Elementary Mathematics Student Assessment

Measuring the Performance of Grade 1 and 2 Students in Counting, Word Problems, and Computation in Fall 2014

Robert C. Schoen
Mark LaVenia
Charity Bauduin
Kristy Farina

DECEMBER 2016

Research Report No. 2016-04

The research and development reported here were supported by the Institute of Education Sciences, U.S. Department of Education, through Award No. R305A120781 to Florida State University. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education.

Suggested citation: Schoen, R. C., LaVenia, M., Bauduin, C., & Farina, K. (2016). *Elementary mathematics student assessment: Measuring the performance of grade 1 and 2 students in counting, word problems, and computation in fall 2014* (Research Report No. 2016-04). Tallahassee, FL: Learning Systems Institute, Florida State University. DOI: 10.17125/fsu.1508174887.

Elementary Mathematics Student Assessment (EMSA)

Measuring the Performance of Grade 1 and 2 Students in Counting, Word Problems, and Computation in Fall 2014

Research Report No. 2016-04

Robert C. Schoen

Mark LaVenia

Charity Bauduin

Kristy Farina

December 2016

Florida Center for Research in Science, Technology, Engineering, and Mathematics (FCR-STEM)
Learning Systems Institute
Florida State University
Tallahassee, FL 32306
(850) 644-2570

Acknowledgements

A great many people were involved with the development, field-testing, data entry, data analysis, and reporting. Here we name some of the key players and briefly describe their roles, starting with the report coauthors.

Robert Schoen designed the test and managed the overall process of test development, external review, editing and proofing, scoring, and interpreting the results. Mark LaVenia performed the data analysis for the factor analytic models, reliability estimates, and regression models. Charity Bauduin managed the report-writing process. Kristy Farina managed the data entry, verification, and management process and assisted with preparation of descriptive statistics for the present report.

We would like to acknowledge the reviewers of early drafts of the EMSA tests and express our gratitude for their contributions of expertise. These reviewers include Thomas Carpenter, Victoria Jacobs, and Ian Whitacre.

Amanda Tazaz managed the distribution and collection of tests and consent forms for students. Anne Thistle provided valuable assistance with editing the manuscript. Casey Yu provided valuable assistance with laying out the style and format of the final version of the report.

We are especially grateful to the Institute of Education Sciences at the U.S. Department of Education for their support and to the students, parents, principals, district leaders, and teachers who agreed to participate in the study and contribute to advancing knowledge in mathematics education. Without them, this work is not possible.

Table of Contents

Acknowledgements iv

Executive Summary 1

Purpose 1

Content 1

Sample and Setting 1

Scoring 2

Reliability 2

Predictive Validity 2

Summary 3

1. Introduction and Overview 4

1.1. Test Overview 4

1.1.1. Section 1: Counting 5

1.1.2. Section 2: Word Problems 5

1.1.3. Section 3: Computation 6

1.2. Administration of Test 7

1.3. Description of the Sample 7

2. Test Development 9

2.1. Content 9

2.2. Test Specifications 9

2.3. Item Development 10

2.4. Test Design and Assembly 11

2.5. Test Production and Administration 11

3. Data Entry and Analysis Procedures 13

3.1. Data Entry and Verification Procedures 13

3.2. Data Analysis 14

4. Results 17

4.1. Three-factor Test Blueprint 17

4.2. Item Screening 17

4.2.1. Grade 1 Item Screening 18

4.2.2. Grade 2 Item Screening 20
4.3. Correlated Trait Model Evaluation 21
4.3.1. Grade 1 Correlated Trait Model Evaluation 21
4.3.2. Grade 2 Correlated Trait Model Evaluation 23
4.4. Higher-Order Model Evaluation 25
4.4.1. Grade 1 Higher-order Model Evaluation 25
4.4.2. Grade 2 Higher-order Model Evaluation 27
4.5. Scale Reliability Evaluation 29
4.5.1. Grade 1 Scale Reliabilities 29
4.5.2. Grade 2 Scale Reliabilities 32
4.6. Predictive Validity Evaluation 34
5. Discussion and Conclusions 35
5.1. Validation 35
5.1.1. Substantive Validation 35
5.1.2. Structural Validation 35
5.1.3. External Validation 36
5.2. Summary and Conclusions 36
References 37

List of Appendices

Appendix A—First Grade Test 39

Appendix B—Second Grade Test 52

Appendix C—First Grade Administration Guide 66

Appendix D—Second Grade Administration Guide 79

Appendix E—Distributions of Number of Items Answered Correctly Within Each Factor 93

Appendix F—Most Common Incorrect Response for Each Item 96

List of Tables

Table 1. Number of Items That Remained on the Fall 2014 Tests After Screening and Respecification 4

Table 2. Items in the Counting Section 5

Table 3. Summary of Items Used in the Word Problems Section 6

Table 4. Items in the Computation Section 6

Table 5. Student Sample Demographics 8

Table 6. Number of Items That Remained on the Fall 2014 Tests After Screening and Respecification 17

Table 7. Grade 1 Test Item Descriptions, Percentage Correct, and Unidimensional IRT Parameters 18

Table 8. Grade 2 Test Item Descriptions, Descriptive Statistics, and Unidimensional IRT Parameters 20

Table 9. Grade 1 Standardized Factor Loadings for Initial and Revised Correlated Trait Model 22

Table 10. Grade 1 Factor Correlations (and Standard Errors) for the Revised Correlated Trait Model 23

Table 11. Grade 2 Standardized Factor Loadings for Initial and Revised Correlated Trait Model 24

Table 12. Grade 2 Factor Correlations for the Revised Correlated Trait Model 25

Table 13. Standardized Factor Loadings and Factor Residual Variances for the Grade 1 Higher-Order Measurement Model 26

Table 14. Standardized Factor Loadings and Factor Residual Variances for the Grade 2 Higher-Order Measurement Model 28

Table 15. Grade 1 Scale Reliability Estimates 30

Table 16. Grade 2 Scale Reliability Estimates 32

Table 17. Results for Single Linear Regressions of Standard Scores on the Iowa Test of Basic Skills (ITBS) Math Problems and Math Computation Tests on the Math Factor Scores for the Grade 1 and Grade 2 Control Group 34

Table 18. Proportion of Grade 1 Student Responses by Item 96

Table 19. Proportion of Grade 2 Responses by Item 96

List of Figures

Figure 1. Example of an image used in place of a page number. 9

Figure 2. Grade 1 test 2-pl UIRT difficulty vs. discrimination scatterplot. 19

Figure 3. Grade 2 test 2-pl UIRT difficulty vs. discrimination scatterplot. 21

Figure 4. Grade 1 revised model – correlated trait model diagram with standardized parameter estimates. Factor g1cntf14 is the grade 1 Counting factor for fall 2014. Factor g1wpf14 is the grade 1 Word Problems factor for fall 2014. Factor g1cmpf14 is the grade 1 Computation factor for fall 2014. ..23

Figure 5. Grade 2 revised model – correlated trait model diagram with standardized parameter estimates. Factor g2cntf14 is the grade 2 Counting factor for fall 2014. Factor g2wpf14 is the grade 2 Word Problems factor for fall 2014. Factor g2cmpf14 is the grade 2 Computation factor for fall 2014. ..25

Figure 6. Grade 1 final model – higher-order factor diagram with standardized parameter estimates. ...27

Figure 7. Grade 2 final model – higher-order factor diagram with standardized parameter estimates. ...29

Figure 8. Grade 1 2-pl UIRT total information curve and participant descriptives for the reduced set of items modeled as a single factor. 31

Figure 9. Distribution of the number of items individual students in the grade 1 sample answered correctly on the reduced set of items. 31

Figure 10. Grade 2 2-pl UIRT total information curve and participant descriptives for the reduced set of items modeled as a single factor. 33

Figure 11. Distribution of the number of items individual students in the grade 2 sample answered correctly on the complete reduced set of items. 33

Figure 12. Distribution of the number of items individual students in the grade 1 sample answered correctly within the Counting factor. 93

Figure 13. Distribution of the number of items individual students in the grade 1 sample answered correctly within the Word Problems factor. 93

Figure 14. Distribution of the number of items individual students in the grade 1 sample answered correctly within the Computation factor. 94

Figure 15. Distribution of the number of items individual students in the grade 2 sample answered correctly within the Counting factor. 94

Figure 16. Distribution of the number of items individual students in the grade 2 sample answered correctly within the Word Problems factor. 95

Figure 17. Distribution of the number of items individual students in the grade 2 sample answered correctly within the Computation factor. 95

List of Equations

Equation 1. Composite reliability for the second-order Math Factor (1) 15

Equation 2. Reliability along range of person abilities (2)..15

Equation 3. Grade 1 higher-order Math factor composite reliability estimate (3)....................................29

Equation 4. Grade 2 higher-order Math factor composite reliability estimate (4)....................................32

List of Abbreviations

CCSS-M	Common Core State Standards for Mathematics
CDU	Compare Difference Unknown
CFI	Comparative Fit Index
CGI	Cognitively Guided Instruction
CQU	Compare Quantity Unknown
DNS	Did Not Solve
EMSA	Elementary Mathematics Student Assessment
IRT	Item Response Theory
ITBS	Iowa Test of Basic Skills
JCU	Join Change Unknown
JRU	Join Result Unknown
MD	Measurement Division
MG	Multiplication Grouping
MPAC	Mathematics Performance and Cognition
PD	Partitive Division
PPU	Part-Part-Whole Part Unknown
RMSEA	Root Mean Square Error of Approximation
SRU	Separate Result Unknown
TIC	Total Information Curve
TLI	Tucker-Lewis Index
UI	Unclear Intent
UIRT	Unidimensional Item Response Theory

Executive Summary

The subject of this report is a pair of written, group-administered tests designed to measure the performance of grade 1 and grade 2 students at the beginning of the school year in the domain of number and operations. These tests build on previous versions field-tested in fall 2013 (Schoen, LaVenia, Bauduin, & Farina, 2016). Because the tests are designed to be a measure of student achievement in elementary mathematics, we call them the Elementary Mathematics Student Assessment (EMSA) tests.

Purpose

The EMSA tests were designed to serve as a covariate for students' baseline performance in statistical models estimating the impact of a teacher professional-development program on student achievement in mathematics.

This report is written for researchers and evaluators who may be interested in using the tests in the future or who wish to know about the psychometric properties of the tests.

Content

The contents of the EMSA tests are designed to align with core content in the *operations and algebraic thinking* and the *number and base ten* domains in the Common Core State Standards for Mathematics at grades 1 and 2, respectively (NGACBP & CCSSO, 2010). In a few instances, the content of the tests extends beyond the CCSS-M for the given grade level. These exceptions include *multiplication-grouping* problems in grade 2. The purpose of the focus on more advanced problems is to increase the ability of the test to discriminate among a wide range of levels of knowledge and understanding in the area of number and operations. Moreover, some ambiguity remains about whether place value is about grouping by tens, and items on the tests reflect this ambiguity.

The final versions of the tests were the result of extensive development, feedback, and revisions from a variety of experts. The expert review verified the alignment of the content with the content of the Common Core State Standards for Mathematics at grades 1 and 2.

Because of the paper-and-pencil format of the tests and the range in reading ability of the test takers, careful consideration was given to placement of the problems on each page and assisting students with identification of the correct page of the test during administration. Teachers administered the tests to their own students with the assistance of an administration guide and script (provided in Appendices C and D).

Sample and Setting

The 2014 EMSA tests were administered with 3,080 participating grade 1 and grade 2 students in 22 schools located in two public school districts in Florida during fall 2014. The school districts were implementing a curriculum based on the Mathematics Florida Standards, which are very similar to the Common Core State Standards for Mathematics (CCSS-M; NGACBP & CCSSO, 2010).

Test Specifications and Administration

The fall 2014 EMSA test has three main sections corresponding to counting and the number sequence, word problems, and computation. The test forms include 22 items at grade 1 and 23 items at grade 2.

Sixteen of the items at each grade level are presented in a constructed-response format. Six items are presented in a selected-response format on the grade 1 test and seven items on the grade 2 test.

On the basis of an iterative process of data modeling and item diagnostics, some of the items on the test forms were not used in the final scale. The final grade 1 scale uses data from 19 items. The final grade 2 scale uses data from 20 items. The two forms were not designed to be directly comparable.

Teachers administered the tests to their own students with the assistance of an administration guide and script (provided in Appendices C and D). Because of the paper-pencil format of the tests and the range in reading ability of the test takers, careful consideration was given to placement of the problems on each page and assisting students with identification of the correct page of the test during administration.

Scoring

The data were fit to both a correlated-traits and a second-order factor-analysis model. To generate overall test scores, we first regressed three first-order factors (i.e., Counting, Word Problems, Computation) onto a single second-order factor (i.e., Math). The second-order Math factor score is intended to serve as the overall achievement score on the test. Goodness-of-fit statistics varied but generally indicated that the specified measurement models provided a reasonable fit to the data. The grade 1 model root mean square error of approximation (RMSEA) statistic indicated mediocre fit and the comparative fit index (CFI) and Tucker-Lewis index (TLI) statistics indicated reasonable fit: $\chi^2(149) = 1715.379$, $p < .001$; RMSEA = .081, 90% Confidence Interval (CI) [.078, .085]; CFI = .916; and TLI = .904. The grade 2 model RMSEA, CFI, and TLI statistics indicated close fit: $\chi^2(167) = 532.780$, $p < .001$; RMSEA = .038, 90% CI [.035, .042]; CFI = .968; and TLI = .964.

