Retrieved from <http://education.umn.edu/NCEO/OnlinePubs/Synthesis44.html>.
- Wang, W. C., & Wilson, M. (2005). The Rasch testlet model. *Applied Psychological Measurement*, *29*(2), 126–149.
- Yung, Y. F., Thissen, D., & McLeod, L. D. (1999). On the relationship between the higher-order factor model and the hierarchical factor model. *Psychometrika*, *64*, 113–128.