Reliability

The reliabilities of the test scales were determined by means of a composite reliability estimate for the Math factor and ordinal forms of Cronbach's α for the three subscales. The grade 1 math composite reliability was .88. The grade 2 math composite reliability was .91. Grade 1 α estimates for the three subscales all met or exceeded the conventional target value of .8 (range .80 to .92). Grade 2 α estimates for the three subscales all exceeded the conventional target value of .8 (range .84 to .85). Diagnostic and supplementary analyses of scale reliability, including ordinal forms of Revelle's β and McDonald's ω_h coefficients and IRT information-based reliability estimates, are provided in Chapter 4 of the full report.

Predictive Validity

Evidence for the predictive validity of the EMSA tests was examined by regression of the standard scores for the level 7 and level 8 Iowa Test of Basic Skills (ITBS; Dunbar et al., 2008) tests on the EMSA Math factor scores for grades 1 and 2, respectively. Regression results suggested that the EMSA Math score was a moderate to strong predictor of students' scores on the ITBS Math Problems test, where an $R^2_{Adjusted}$ of .45 was found for grade 1 and an $R^2_{Adjusted}$ of .55 was found for grade 2. The EMSA Math scores provided more modest predictive power with the ITBS Math Computation test, where an $R^2_{Adjusted}$ of .28 was found for grade 1 and an $R^2_{Adjusted}$ of .36 was found for grade 2. All of these relations were statistically significant at $p < .001$. The regression analyses suggest the EMSA tests to be an appropriate covariate in analyses that use the ITBS tests as outcomes, where the results suggest the test is particularly well suited in analyses with the ITBS Math Problems test.

Summary

We report on the initial validation efforts examining the substantive, structural, and external validity (Flake, Pek, & Hehman, 2017) for the fall 2014 EMSA tests. The fall 2014 EMSA tests were designed to be a measure of student achievement in grades 1 and 2 for use as a student pretest covariate in the study of the effects of a mathematics-teacher professional-development program in mathematics. EMSA test items were constructed and reviewed by mathematicians and mathematics education experts and measure student achievement in the domain of operations and algebraic thinking as well as number and base ten. The development process, model fit, and scale-reliability estimates meet the basic standards for educational measurement. Test scores are moderately correlated with the scores of policy-relevant, standardized tests used to measure student achievement in grades 1 and 2. The EMSA tests appear to be sufficiently well suited for their intended use as a test covariate for the evaluation of educational interventions involving grade 1 and grade 2 students.

1. Introduction and Overview

The fall 2014 EMSA tests were designed to measure student mathematics performance at the beginning of grade 1 and grade 2. The items focus on tasks involving counting, solving word problems, and computational problems. The tests were based on a previous version of these tests (Schoen, LaVenia, Bauduin, & Farina, 2016).

The test-development process involved multiple iterations of item and test blueprint development, review of items and the test blueprint by experts in mathematics and mathematics education, and extensive revisions and proofreading of the items, sequence, and formatting. Experts provided feedback on the accuracy of the mathematics content, clarity of questions, number choices in the selected-response items, overall length of the test, and predictions about how students could potentially misinterpret the items in ways that might obscure their ability to measure student knowledge and ability. Experts also reviewed the items on both tests to determine the extent of the alignment of the items with the domains of counting and algebraic thinking in the CCSS-M (NGACBP & CCSSO, 2010).

The EMSA tests were designed to be administered in a whole-group setting in a paper-pencil format. The students' classroom teachers were asked to administer the tests during the first two weeks of the school year. The teachers were given an administration guide explaining how to administer the tests and a script to use while administering them. Questions were read aloud to students, and students either filled in a box with the correct number for open-ended items or shaded bubbles to indicate their responses to multiple-choice items. Teachers were encouraged to allow students to use manipulatives in accordance with their typical classroom practice.

The immediate purpose of the tests was for use as a student pretest covariate in a randomized controlled trial evaluating the impact of a teacher professional-development program on student achievement in the domains of number, operations, and algebraic thinking. In the state and school districts where the efficacy trial took place, no uniform measure of student mathematics achievement was used with kindergarten, grade 1, or grade 2 students. A measure of student achievement in mathematics was desired for the purposes of investigating baseline equivalence of participating schools and as a student-level covariate in statistical models estimating the impact of the program on student achievement.

1.1. Test Overview

The EMSA tests contain 22 items in grade 1 and 23 items in grade 2. These items are grouped into three sections for the administration of the tests: Counting, Word Problems, and Computation. Table 1 provides a listing of the sections and number of items administered to grade 1 and grade 2 students.

Table 1. Number of Items that Remained on the Fall 2014 Tests after Screening and Respecification

Section	Grade 1	Grade 2	Common items
Counting	4	4	0
Word Problems	6	7	0
Computation	12	12	3
Total	22	23	3

Although the two tests contain the same three sections and approximately the same number of items, they are not designed to be vertically scaled. Only three of the items on the two tests are identical, and all three of those are in the Computation section. When individual items on the grade 1 and grade 2 tests are similar (but not identical), the questions on the grade 2 test involve higher numbers in an attempt to increase the difficulty proportionally with age and to elicit information about how these older students make sense of operations on multidigit whole numbers.

1.1.1. Section 1: Counting

The initial section of the test was intended to ask students questions about number and quantity. Table 2 shows the number of items and the question asked within each item. All four of the items in the Counting section for both the grade 1 and grade 2 tests have a constructed-response format.

Table 2. Items in the Counting Section

Grade 1 test item number	Grade 1 item	Grade 2 test item number	Grade 2 item
1[a]	[redacted]	1	[redacted]
2	[redacted]	2	[redacted]
3	[redacted]	3	[redacted]
4	[redacted]	4	[redacted]

[a] Item 1 on the grade 1 test presented seven stars in two rows, five in the upper row and two in the lower row.

As Table 2 demonstrates, three of the grade 1 items in the Counting section are identical in structure to three of the grade 2 items, but the grade 2 items involve higher numbers, for two reasons. The numbers in the beginning-of-year grade 1 test are less than 20 to align with expectations in the state mathematics curriculum standards (and the CCSS-M). Two- and three-digit numbers are used in the grade 2 test items as a means of increasing difficulty of items. This increase was used as a strategy to improve the ability of the test to discriminate among students with different ability levels and to improve alignment with the learning expectations in the curriculum standards.

1.1.2. Section 2: Word Problems

The second section of the test contains a set of word problems representing a range of difficulty. Table 3 provides the sequence of word problems in this section. For brevity, the list indicates only the type of problem and the numbers presented in the problem. All the Word Problems items in both tests used a selected-response (i.e., multiple-choice) format. This format is consistent with the format of the ITBS tests (Dunbar et al., 2008). The ITBS tests comprise two of the three outcomes of interest in the randomized controlled trial in which the fall 2014 EMSA data were used as a student achievement covariate.

Table 3 shows that the grade 1 test included *join result unknown* (JRU) and *separate result unknown* (SRU) problems. These two problem types were not included on the grade 2 test because the difficulty of these particular problems (with the numbers used in the fall 2013 EMSA test) was too low to be useful in discriminating between different levels of ability in beginning-of-year grade 2 students. Although the grade 1 and 2 tests each contain two *join change unknown* (JCU) problems, the wording, contexts and number choices on the two tests differ. The numbers on the grade 2 test were selected with the intent to increase the difficulty level of the item for use with the grade 2 population.

Table 3. Summary of Items Used in the Word Problems Section

Grade 1 test item number	Grade 1 item	Grade 2 test item number	Grade 2 item
5	[redacted]	5	[redacted]
6	[redacted]	6	[redacted]
7	[redacted]	7	[redacted]
8	[redacted]	8	[redacted]
9	[redacted]	9	[redacted]
10	[redacted]	10	[redacted]
—	—	11	[redacted]

Note. See the list of the abbreviations for elaboration on the problem type categories (Carpenter et al., 1999).

1.1.3. Section 3: Computation

The Computation section contains items asking students to perform calculations involving addition and subtraction on whole numbers. Table 4 presents the sequence of problems in the Computation section of the tests. Three computation items on the grade 1 and grade 2 tests are identical: evaluation of [redacted], [redacted] and [redacted].

Table 4. Items in the Computation Section

Grade 1 test item number	Grade 1 item	Grade 2 test item number	Grade 2 item
11	[redacted]	12	[redacted]
12	[redacted]	13	[redacted]
13	[redacted]	14	[redacted]
14	[redacted]	15	[redacted]
15	[redacted]	16	[redacted]
16	[redacted]	17	[redacted]
17	[redacted]	18	[redacted]
18	[redacted]	19	[redacted]
19	[redacted]	20	[redacted]
20	[redacted]	21	[redacted]
21	[redacted]	22	[redacted]
22	[redacted]	23	[redacted]

1.2. Administration of Test

Tests were delivered to schools by project staff during the week of preplanning (i.e., the week before students return to school for the year). Teachers were given detailed instructions on how to administer the tests. The tests were accompanied by a document for teachers—provided here in Appendices C and D—containing detailed test-administration instructions, including a script to use while administering the tests.

Teachers were asked to write the students' names on the front covers of the tests to increase legibility and accuracy in data entry. Teachers were also instructed to permit students to use manipulable materials if that was common practice in their classrooms. For the first two sections of the test, teachers were instructed to read the problems aloud to students—in their entirety—to reduce the effect of reading ability on students' mathematics performance. Reading problems aloud to students is consistent with the administration procedures for the ITBS and the Mathematics Performance and Cognition (MPAC) interview, the two outcome measures used for the randomized controlled trial. As necessary, teachers were encouraged to provide appropriate testing accommodations for students in accordance with their individual educational plans. Teachers were instructed to insert completed tests into an opaque, sealed envelope and deliver the envelopes to the front office for project personnel to pick up during a window of time outlined in the administration instructions.

We acknowledge that teacher administration presents the potential for breaches in security. These were not high-stakes tests, so strict security was not a high priority. In this case, teachers and schools were trusted to administer the tests in accordance with the instructions.

1.3. Description of the Sample

The student sample included 3,080 students (1,595 grade 1 and 1,485 grade 2) with consent to participate. The student sample comes from the classrooms of participating grade 1 and 2 teachers representing 22 schools in two diverse public school districts (7 schools in one district; 15 in the other) in Florida. Grade 1 and 2 teachers in these schools elected to participate in a large-scale, cluster-randomized controlled trial evaluating the efficacy of a teacher professional-development program in mathematics. Half of the schools in the sample were assigned at random to the treatment condition; the other half to the control condition. Our sampling procedure attempted to measure all grade 1 and grade 2 students in participating teachers' classrooms. Other than the requirement for parental consent in order for data on students to be collected, no exclusion criteria were applied that would have limited the sample by student characteristic. Table 5 relays the student demographics for the total participating student sample as of fall 2014 and the subsample of students for whom fall 2014 measurement with the EMSA was conducted.

Table 5. Student Sample Demographics

Characteristic	Total student sample (*n* = 3,362)		Student test sample (*n* = 3,080)	
	Proportion	*n*	Proportion	*n*
Gender				
Male	.46	1,539	.46	1,421
Female	.48	1,629	.48	1,484
Unreported	.06	194	.06	175
Grade				
1	.52	1,738	.52	1,595
2	.48	1,624	.48	1,485
Race/Ethnicity				
Asian	.04	140	.04	125
Black	.15	521	.15	470
White	.32	1,085	.33	1,004
Other	.03	87	.03	83
Hispanic	.32	1,063	.32	973
Unreported	.14	466	.14	425
English language learners	.17	557	.16	491
Eligible for free or reduced-price lunch	.53	1,788	.53	1,626
Exceptionality				
Students with disabilities	.07	223	.07	201
Gifted	.03	95	.03	91
Unknown	.14	466	.14	425

Note. Proportion provided reflects percentage of total sample. Some characteristic categories are not mutually exclusive. Students with unreported demographic information are represented in the “Unknown” category. The Asian, Black, and White categories are non-Hispanic. Full sample descriptive statistics include all students with consent to participate.

2. Test Development

2.1. Content

The content standards at grades 1 and 2 in the CCSS-M (NGACPB & CCSSO, 2010) were used to provide guidelines for content specifications. Overall, the focus of the test is on number and operations, but it includes some items designed to favor students who have a solid grasp of place-value concepts. The numbers used on the test are limited to positive integers (i.e., Counting numbers) between 1 and 100, with one exception. In the Counting section, the beginning-of-year grade 2 students were asked [redacted]. That decision was informed by results of the fall 2013 version of the test and was designed to increase the level of difficulty of the grade 2 test. Computation items presented symbolically involve applying the addition or the subtraction operation with exactly two positive integers. Problems involving subtraction result in a difference with a positive, integer value. Word problems involve additive situations as well as grouping situations that could be solved by multiplication, division, addition, counting strategies, or direct place-value understanding (Carpenter et al., 1999).

2.2. Test Specifications

Test design involved finding an optimum point at the intersection of three potentially competing goals: (1) sample a range of difficulty of problems and cognitive demand to reflect the focus of the teacher professional-development program goals and the learning goals outlined in grades 1 and 2 in the CCSS-M, (2) serve as a reasonably strong student-level test covariate to explain some of the variance in the ITBS and MPAC interview data, and (3) minimize the test-taking burden on teachers and students.

The Counting and Word Problems sections of the test include only one item per page to minimize student distraction and confusion. Rather than using Arabic numerals as page numbers or to enumerate items, we used a child-friendly image to identify each page. We used graphics in order to be as considerate as possible to the test taker (who may not read Arabic numerals fluently). Figure 1 provides one example of these graphics.

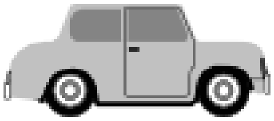


Figure 1. One of the images used in place of a page number.

Beginning-of-year grade 1 students, in particular, may not recall all of their numerals, and numbered pages could cause confusion and anxiety. The large and easily distinguished image is also useful for the test administrator to use as a way to verify from across the room that students have turned to the correct page. Moreover, the ITBS test forms use a similar tactic, so this test serves as practice for that type of format.

Response types include selected-response (i.e., multiple-choice) and constructed-response items. All of the constructed-response items are short answer; none of them requires extended or elaborated responses. Sample items with examples of responses are provided on the first page of the test for the administrator to demonstrate how students are expected to respond (e.g., completely shade the bubble, write a numeral in a rectangular area designated for the response).

Selected-response options are ordered from least to greatest and from left to right. Bubbles are centered beneath each response option, and responses are centered horizontally across the page. Test items were reviewed internally for bias and sensitivity in an effort to neutralize any need for vocabulary development with students. Whenever possible, word problems are written to avoid the use of keywords (i.e., altogether, in all, left).

Although the tests designed for the two grade levels have the same three sections (i.e., Counting, Word Problems, Computation), the tests are not designed to be vertically scaled or equated. The grade 2 test was designed to be more difficult than the grade 1 test.

2.3. Item Development

The items were written by the first author of the present report. Schoen holds postsecondary degrees in atmospheric science, mathematics, and mathematics education. He has extensive experience developing assessment items and scales designed to measure student cognition and achievement in early elementary mathematics as well as teacher knowledge and beliefs. The items were reviewed by other individuals with expertise in elementary education, assessment, and mathematics.

The development process for the tests consisted of several phases. These phases included:

1. Analysis of the goals of the mathematics professional-development program we were evaluating: Cognitively Guided Instruction (CGI).
2. Review of the learning goals delineated in the CCSS-M grades 1 and 2.
3. Review of literature and related measures in the domain of number and operations at grades 1 and 2.
4. Creation of a draft test blueprint.
5. Review of item and scale performance from the 2013 version of the test; review of student responses for those items used on the 2013 tests.
6. Development of a first written draft of the grade 1 and grade 2 test items.
7. Internal review of drafted tests by members of the research team as well as review by several members of the project advisory board.
8. Revision of drafts based upon feedback.

Because the tests were used in the evaluation of a program related to CGI, an extensive body of literature related to CGI was reviewed carefully (cf. Carpenter et al., 1989, 1999; Fennema et al., 1996; Jacobs et al., 2007). The CGI program is focused on number (including place value), operations, and algebraic thinking. As part of a strategy to avoid overalignment with the intervention, we also completed a review of the learning goals set forth in the CCSS-M (NGACBP & CCSSO, 2010). The topics at the intersection of the program goals and the expectations outline in the CCSS-M provided the starting place for defining the content of the test.

Once the blueprint was developed, a draft set of items was written and reviewed internally by the research team, which consists of experts in mathematics, mathematics education, educational psychology related to student thinking in mathematics, and educational measurement. After this internal review, the draft set of items and testing format were revised and sent to advisory board members Thomas Carpenter, Victoria Jacobs, and Ian Whitacre for review and feedback. Dr. Carpenter provided extensive feedback based on his experience assessing students, and the items were heavily revised on the basis of his recommendations. Revised versions of the items were then internally reviewed by members of the test development research team.

One major advantage in the development of the fall 2014 tests was the data from the fall 2013 tests (Schoen, LaVenia, Bauduin, & Farina, 2016). Those tests and the spring 2014 MPAC interview data (Schoen, LaVenia, Champagne, & Farina, 2016) provided useful insight to enable us to refine the alignment of difficulty of items with students' abilities at start of grade 1 or 2.

Approximately half of the items from the fall 2013 tests were used again on the fall 2014 tests. More items were carried forward on the grade 1 test than on the grade 2 test. Two primary reasons for not carrying forward items from fall 2013 to fall 2014 test were model fit and difficulty level. Items with very high or low difficulty or low factor loadings from the 2013 tests were dropped from the 2014 version. Items replaced or added to the grade 2 test were designed to increase the overall difficulty of the grade 2 test over that of the fall 2013 version.

2.4. Test Design and Assembly

The student tests consist of three sections: Counting, Word Problems, and Computation. The Counting section consists of four items aimed at measuring students' understanding in the domain of counting and cardinality. All of the Counting items use a constructed-response format, in which the students are expected to write each answer as a numeral in a designated box. The Word Problems section includes six items in grade 1 and seven items in grade 2, all of which use a selected-response format and offer five response options for each item. The response options are always numerals and are ordered from least to greatest, from left to right. The students are directed to fill in the circles below their answer choices. The Computation section consists of 12 items presented as open equations. Each problem is presented as a single equation involving either the addition or the subtraction operator and exactly two numerals. Each is presented in the standard (i.e., $a + b = c$, $a – b = c$) form (Stigler et al., 1986; Schoen et al., in review) with an open box providing a place for the student to write the numeral representing the sum or difference.

In the Counting and Word Problems sections, only one problem is displayed per page so that students will not record their answers in the wrong places or be overwhelmed by too much text on the page. Computation items are presented with multiple items split across two pages. In an effort to avoid confusion, as well as to match the format of the ITBS outcome measure, a line is placed after each Computation item on the page. The grammar used in word problems was reviewed by those with experience in teaching emergent bilingual students. The font used in the final version of the test is large (18-point) to increase legibility. Copies of the grade 1 and grade 2 tests are presented in Appendices A and B, respectively.

2.5. Test Production and Administration

The tests, administration guides, and consent forms were printed at the university and distributed to the participating schools. Tests were printed single-sided on 20-pound, white paper in the 18-point Calibri font.

Administration guides were designed and created for teachers to use while administering the tests. They provide an overview of the tests, describe the administration process and directions, explain how to submit completed tests, and provide a full script to be read verbatim during administration of the test. In addition, the administration guides include a student information sheet on the last page. Teachers completed this sheet to provide student and class information (e.g., student names, student ID numbers, testing accommodations provided) and returned it with the completed student tests. The administration guide was repeatedly reviewed, edited, and proofread by research project staff before it the final version was produced. The final forms of the test administration guides for grades 1 and 2 are presented in Appendices C and D, respectively.

Participating teachers were provided with a test packet containing:

- Testing administration guide (for the corresponding grade level)
- Class set of student tests
- Parental consent forms
- Student information sheet

These materials were distributed to the teachers participating in the study through the main office personnel or principal-appointed designee. Test materials were distributed to the main offices at school sites on August 4–8, 2014. Teachers were instructed to administer the tests during the first two weeks of school.

Test administrators (which were usually the participating teachers) were directed to read each math problem aloud to students in accordance with the administration script. In addition, they were asked to provide and allow students to use manipulatives, like counters or linking cubes, during the test. If students generally had testing accommodations due to IEP, ELL or 504 plans, then the teacher was asked to provide any and all required accommodations for those individual students and to document the accommodation on the student information sheet. The test is not timed, so test administrators were instructed to allow students adequate time to answer all of the questions.

Upon conclusion of administration, teachers were instructed to submit all testing materials (i.e., test administration guide, student test booklets, student information sheet, student booklist form, and parental consent forms) to their principals or designees. Teachers were asked to return only completed test booklets completed by those students with corresponding signed parental consent on the parental consent form. The principal or designee placed the testing materials in the main office at the front desk for pickup. Members of the project team picked up test materials during the last two weeks of September 2014.

Teachers who presented extenuating circumstances to the research team and did not administer the test during the administration window or missed the materials pickup date were handled on a case-by-case basis with respect to when to administer the test and arrangement of a materials pickup date. Very few instances of these special cases arose.

3. Data Entry and Analysis Procedures

3.1. Data Entry and Verification Procedures

Research assistants typed student responses into InfoPath forms hosted on the project's secure SharePoint site page. All response fields were restricted to allow only whole numbers and accepted codes for missing items. The response fields for selected-response items were further restricted to allow only the integers presented as possible responses. Two codes were used for items missing a response: UI indicated unclear intent, and DNS indicated did not solve. The code DNS indicated that the student made no apparent effort to provide a response to the item. Research assistants were asked to interpret both the student's handwriting and the student's intent, with the goal of entering the student's intended response exactly as it was written. Because this test was administered to grade 1 students at the beginning of the school year, many student responses displayed immature handwriting that took careful consideration. As a result, regular meetings of the data-entry personnel were held to discuss—and come to consensus on—how to record unusual student responses. In most cases, the discussion was over which numerals the student wrote, although occasionally discussion was needed to determine which of the several numerals written by the student was intended as the answer.

The code UI was used when the committee could not come to an agreement about the student's intended response or when the student's response was too far from standard numeric representations to be interpreted. Common examples of responses that required interpretation and discussion are listed below, with a description of the decision that was made.

- *The answer was "7" and the student wrote "07" on the answer line.* Correct responses preceded by a zero were interpreted as correct. In this example, the exact student response would be entered as written.
- *The answer was "3" and the student wrote a backward three.* Backward numerals were interpreted as though they were written correctly. No indication was made during data entry to signal that a numeral was written backward. This decision only applies to individual digits, and did not override the decision for reversals of multi-digit numbers.
- *The answer was "13", but the student wrote "31" on the answer line.* Numeric reversals were entered as written, and interpreted as incorrect. Committee members agreed that although students who responded with "31" may have intended to write "13," the evidence was insufficient to support that claim.
- *The answer was "15" and at least one of the digits could have been interpreted as another numeral.* Some numerals proved more difficult to determine. The most common numerals that could be confused were 7s and serifed 1s and backward 2s and 5s. When researchers were presented with immature handwriting for numerals with similar shapes, other handwriting samples found within the assessment were used as a guide to determine the student's intent.

To verify accuracy of data entry, a sample of 10% of the tests was randomly selected for second entry by personnel at FSU who did not participate in the original data entry or adjudication process. The two sets of entries were compared for agreement on scored (i.e., correct, incorrect) responses for each item and were found to have a 99.5% overall agreement.

3.2. Data Analysis

All analyses were performed with Mplus version 7.11 (Muthén & Muthén, 1998-2012), with the exception of the estimation of Cronbach's α, Revelle's β, and McDonald's ω_h reliability coefficients, which were performed in R 3.1.2 (R Development Core Team, 2014) with the psych package (Revelle, 2016) α, splithalf, ω_h, and polychoric functions.

Our investigation was conducted in five steps. We aimed (1) to screen out items that demonstrated outlier parameter estimates when fit to a unidimensional framework, (2) to evaluate item performance when structured in accordance with the three-factor blueprint and drop items that demonstrate low salience with their respective factor, (3) to respecify the structure of the model from one of correlated factors to one of a single second-order factor and three first-order factors, (4) to estimate reliabilities for the test overall and for each subscale, and (5) to estimate the predictive validity of the test for each grade level.

The first step was to screen the initial set of items within a 2-parameter logistic (2-pl), unidimensional, item response theory (UIRT) framework. Discrimination and difficulty parameters were inspected. An item was flagged for scrutiny if (a) its discrimination estimate was less than .4 or greater than 3 or (b) the absolute value of its difficulty estimate was greater than 3. These cut points were not strictly enforced. For example, items with low discrimination that appeared to fill a void along the difficulty continuum received special consideration for being retained.

The second step was to fit the screened data to a correlated-trait item-factor analysis (confirmatory factor analysis with ordered categorical indicators) model that paralleled a 3-factor model structure specified by the principal investigator in consultation with item reviewers.

We used the model chi-square (χ^2), RMSEA, CFI, and TLI to evaluate overall model fit. Following guidelines in the structural-equation modeling literature (Browne & Cudeck, 1992; MacCallum, Browne, & Sugawara, 1996), we interpreted RMSEA values of .05, .08, and .10, as thresholds of close, reasonable, and mediocre model fit, respectively, and interpreted values > .10 to indicate poor model fit. Drawing from findings and observations noted in the literature (Bentler & Bonett, 1980; Hu & Bentler, 1999), we interpreted CFI and TLI values of .95 and .90 as thresholds of close and reasonable fit, respectively, and interpreted values < .90 to indicate poor model fit. We note that little is known about the behavior of these indices when based on models fit to categorical data (Nye & Drasgow, 2011), which adds to the chorus of cautions associated with using universal cutoff values to determine model adequacy (e.g., Chen, Curran, Bollen, Kirby, & Paxton, 2008; Marsh, Hau, & Wen, 2004). Because fit indices were not used within any of the decision rules, a cautious application of these threshold interpretations bears on the evaluation of the final models but has no bearing on the process employed in specifying the models.

Confirmatory factor-analysis models with standardized factor loadings > .7 in absolute value are optimal, as they ensure that at least 50% of the variance in responses is explained by the specified latent trait. In practice, however, this criterion is often difficult to attain while maintaining the content representativeness intended for many scales. Researchers working with applied measurement (e.g., Reise, Horan, & Blanchard, 2011) have used standardized factor loadings as low as .5 in absolute value as a threshold for item salience. In accordance with this practice, we aimed to retain only items in the final model that had standardized factor-loading estimates > .5 and unstandardized factor-loading *p*-values < .05.

The third step was to respecify the reduced set of items with a higher-order factor structure, in which the three first-order factors were regressed onto a single second-order factor. The purpose of respecifying the factor structure as a higher-order model was to select a more parsimonious factor structure that provided the pragmatic benefit and utility of having a single underlying factor (and composite score).

The fourth step was to inspect the scale reliabilities, which we did by calculating the composite reliability for the higher-order total Math factor and estimating ordinal forms of Cronbach's α, Revelle's β, and McDonald's ω_h for the subscales. As a supplementary analysis, we also estimated the reliability for the total Math scale, except modeled as a single factor on which the reduced set of items loaded directly. To evaluate reliability coefficients, we applied the conventional values of .7 and .8 as the minimum and target values for scale reliability, respectively (Nunnally & Bernstein, 1994; Streiner, 2003).

Using the equation described by Geldhof, Preacher, and Zyphur (2014), we calculated the composite reliability as the squared sum of unstandardized second-order factor loadings divided by the squared sum of unstandardized second-order factor loadings plus the sum of the first-order factor residual variances. The first-order factors are Counting, Word Problems, and Computation. Equation 1 shows the equation for the composite reliability for the second-order Math factor, where λ is the unstandardized second-order factor loading and ζ is the residual variance for the respective first-order factor.

$$\text{Composite reliability} = \frac{(\lambda_{\text{CNT}} + \lambda_{\text{WP}} + \lambda_{\text{CMP}})^2}{(\lambda_{\text{CNT}} + \lambda_{\text{WP}} + \lambda_{\text{CMP}})^2 + (\zeta_{\text{CNT}} + \zeta_{\text{WP}} + \zeta_{\text{CMP}})} \tag{1}$$

This calculation is analogous to the classical conceptualization of reliability as the ratio of true-score variance to the true-score variance plus error-variance.

For our estimation of ordinal forms of Cronbach's α, Revelle's β, and McDonald's ω_h, we executed the procedure described by Gadermann, Guhn and Zumbo (2012). Cronbach's α is mathematically equivalent to the mean of all possible split half reliabilities, and Revelle's β is the worst split half reliability. Only when essential τ equivalence (i.e., unidimensionality and equality of factor loadings) is achieved will α equal β; otherwise, α will always be greater than β. Variability in factor loadings can be attributable to microstructures (multidimensionality) in the data: what Revelle (1979) termed *lumpiness*. McDonald's ω_h models lumpiness in the data through a bifactor structure. The relation between α and ω_h is more dynamic than that between α and β, as α can be greater than, equal to, or less than ω_h, as a result of the particular combination of scale dimensionality and factor-loading variability. We investigated these scale properties by examining the relation among coefficients α, β, and ω_h through the four-type heuristic proposed by Zinbarg, Revelle, Yovel, and Li (2005).

The reduced set of items in the final model of the test were fit to a 2-pl UIRT model to generate a total information curve (TIC) for each grade-level test for the purpose of judging scale reliability across the distribution of person ability. Inspecting the TICs allowed us to make the conversion from information function to reliability along a given range of person abilities with Equation 2.

$$\text{Reliability} = \frac{\text{Information}}{\text{Information}+1} \tag{2}$$

Accordingly, information of 2.33 corresponds to reliability of approximately .70 and information of 4.00 corresponds to a reliability of .80, for example. Equation 2 derives from the classical test theory equation of reliability = true variance / (true variance + error variance). Applied to an IRT framework, where error variance = 1 / information, the equation works out to reliability = 1 / 1 + (1 / information), which coverts algebraically to information / (information + 1) (http://www.lesahoffman.com; cf. Embretson & Reise, 2000).

The reliability estimates directly relevant to the scales as described and presented as the final models in this research report are the composite reliabilities for the higher-order Math factor and the α, β, and ω_h reliability coefficients for the subscales. That is, the α, β, and ω_h reliability coefficients and the 2-pl UIRT information-based reliability estimates for the total Math scale apply to structures and modeling approaches different from that of the higher-order structure described in this research report. These supplementary analyses of reliability for the total Math scale were conducted as part of our endeavor to obtain a broad understanding of how the items from the final model worked together and are presented principally with the purpose of thoroughness and transparency in reporting.

The fifth, and final, step of our investigation of the tests' psychometric properties was to inspect for evidence of predictive validity for the scales. All analyses of predictive validity involved first saving the factor scores from the final higher-order factor model for the grade 1 and grade 2 tests; then, as manifest variables, the factor scores were merged into a file containing scores for the ITBS Math Problems test and ITBS Math Computation test (Dunbar et al., 2008). We investigated evidence of predictive validity by regressing the ITBS tests' standard scores onto the grade 1 and grade 2 tests' factor scores. Standardized β) coefficients, corresponding *p*-values, and adjusted R-squared ($R^2_{Adjusted}$) coefficients of determination are reported, and an $R^2_{Adjusted} > .4$ is interpreted to indicate that a substantial proportion of variance in the target outcome was explained by the test score. The ITBS tests were administered to the sample in spring 2015. For the predictive validity analyses, the sample was restricted to the control group students only.

4. Results

The following sections describe the process of item screening, evaluation, and model respecification that was used to determine the final set of items. Before we report on the detailed results of those analyses, we provide a blueprint for the final tests in section 4.1 that shows the number of items corresponding to the three lower-order factors in the final scale for the tests. After providing the blueprint, we proceed chronologically through the steps of screening, model specification, and evaluation.

4.1. Three-factor Test Blueprint

Table 1 in section 1.1 provided an overview of the original items offered to students on the 2014 EMSA. The grade 1 test initially included 22 items and the grade 2 test 23 items. Some of the items were dropped from the scales because of poor item statistics. Table 6 provides an overview of the number of items that remained in the final scales for grade 1 and 2.

Table 6. Number of Items That Remained on the Fall 2014 Tests After Screening and Respecification

Section	Grade 1	Grade 2	Common items
Counting	3	4	0
Word Problems	5	6	0
Computation	11	10	1
Total	19	20	1

4.2. Item Screening

Tables 7 and 8 present the full set of items on the grade 1 and grade 2 student tests, respectively. The tables report the proportion answered correctly as well as the 2-pl UIRT discrimination and difficulty parameter estimates for each item on each grade level test. For ease of reference, we presented in italics the entries for items that remained in the final model after the full procedure of screening, evaluation, and respecification. Also for ease of reference, we have inserted a column that names which section each item belonged to, according to the item blueprint. Tables 7 and 8 present the items in the order administered and organizes them according to whether the item structure was that of counting, word problem, or computation prompt. Interested readers will find information about the most common incorrect responses to each item in Appendix E.

4.2.1. Grade 1 Item Screening

Table 7 reveals that one item on the grade 1 test fell below the minimum acceptable value (–3) for item difficulty. The high proportion correct observed for Item 1 (.96) is consistent with the estimate for its difficulty parameter.

Table 7. Grade 1 Test Item Descriptions, Percentage Correct, and Unidimensional IRT Parameters

		Proportion	2-pl UIRT parameters	
Section	Item description	correct	Discrimination	Difficulty
Counting				
Item 1[a]	[redacted]	*.955*	*0.302*	*–6.159*
Item 2	[redacted]	.778	0.763	–1.260
Item 3	[redacted]	.558	0.867	–0.225
Item 4	[redacted]	.321	0.824	0.726
Word Problems				
Item 5	[redacted]	.781	0.647	–1.420
Item 6	[redacted]	.378	0.679	0.543
Item 7	[redacted]	.315	0.604	0.914
Item 8	[redacted]	.201	0.554	1.716
Item 9[a]	[redacted]	*.603*	*0.521*	*–0.552*
Item 10	[redacted]	.359	0.733	0.602
Computation				
Item 11	[redacted]	.683	0.961	–0.661
Item 12	[redacted]	.436	1.350	0.231
Item 13	[redacted]	.493	0.766	0.068
Item 14	[redacted]	.368	1.102	0.484
Item 15	[redacted]	.453	0.812	0.224
Item 16	[redacted]	.355	1.223	0.485
Item 17	[redacted]	.330	1.107	0.644
Item 18	[redacted]	.292	1.275	0.753
Item 19	[redacted]	.365	1.284	0.501
Item 20[a]	[redacted]	*.364*	*0.612*	*0.718*
Item 21	[redacted]	.342	0.658	0.796
Item 22	[redacted]	.245	1.277	0.950

Note. n = 1,595 grade 1 students who completed the EMSA in fall 2014. 2-pl UIRT refers to 2-parameter logistic unidimensional item response theory model. Discrimination estimates use a 1.702 scaling constant to minimize the maximum difference between the normal and logistic distribution functions (Camilli, 1994). [a]Information about items that were removed during the calibration process and not used in the final scale is presented in italics.

We plotted the discrimination and difficulty parameters to inform our decision on retaining or dropping items. Figure 2 presents the grade 1 difficulty-versus-discrimination scatterplot. Because several satisfactorily discriminating items fell near the lower-end of the difficulty range, the lower end of the difficulty distribution seemed adequately represented without the retention of item 1. In addition, the difficulty parameter estimate for item 1 of –6.16 exceeded the minimum threshold of –3 by a large margin. We therefore determined that item 1 did not pass the item screening.

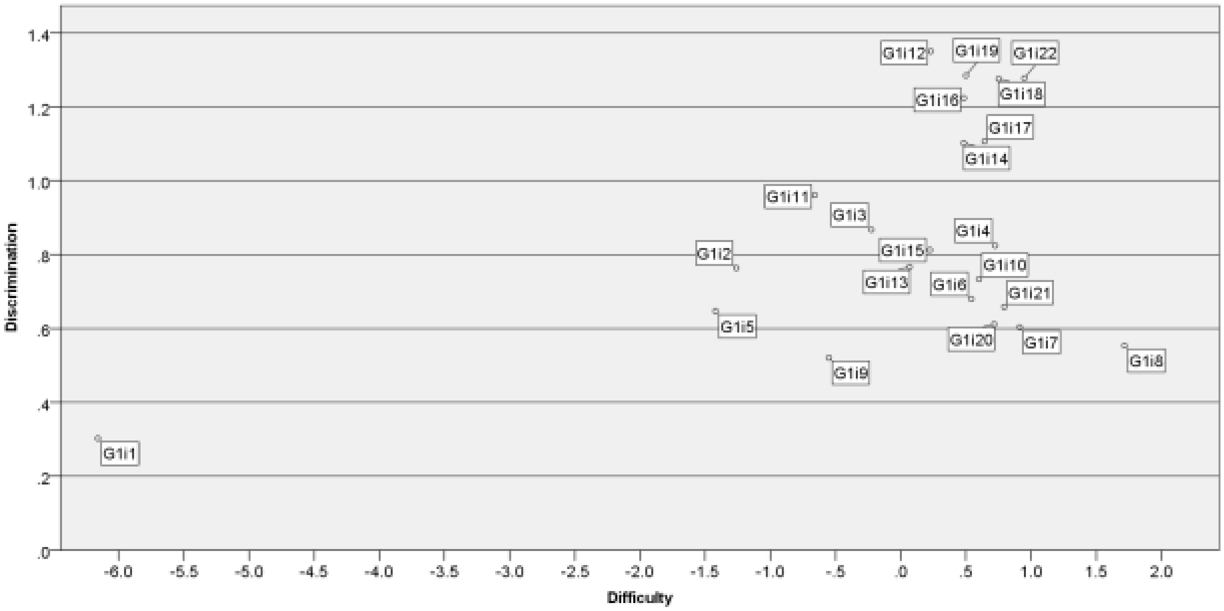


Figure 2. Grade 1 test 2-pl unidimensional item response theory (UIRT) difficulty-vs.-discrimination scatterplot.

4.2.2. Grade 2 Item Screening

Table 8 reveals that, on the grade 2 test, item 6 fell below the minimum acceptable value (0.4) for item discrimination, and item 12 fell below the minimum acceptable value (–3) for item difficulty. For item 12, the observed high proportion correct (.94) is consistent with the estimate of its difficulty parameter.

Table 8. Grade 2 Test Item Descriptions, Descriptive Statistics, and Unidimensional IRT Parameters

		Proportion	2-pl UIRT parameters	
Section	Item description	correct	Discrimination	Difficulty
Counting				
Item 1	[redacted]	.877	0.782	–1.902
Item 2	[redacted]	.624	1.148	–0.413
Item 3	[redacted]	.694	0.931	–0.741
Item 4	[redacted]	.539	1.135	–0.126
Word Problems				
Item 5	[redacted]	.768	1.019	–1.030
Item 6[a]	[redacted]	*.618*	*0.270*	*–1.091*
Item 7	[redacted]	.669	0.911	–0.645
Item 8	[redacted]	.523	1.065	–0.074
Item 9	[redacted]	.568	1.162	–0.221
Item 10	[redacted]	.479	0.982	0.078
Item 11	[redacted]	.444	0.800	0.225
Computation				
Item 12[a]	[redacted]	*.943*	*0.623*	*–3.082*
Item 13	[redacted]	.628	0.434	–0.783
Item 14	[redacted]	.687	0.584	–0.937
Item 15	[redacted]	.814	0.524	–1.903
Item 16[a]	[redacted]	*.758*	*0.464*	*–1.613*
Item 17	[redacted]	.561	0.579	–0.299
Item 18	[redacted]	.567	0.473	–0.362
Item 19	[redacted]	.500	0.666	0.024
Item 20	[redacted]	.234	0.616	1.402
Item 21	[redacted]	.733	0.560	–1.231
Item 22	[redacted]	.469	0.863	0.154
Item 23	[redacted]	.206	0.513	1.803

Note. n = 1,485 grade 2 students who completed the EMSA in fall of 2014. 2-pl UIRT refers to 2-parameter logistic unidimensional item response theory model. Discrimination estimates use a 1.702 scaling constant to minimize the maximum difference between the normal and logistic distribution functions (Camilli, 1994). [a]Information about items that were removed during the calibration process and not used in the final scale is presented in italics.

We plotted the discrimination and difficulty parameters to inform our decisions about retaining or dropping items. Figure 3 presents the grade 2 difficulty-versus-discrimination scatterplot. Because several satisfactorily discriminating items fell near the middle of the distribution of difficulty estimates, the lower end of the difficulty distribution seemed adequately represented without the retention of item 6. Accordingly, we determined that item 6 did not pass the item screening. With regard to item 12, a few acceptably discriminating items also fell at the lower end of the difficulty distribution, suggesting that this area could be adequately represented without it, but because the difficulty estimate of –3.08 for item 12 was right at the retention threshold, we determined that it passed the initial screening, though we flagged it for further scrutiny in subsequent models.

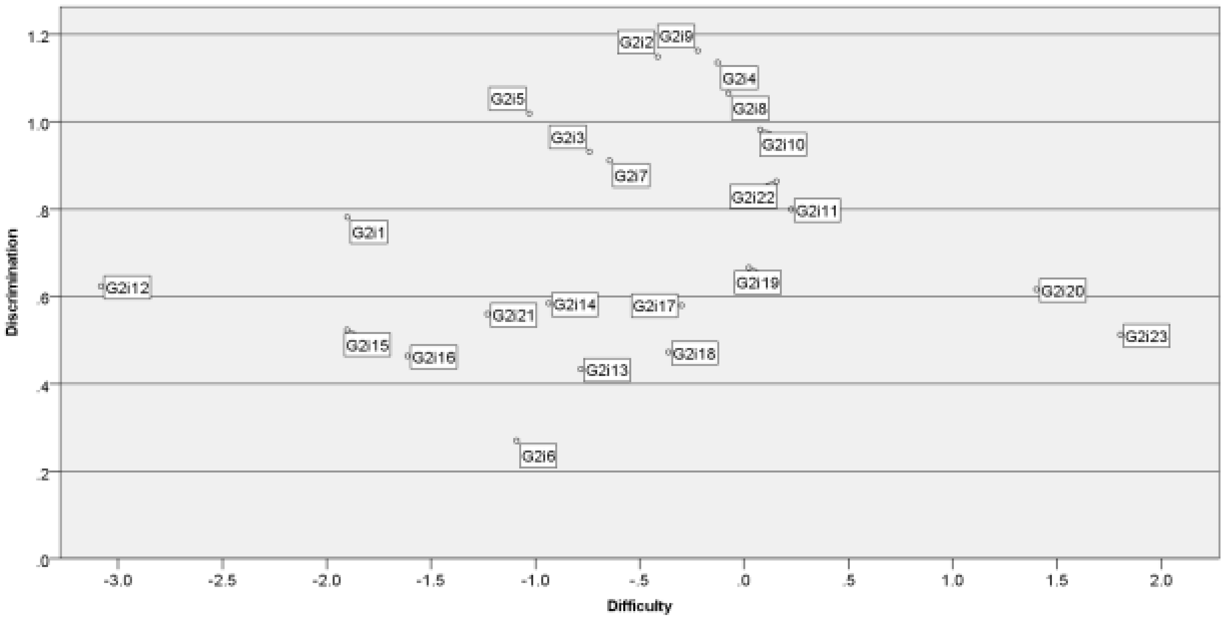


Figure 3. Grade 2 test 2-pl UIRT difficulty-vs.-discrimination scatterplot.

4.3. Correlated Trait Model Evaluation

4.3.1. Grade 1 Correlated Trait Model Evaluation

The initial grade 1 correlated-trait model contained all items that were administered on the grade 1 test except item 1. All items in the initial model had statistically significant unstandardized factor loadings ($p < .001$). Three items (8, 9, and 20) had standardized factor loadings that were near the factor-loading minimum acceptable value of .5. Upon inspection of the standardized loadings for item 8 (.57), item 9 (.54), and item 20 (.58) and their representation of the range of item difficulty, as well as consideration of their relative contribution toward the content validity of the scale, we decided that Item 9 and Item 20 could be dropped for the revised model. Item 8, however, was retained because of its representation of the upper end of the difficulty distribution.

We then fit the data for the reduced set of grade 1 items to a revised correlated-trait structure and evaluated the factorial validity of the model on the basis of overall goodness of fit and interpretability, size, and statistical significance of the parameter estimates. The revised grade 1 correlated-trait model-fit statistics indicated mediocre fit by the RMSEA statistic and reasonable fit by the CFI and TLI statistics: $\chi^2(149) = 1715.379$, $p < .001$; RMSEA = .081, 90% Confidence Interval [.078, .085]; CFI = .916; and TLI = .904. All unstandardized factor loadings for the revised grade 1 model were statistically significant. Table 9 presents the standardized factor loadings for the initial and revised correlated trait model. All standardized factor loadings for the revised grade 1 model were above the minimum acceptable value of .5, and most were well above the target value of .7.

Table 9. Grade 1 Standardized Factor Loadings for Initial and Revised Correlated Trait Model

		Initial model		Revised model	
Factor	Indicator description	Estimate	(*SE*)	Estimate	(*SE*)
Counting					
Item 1	[redacted]	—	—	—	—
Item 2	[redacted]	.746	(.027)	.750	(.027)
Item 3	[redacted]	.843	(.022)	.846	(.023)
Item 4	[redacted]	.809	(.027)	.802	(.028)
Word Problems					
Item 5	[redacted]	.605	(.034)	.606	(.035)
Item 6	[redacted]	.697	(.027)	.706	(.027)
Item 7	[redacted]	.646	(.029)	.652	(.030)
Item 8	[redacted]	.572	(.037)	.578	(.038)
Item 9	[redacted]	.543	(.032)	—	—
Item 10	[redacted]	.714	(.027)	.720	(.027)
Computation					
Item 11	[redacted]	.716	(.023)	.702	(.023)
Item 12	[redacted]	.880	(.014)	.888	(.013)
Item 13	[redacted]	.674	(.023)	.659	(.024)
Item 14	[redacted]	.802	(.017)	.812	(.017)
Item 15	[redacted]	.695	(.022)	.682	(.023)
Item 16	[redacted]	.850	(.015)	.858	(.015)
Item 17	[redacted]	.770	(.021)	.777	(.020)
Item 18	[redacted]	.815	(.019)	.821	(.019)
Item 19	[redacted]	.815	(.019)	.821	(.018)
Item 20	[redacted]	.580	(.029)	—	—
Item 21	[redacted]	.604	(.028)	.560	(.030)
Item 22	[redacted]	.801	(.021)	.806	(.021)

Note. *n* = 1,595.

Table 10 presents the correlations among the factors for the grade 1 revised model. All interfactor correlations were statistically significant and moderate to large in size. No interfactor correlations were so large as to suggest colinearity. Figure 4 illustrates the correlated factor structure and standardized factor loadings for the revised grade 1 model.

Table 10. Grade 1 Factor Correlations (and Standard Errors) for the Revised Correlated Trait Model

Factors	Counting	Word Problems	Computation
Counting	—		
Word Problems	.835 (.024)	—	
Computation	.624 (.026)	.667 (.025)	—

Note. *n* = 1,595

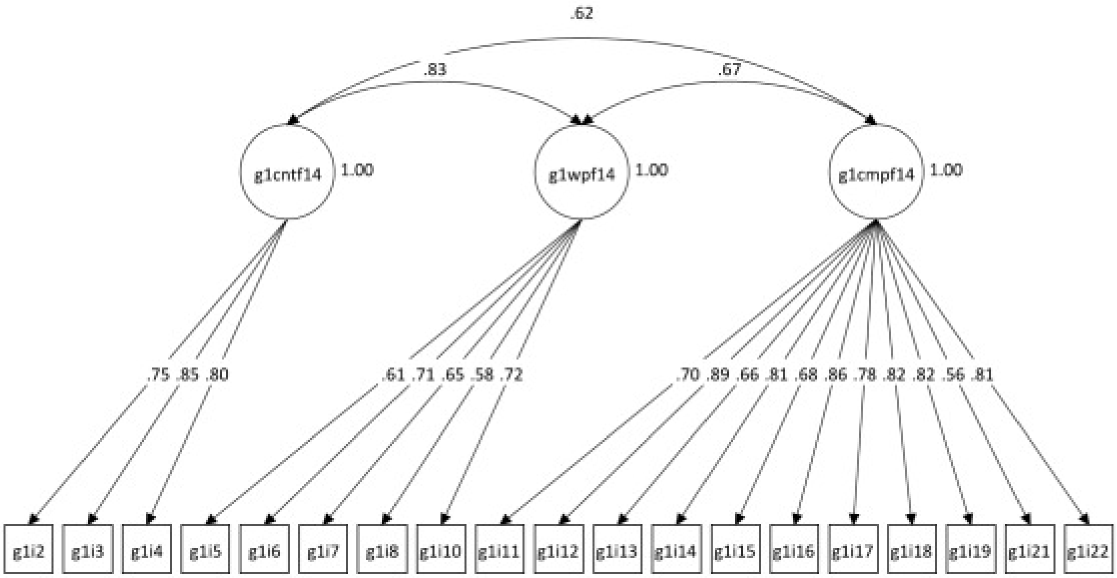


Figure 4. Grade 1 revised model – correlated trait model diagram with standardized parameter estimates. Factor g1cntf14 is the grade 1 Counting factor for fall 2014. Factor g1wpf14 is the grade 1 Word Problems factor for fall 2014. Factor g1cmpf14 is the grade 1 Computation factor for fall 2014.

4.3.2. Grade 2 Correlated Trait Model Evaluation

The initial grade 2 model contained all items that were administered on the grade 2 test except Item 6. All items in the initial model had statistically significant unstandardized factor loading ($p < .001$). Nine items (12, 13, 14, 15, 16, 18, 20, 21, and 23) had standardized factor loadings that were near or below the factor-loading minimum acceptable value of .5. Upon inspection of the standardized loadings for item 12 (.52), item 13 (.50), item 14 (.60), item 15 (.56), item 16 (.49), item 18 (.54), item 20 (.58), item 21 (.59), and item 23 (.52) and their representation of the range of item difficulty, as well as consideration of their relative contribution toward the content validity of the scale, we determined that items 12 and 16 should be dropped for the revised model and the others should remain. Considerations in this determination were that item 12 was already flagged for further scrutiny because of an outlier difficulty parameter estimate in the 2-pl UIRT model, and with continued marginal performance in the correlated trait model, it was determined not to perform adequately. An example of other considerations was the retention of item 20 and item 23 because of their representation of the upper end of the difficulty distribution.

We then fit the data for the reduced set of grade 2 items to a revised correlated-trait structure and evaluated the factorial validity of the model on the basis of overall goodness of fit and interpretability, size, and statistical significance of the parameter estimates. The revised grade 2 correlated-trait model-fit statistics indicated close fit for the RMSEA, CFI, and TLI statistics: $\chi^2(167) = 532.780$, $p < .001$; RMSEA = .038, 90% Confidence Interval [.035, .042]; CFI = .968; and TLI = .964. All unstandardized factor loadings for the revised grade 2 model were statistically significant. Table 11 presents the standardized factor loadings for the initial and revised correlated trait model. All standardized factor loadings for the revised grade 2 model were above the minimum acceptable value of .5, and most were well above the target of .7.

Table 11. Grade 2 Standardized Factor Loadings for Initial and Revised Correlated Trait Model

		Initial model		Revised model	
Factor	Indicator description	Estimate	(*SE*)	Estimate	(*SE*)
Counting					
Item 1	[redacted]	.651	(.038)	.646	(.039)
Item 2	[redacted]	.830	(.021)	.829	(.021)
Item 3	[redacted]	.750	(.026)	.751	(.026)
Item 4	[redacted]	.815	(.021)	.818	(.021)
Word Problems					
Item 5	[redacted]	.767	(.026)	.765	(.026)
Item 6	[redacted]	—	—	—	—
Item 7	[redacted]	.729	(.025)	.730	(.025)
Item 8	[redacted]	.784	(.022)	.783	(.022)
Item 9	[redacted]	.807	(.021)	.806	(.021)
Item 10	[redacted]	.751	(.024)	.753	(.024)
Item 11	[redacted]	.668	(.027)	.669	(.027)
Computation					
Item 12	[redacted]	.523	(.065)	—	—
Item 13	[redacted]	.504	(.032)	.510	(.034)
Item 14	[redacted]	.595	(.032)	.577	(.036)
Item 15	[redacted]	.559	(.038)	.564	(.040)
Item 16	[redacted]	.487	(.037)	—	—
Item 17	[redacted]	.621	(.028)	.626	(.030)
Item 18	[redacted]	.540	(.032)	.549	(.033)
Item 19	[redacted]	.656	(.027)	.660	(.029)
Item 20	[redacted]	.577	(.033)	.590	(.035)
Item 21	[redacted]	.589	(.034)	.581	(.037)
Item 22	[redacted]	.742	(.025)	.757	(.027)
Item 23	[redacted]	.520	(.037)	.532	(.038)

Note. n = 1,485.

Table 12 presents the correlations among the factors for the revised grade 2 model. All interfactor correlations were statistically significant and moderate to large in size. No interfactor correlations were so large as to suggest colinearity. Figure 5 illustrates the correlated-factor structure and standardized factor loadings for the revised grade 2 model.

Table 12. Grade 2 Factor Correlations for the Revised Correlated Trait Model

Factor	Counting	Word Problems	Computation
Counting	—		
Word Problems	.845 (.020)	—	
Computation	.662 (.028)	.655 (.026)	—

Note. *n* = 1,485.

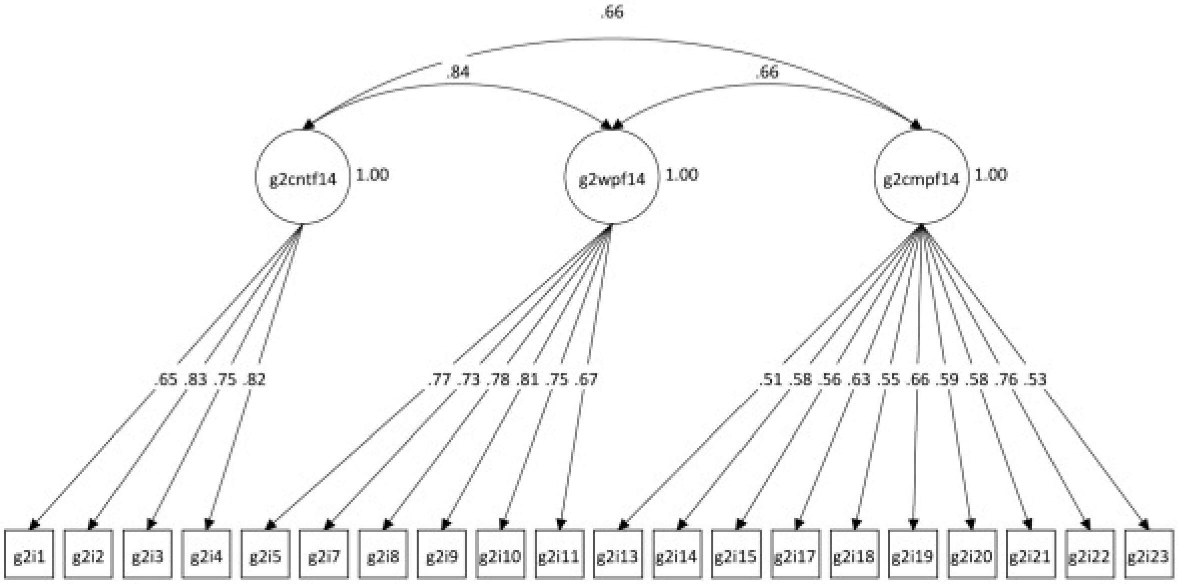


Figure 5. Grade 2 revised model – correlated trait model diagram with standardized parameter estimates. Factor g2cntf14 is the grade 2 Counting factor for fall 2014. Factor g2wpf14 is the grade 2 Word Problems factor for fall 2014. Factor g2cmpf14 is the grade 2 Computation factor for fall 2014.

4.4. Higher-Order Model Evaluation

Higher-order factor models with three first-order factors are considered just identified. That is, the higher-order model and the correlated trait model each use three parameters to specify the relationship between the first-order factors. Accordingly, which model fits the data better cannot be determined. Also, the fit statistics are identical for the two structures, and the standardized factor loadings are nearly identical. Notwithstanding the indeterminacy of which model is better, the pragmatic advantage of using a second-order factor structure to derive an overall score for the tests was compelling enough to justify use of a higher-order structure for the final model.

4.4.1. Grade 1 Higher-order Model Evaluation

Table 13 presents the standardized factor loadings and factor residual variances for the grade 1 higher-order measurement model. Figure 6 illustrates the higher-order factor structure and standardized factor loadings for the final grade 1 model.

Table 13. Standardized Factor Loadings and Factor Residual Variances for the Grade 1 Higher-Order Measurement Model

Factor	Indicator description	Estimate	(*SE*)
	Lower-order factors		
Counting			
Item 1	[redacted]	—	—
Item 2	[redacted]	.750	(.027)
Item 3	[redacted]	.846	(.023)
Item 4	[redacted]	.802	(.028)
Word Problems			
Item 5	[redacted]	.606	(.035)
Item 6	[redacted]	.706	(.027)
Item 7	[redacted]	.652	(.030)
Item 8	[redacted]	.578	(.038)
Item 9	[redacted]	—	—
Item 10	[redacted]	.720	(.028)
Computation			
Item 11	[redacted]	.702	(.023)
Item 12	[redacted]	.888	(.013)
Item 13	[redacted]	.659	(.024)
Item 14	[redacted]	.812	(.017)
Item 15	[redacted]	.682	(.023)
Item 16	[redacted]	.858	(.015)
Item 17	[redacted]	.777	(.020)
Item 18	[redacted]	.821	(.019)
Item 19	[redacted]	.821	(.018)
Item 20	[redacted]	—	—
Item 21	[redacted]	.560	(.030)
Item 22	[redacted]	.806	(.021)
	Higher-order factor		
Math			
Counting	Counting latent variable	.883	(.025)
Word Problems	Word Problems latent variable	.945	(.023)
Computation	Computation latent variable	.706	(.022)
	Residual variance		
Counting		.220	(.045)
Word Problems		.107	(.044)
Computation		.501	(.032)

Note. *n* = 1,595.

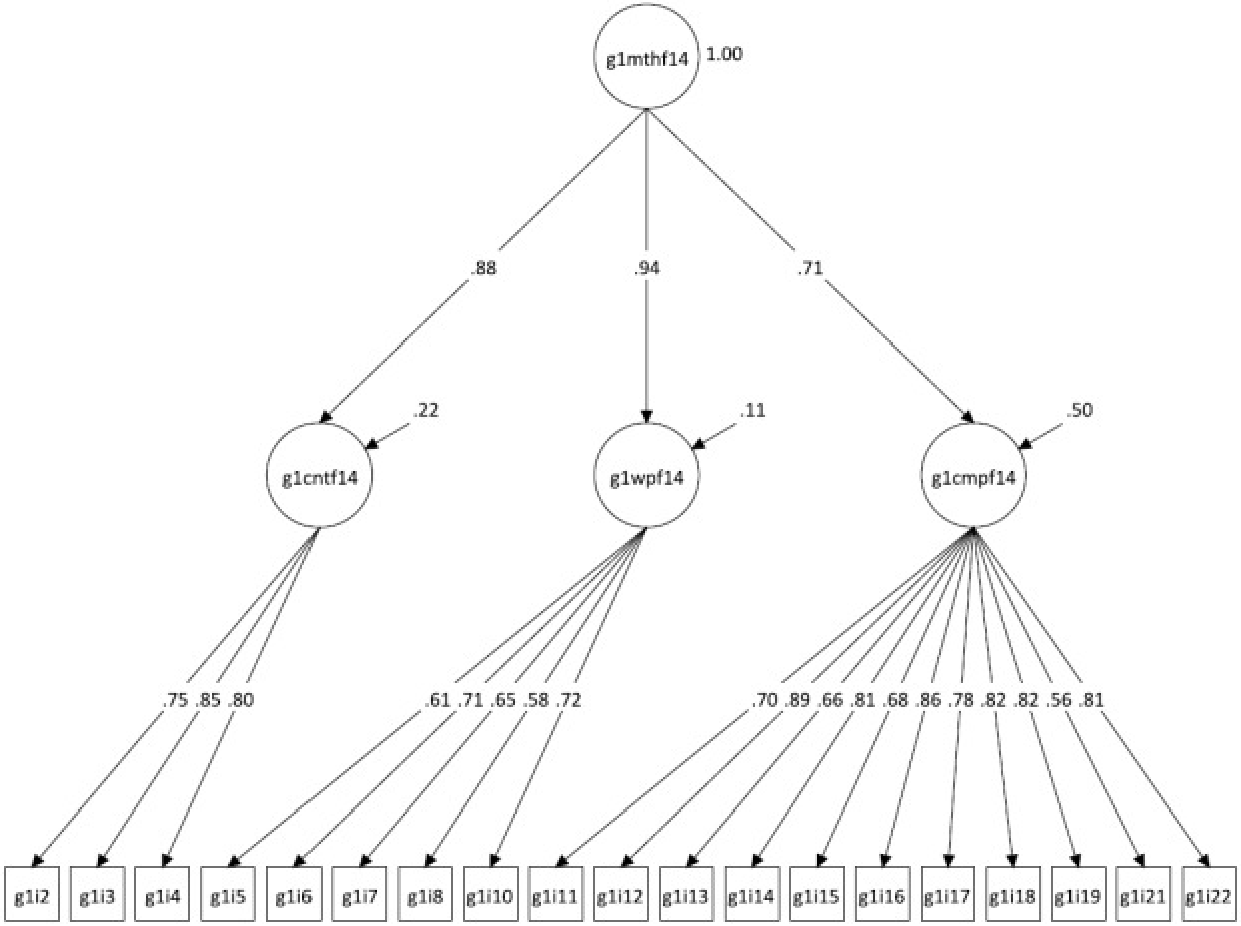


Figure 6. Grade 1 final model – higher-order factor diagram with standardized parameter estimates.

4.4.2. Grade 2 Higher-order Model Evaluation

Table 14 presents the standardized factor loadings and factor residual variances for the grade 2 higher-order measurement model. Figure 7 illustrates the higher-order factor structure and standardized factor loadings for the final grade 2 model.

Table 14. Standardized Factor Loadings and Factor Residual Variances for the Grade 2 Higher-Order Measurement Model

Factor	Indicator description	Estimate	(*SE*)
	Lower-order factors		
Counting			
Item 1	[redacted]	.646	(.039)
Item 2	[redacted]	.829	(.021)
Item 3	[redacted]	.751	(.026)
Item 4	[redacted]	.818	(.021)
Word Problems			
Item 5	[redacted]	.765	(.026)
Item 6	[redacted]	—	—
Item 7	[redacted]	.730	(.025)
Item 8	[redacted]	.783	(.022)
Item 9	[redacted]	.806	(.021)
Item 10	[redacted]	.753	(.024)
Item 11	[redacted]	.669	(.027)
Computation			
Item 12	[redacted]	—	—
Item 13	[redacted]	.510	(.033)
Item 14	[redacted]	.577	(.034)
Item 15	[redacted]	.564	(.038)
Item 16	[redacted]	—	—
Item 17	[redacted]	.626	(.029)
Item 18	[redacted]	.549	(.032)
Item 19	[redacted]	.660	(.028)
Item 20	[redacted]	.590	(.034)
Item 21	[redacted]	.581	(.035)
Item 22	[redacted]	.757	(.025)
Item 23	[redacted]	.532	(.037)
	Higher-order factor		
Math			
Counting	Counting latent variable	.924	(.023)
Word Problems	Word Problems latent variable	.914	(.022)
Computation	Computation latent variable	.717	(.024)
	Residual variance		
Counting		.145	(.043)
Word Problems		.164	(.039)
Computation		.487	(.034)

Note. *n* = 1,485.

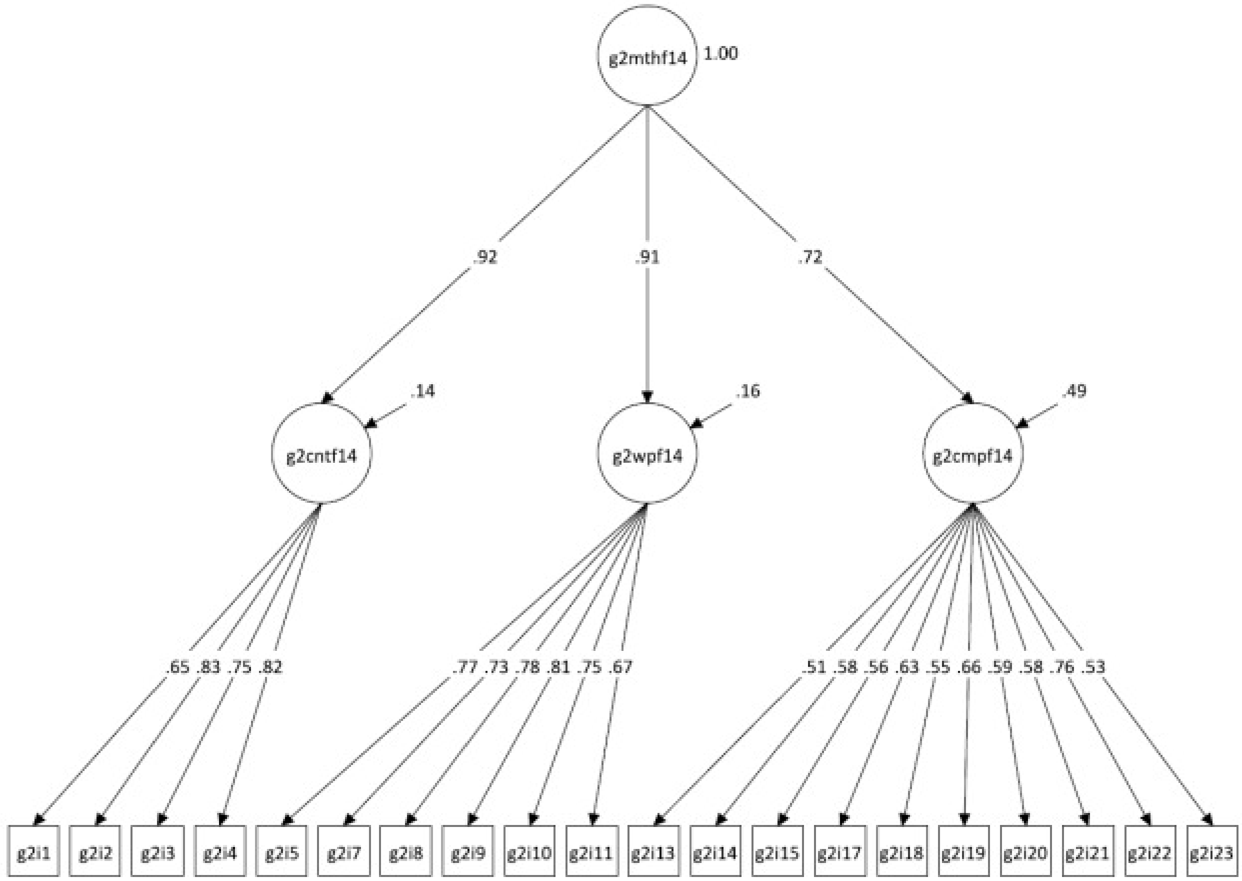


Figure 7. Grade 2 final model – higher-order factor diagram with standardized parameter estimates.

4.5. Scale Reliability Evaluation

4.5.1. Grade 1 Scale Reliabilities

The scale reliabilities for the grade 1 test suggested acceptable reliability for all scales. The grade 1 higher-order Math factor composite reliability estimate was evaluated by means of Equation 3, where the numerator is the squared sum of the unstandardized second-order factor loadings and the denominator is the squared sum of the unstandardized second-order factor loadings plus the sum of the first-order factor residual variances.

$$\frac{(0.708 + 0.681 + 0.569)^2}{(0.708 + 0.681 + 0.569)^2 + (0.141 + 0.055 + 0.325)} = .880 \tag{3}$$

The present sample indicated a composite reliability estimate of .88 for the grade 1 higher-order Math factor.

Table 15 displays the α, β, and ω_h ordinal scale reliability coefficients by subscale and for the total scale. The α estimates for the Counting, Word Problems, Computation, and Math scales exceeded the target of .8. Comparison between the αs and βs revealed a range of discrepancies, some moderate (such as for the Word Problems scale, where α = .80 and β = .75) and others large (such as for the Computation scale, where α = .92 and β = .81, or for the Math scale, where α = .93 and β = .79). The magnitudes of discrepancies indicate heterogeneity among the factor loadings, challenging the assumption of essential τ equivalence. Comparison between the α and ω_h coefficients revealed discrepancies to be negligible for the Counting scale (–.01), small for the Word Problems scales (.03), moderate for the Computation scale (.06) and large for the Math scale (.22). Except for the Counting scale, α exceeded ω_h for all estimates, and the α to ω_h discrepancies indicated the presence of multidimensionality within the scales. The ω_h estimates for each subscale and the Math scale exceeded the conventional minimum value of .7, suggesting composite scores can be interpreted as reflecting a single common source of variance for each scale in spite of evidence of some within-scale multidimensionality (Gustafsson & Aberg-Bengtsson, 2010).

Table 15. Grade 1 Scale Reliability Estimates

	Number	Reliability		
Scale	of items	α	β	ω_h
Counting	3	.83	.75	.84
Word problems	5	.80	.75	.77
Computation	11	.92	.81	.86
Math	19	.93	.79	.71

Note. *n* = 1,595. α, β, and ω_h are ordinal forms of Cronbach's α, Revelle's β, and McDonald's ω_h, respectively.

Inspection of the 2-pl UIRT TIC in Figure 8 reveals that the information curve for the grade 1 test exceeded 2.33 (i.e., reliability estimate of .7) for the ability range of approximately -1.6 through 2.2. Given the sample descriptive statistics (M = 0.00, SD = 0.92, Min = –1.93, and Max = 2.27), this result suggests acceptable reliability of the scale for approximately 95% of the sample and nearly the full range of observed abilities. The information curve exceeded 4 (i.e., reliability estimate of .8) for the ability range of approximately –1.0 through 1.8, indicating that target reliability of the scale was achieved for approximately 84% of the sample.[1]

[1] Areas under normal distribution calculated with the online normal-distribution calculator found at http://onlinestatbook.com/2/calculators/normal_dist.html

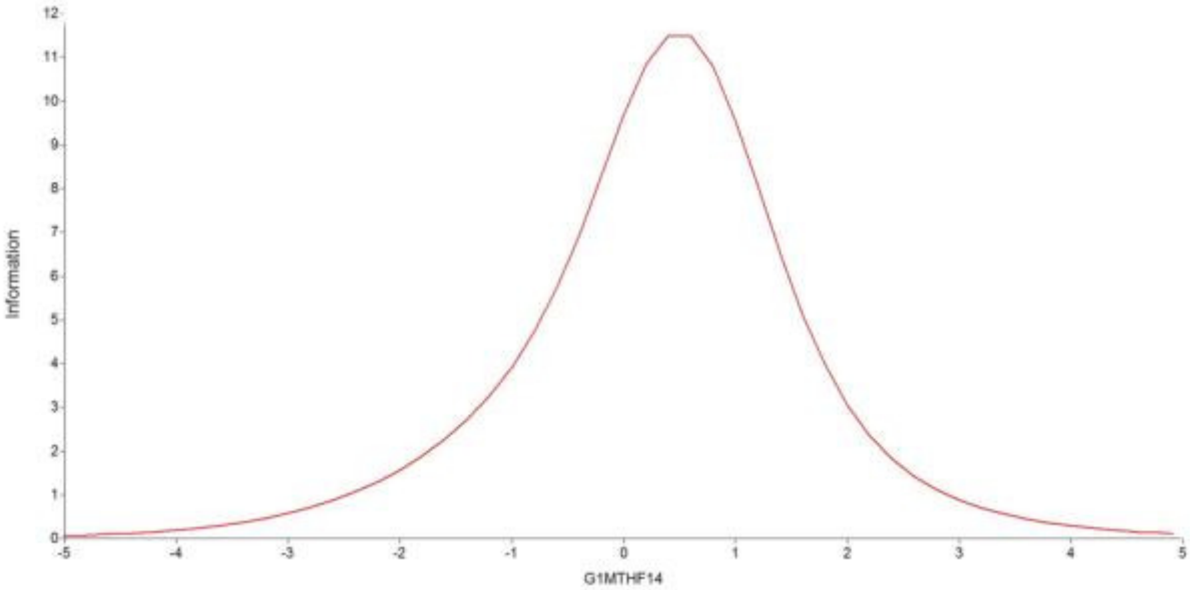


Figure 8. Grade 1 2-pl UIRT total information curve and participant descriptives for the reduced set of items modeled as a single factor.

Figure 9 presents the overall distribution of number of items answered correctly in grade 1 for the reduced set of items. Similar figures for each subscale are provided in Appendix E.

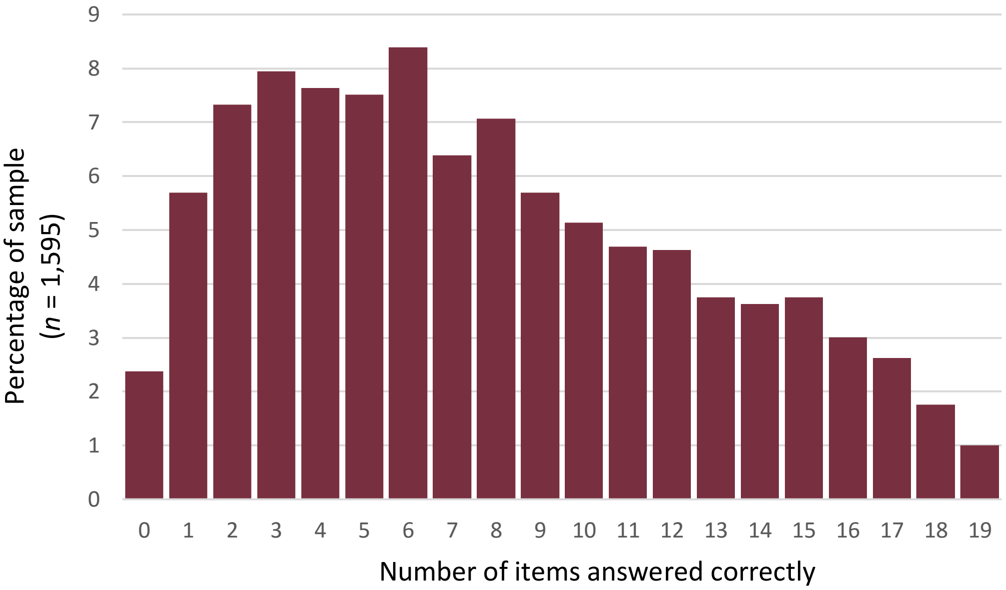


Figure 9. Distribution of the number of items individual students in the grade 1 sample answered correctly on the reduced set of items.

4.5.2. Grade 2 Scale Reliabilities

The scale reliabilities for the grade 2 test suggested acceptable reliability for all scales. The grade 2 higher-order (i.e., Math) factor composite reliability estimate was calculated from Equation 4, where the numerator is the squared sum of the unstandardized second-order factor loadings and the denominator is the squared sum of the unstandardized second-order factor loadings plus the sum of the first-order factor residual variances.

$$\frac{(0.756+0.612+0.381)^2}{(0.756+0.612+0.381)^2+(0.097+0.073+0.138)}=.909 \tag{4}$$

We calculated a composite reliability for the grade 2 higher-order factor of .91, which exceeds the target reliability of .8.

Table 16 displays the α, β, and ω_h ordinal reliability coefficients for the reduced set of items by subscale and for the total scale. All α estimates for all subscales exceeded or met the target of .8. As with the grade 1 test, comparison between the αs and βs revealed a range of discrepancies (range .03 to .12), challenging the assumption of essential τ equivalence where the discrepancy was sizable. Comparison between the α and ω_h coefficients also revealed a range of discrepancies (range .01 to .27). For all scales, α exceeded ω_h, where the magnitude of the α to ω_h discrepancy indicates the extent of multidimensionality within the respective scale. For the Counting and Word Problems subscales, ω_h exceeded the conventional target value of .8. As demonstrated by Gustafsson and Aberg-Bengtsson (2010), high values of ω_h indicate that composite scores can be interpreted as reflecting a single common source of variance in spite of evidence of some within-scale multidimensionality.

Table 16. Grade 2 Scale Reliability Estimates

	Number	Reliability		
Scale	of items	α	β	ω_h
Counting	4	.85	.82	.82
Word problems	6	.85	.80	.84
Computation	10	.84	.73	.67
Math	20	.91	.79	.64

Note. *n* = 1,485. α, β, and ω_h are ordinal forms of Cronbach's α, Revelle's β, and McDonald's ω_h, respectively.

Inspection of the 2-pl UIRT TIC in Figure 10, reveals the information curve for the grade 2 test to exceed 2.33 (i.e., reliability estimate of .7) for the ability range of approximately –2.3 through 1.6. Given the sample descriptive statistics (M = –0.00, SD = 0.92, Min = –2.47, and Max = 2.00), this result suggests acceptable reliability of the scale for over 95% of the sample and nearly the full range of observed abilities. The information curve exceeds 4 (i.e., reliability estimate of .8) for the ability range of approximately –1.8 through 1.0, indicating target reliability of the scale was achieved for approximately 84% of the sample.

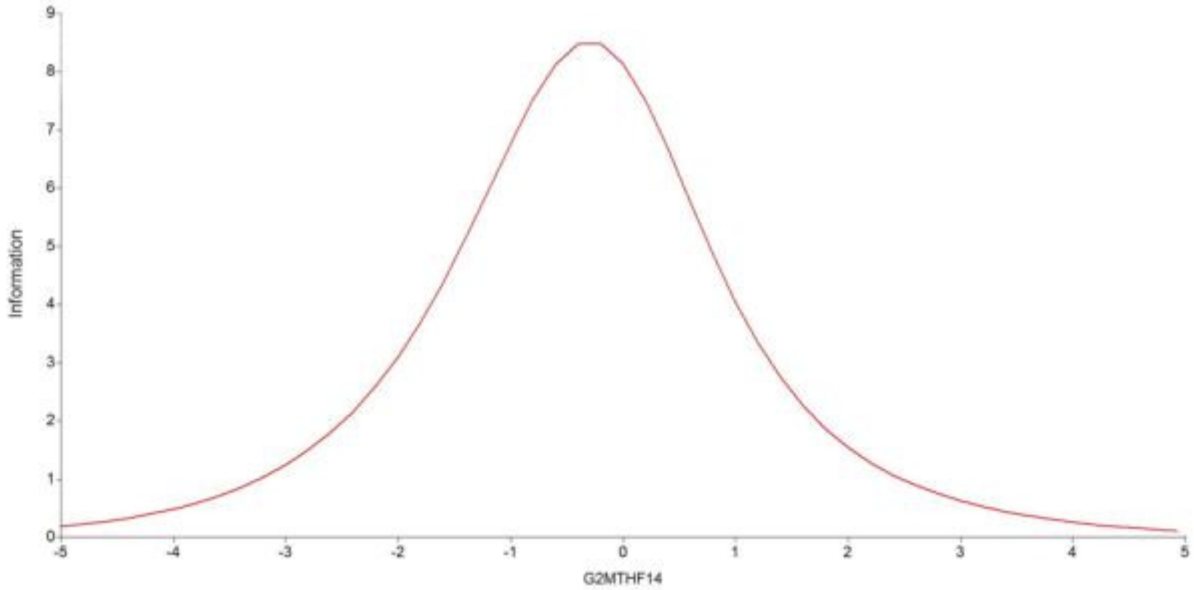


Figure 10. Grade 2 2-pl UIRT total information curve and participant descriptives for the reduced set of items modeled as a single factor.

Figure 11 presents the overall distribution of number of items answered correctly in grade 2 for the reduced set of items. Similar figures for each subscale are provided in Appendix E.

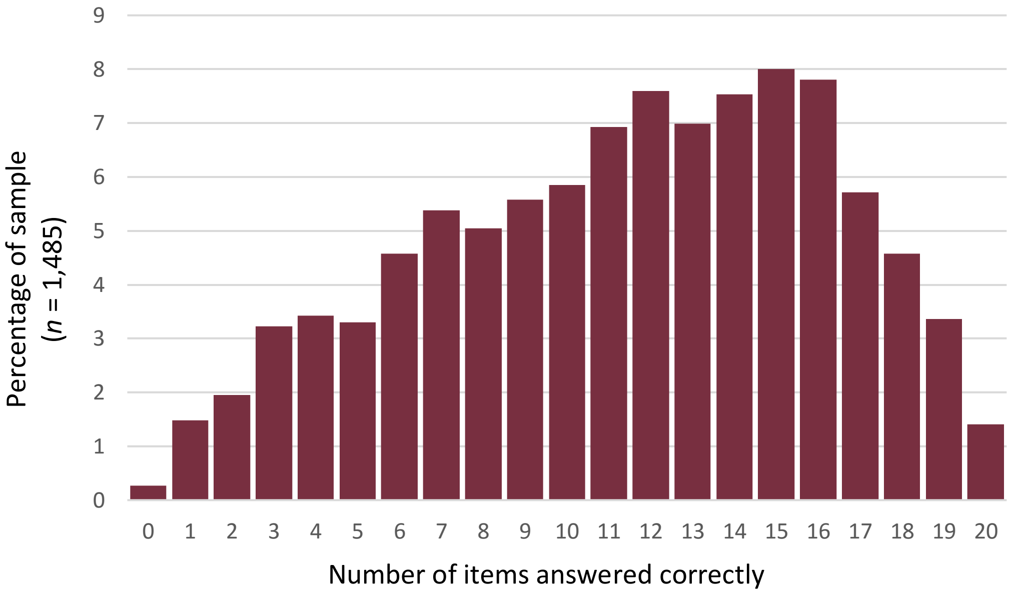


Figure 11. Distribution of the number of items individual students in the grade 2 sample answered correctly on the complete reduced set of items.

4.6. Predictive Validity Evaluation

We used regression analyses to explore the extent to which the EMSA Math factor predicted performance on each of the two ITBS tests (i.e., Math Problems, Math Computation) at each grade level. Regression results suggested that the factor score for the higher-order Math scale was a moderate to strong predictor of the ITBS Math Problems test, where an $R^2_{Adjusted}$ of .45 was found for the grade 1 control group and an $R^2_{Adjusted}$ of .55 was found for the grade 2 control group in the randomized controlled trial. The subgroup of students in the schools assigned at random to the control condition were used for the predictive validity evaluation, because it was not known how the intervention might affect the result, and the control group sample was sufficiently large. The Math factor score provided only modest predictive power with the ITBS Math Computation test, where an $R^2_{Adjusted}$ of .28 was found for the grade 1 control group and an $R^2_{Adjusted}$ of .36 was found for the grade 2 control group. All models were statistically significant at $p < .001$. Table 17 presents the results for the single linear regressions of the ITBS Math Problems and Math Computation tests on the Math scale when applied to the grade 1 and grade 2 control group. Overall, the EMSA Math factor may be a stronger predictor of the ITBS Math Problems test than it is of the ITBS Math Computation test.

Table 17. Results for Single Linear Regressions of Standard Scores on the Iowa Test of Basic Skills (ITBS) Math Problems and Math Computation Tests on the Math Factor Scores for the Grade 1 and Grade 2 Control Group

	df		*F*			
Criterion	Regression	Residual	Statistic	*p*	β	$R^2_{Adjusted}$
Grade 1 Control group						
ITBS Math Problems	1	601	483.508	< .001	.668	.445
ITBS Math Computation	1	588	224.199	< .001	.525	.275
Grade 2 Control group						
ITBS Math Problems	1	417	504.805	< .001	.740	.547
ITBS Math Computation	1	414	230.293	< .001	.598	.356

Note. Grade 1 ITBS Math Problems $n = 603$. Grade 1 ITBS Math Computation $n = 590$. Grade 2 ITBS Math Problems $n = 419$. Grade 2 ITBS Math Computation $n = 416$.

5. Discussion and Conclusions

The intended use of the fall 2014 EMSA tests was to serve as a baseline test of student achievement to be used as a covariate in a randomized controlled trial of a teacher professional-development intervention. The development and analysis of the fall 2014 EMSA tests are consistent with general recommendations for test development and test validation for the intended purposes of the Fall 2014 EMSA. If the test were used for other purposes, such as to distinguish among levels of individual student achievement, it would require further development and validation.

The field tests involved a diverse sample of several thousand grade 1 and 2 students in fall 2014. The tests were administered at the beginning of the school year by classroom teachers in most cases. The test scores were not known by the schools or used for any kind of school- or teacher-accountability purpose. Our sample does not reveal how changes in these testing conditions might affect the data. Further validation efforts would be necessary if the test were administered under different conditions or used for different purposes.

5.1. Validation

Flake et al. (2017) outline three phases of construct validation: substantive, structural, and external. These phases provide a useful lens for evaluating the validity of the test for its intended purpose. The development and field testing of the fall 2014 EMSA provides evidence of validity for each of the three phases. We discuss each of those phases in that order.

5.1.1. Substantive Validation

The analysis of content in the CCSS-M and the CGI professional development program provided a definition of the content. The items were developed on the basis of previous tests and expert knowledge of the CCSS-M and the CGI program. Items were selected or written on the basis of results of the fall 2013 EMSA tests and the spring 2014 MPAC interview. Administration procedures were consistent with typical classroom assessment in mathematics, including that of standardized tests such as the ITBS. External review of items and scoring criteria provided further support for the substantive phase of construct validation.

5.1.2. Structural Validation

The structural phase of validation was fairly extensive in the field test of the fall 2014 EMSA tests. Initial screening provided a calibration phase to determine the difficulty and discrimination of items to the target population. The data were fit to both a correlated-traits and a second-order factor analysis model. To generate overall test scores, we regressed three first-order factors (Counting, Word Problems, Computation) onto a single second-order factor (Math). The second-order Math factor score is intended to serve as the overall achievement score on the test. Goodness-of-fit statistics varied but generally indicated that the specified measurement models provided a reasonable fit to the data. The grade 1 model RMSEA statistic indicated mediocre fit and the CFI and TLI statistics indicated reasonable fit.

The reliabilities of the test scales were determined by means of a composite reliability estimate for the Math factor and ordinal forms of Cronbach’s α for the three subscales. The grade 1 math composite reliability was .88. The grade 2 math composite reliability was .91. Grade 1 α estimates for the three subscales all met or exceeded the conventional target value of .8 (range .80 to .92). Grade 2 α estimates for the three subscales all exceeded the conventional target value of .8 (range .84 to .85).

Diagnostic and supplementary analyses of scale reliability, including ordinal forms of Revelle's β and McDonald's ω_h coefficients and IRT information-based reliability estimates provided further insight into the test. Little discrepancy was apparent among these various reliability estimates, but the McDonald's ω_h for the higher-level Math factor can be interpreted to indicate potential multidimensionality in the scale. The TIC indicates that reliability estimates exceed .80 for a large proportion of the sample at both grade levels. The calibration of items to the ability levels of the target population probably contributed to the high reliability estimates.

5.1.3. External Validation

We examined evidence for the predictive validity of the test by regressing the standard scores for the level 7 and level 8 ITBS tests (Dunbar et al., 2008) tests on the Math factor scores for grades 1 and 2, respectively. This type of information is particularly useful to researchers and evaluators in the power analysis phase of research design. Regression results suggested that the Math score was a moderate to strong predictor of the ITBS Math Problems test. The Math scores provided more modest predictive power with the ITBS Math Computation test. The regression analyses suggest the test to be an appropriate covariate in analyses that use the ITBS tests as outcomes.

5.2. Summary and Conclusions

The development process and results of the fall 2014 field test provide evidence of substantive, structural, and external validity of the fall 2014 EMSA tests (Flake, Pek, & Hehman, 2017). The results indicate that the resulting tests are well suited for their intended purpose. An area for improvement and further development for that intended purpose would be to design the tests so that they can be linked vertically across grade levels (using a common set of anchor items in each of the three sections of the test) to enable the grade 1 and 2 scores to be generated on a common scale. Vertical scaling would permit pooling of data across grade levels, which might increase statistical power for a given sample involving students at multiple grade levels.

References

Bentler, P. M., & Bonett, D. G. (1980). Significance tests and goodness of fit in the analysis of covariance structures. *Psychological Bulletin*, *88*(3), 588–606.

Browne, M. W., & Cudeck, R. (1992). Alternative ways of assessing model fit. *Sociological Methods & Research, 21*(2), 230–258.

Camilli, G. (1994). Origin of the scaling constant d = 1.7 in item response theory. *Journal of Educational and Behavioral Statistics, 19*(3), 293–295.

Carpenter, T. P., Fennema, E., Franke, M. L., Levi, L., & Empson, S. B. (1999). *Children's mathematics: Cognitively guided instruction.* Portsmouth, NH: Heinemann.

Carpenter, T. P., Fennema, E., Peterson, P. L., Chiang, C. P., & Loef, M. (1989). Using knowledge of children's mathematics thinking in classroom teaching: An experimental study. *American Educational Research Journal, 26*(4), 385–531.

Chen, F., Curran, P. J., Bollen, K. A., Kirby, J., & Paxton, P. (2008). An empirical evaluation of the use of fixed cutoff points in RMSEA test statistic in structural equation models. *Sociological Methods & Research, 36*(4), 462-494.

Dunbar, S. B., Hoover, H. D., Frisbie, D. A., Ordman, V. L., Oberley, K. R., Naylor, R. J., & Bray, G. B. (2008). *Iowa Test of Basic Skills®, Form C, Level 7*. Rolling Meadows, IL: Riverside Publishing.

Embretson, S.E. & Reise, S. P. (2000). *Item response theory for Psychologists*. Mahwah, NJ: Lawrence Erlbaum Associates.

Fennema, E., Carpenter, T. P., Franke, M. L., Levi, L., Jacobs, V. R., & Empson, S. B. (1996). A longitudinal study of learning to use children's thinking in mathematics instruction. *Journal for Research in Mathematics Education, 27*(4), 458–477.

Flake, J. K., Pek, J., & Hehman, E. (2017). Construct validation in social and personality research: Current practice and recommendations. *Social Psychological and Personality Science, 8*(4), 1–9.

Gadermann, A. M., Guhn, M., & Zumbo, B. D. (2012). Estimating ordinal reliability for Likert-type and ordinal item response data: A conceptual, empirical, and practical guide. *Practical Assessment, Research & Evaluation*, *17*(3). Available online: http://pareonline.net/getvn.asp?v=17&n=3

Geldhof, G. J., Preacher, K. J., & Zyphur, M. J. (2014). Reliability estimation in a multilevel confirmatory factor analysis framework. *Psychological Methods, 19*(1), 72–91.

Gustafsson, J. E., & Aberg-Bengtsson, L. (2010). Unidimensionality and the interpretability of psychological instruments. In S. E. Embretson (Ed.), *Measuring psychological constructs* (pp. 97–121). Washington, DC: American Psychological Association.

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, doi: 10.1080/10705519909540118.

Jacobs, V. R., Franke, M. L., Carpenter, T. P., Levi, L., & Battey, D. (2007). Professional development focused on children's algebraic reasoning in elementary school. *Journal for Research in Mathematics Education, 38*(3), 258–288.

MacCallum, R. C., Browne, M. W., & Sugawara, H. M. (1996). Power analysis and determination of sample size for covariance structure modeling. *Psychological Methods*, *1*(2), 130–149.

Marsh, H. W., Hau, K.-T., & Wen, Z. (2004). In search of golden rules: Comment on hypothesis-testing approaches to setting cutoff values for fit indexes and dangers in overgeneralizing Hu and Bentler's (1999) findings. *Structural Equation Modeling, 11*(3), 320-341.

Muthén, L. K., & Muthén, B. O. (1998-2012). *Mplus User's Guide*. Seventh Edition. Los Angeles, CA: Muthén & Muthén.

NGACBP (National Governors Association Center for Best Practices) and CCSSO (Council of Chief State School Officers). (2010). *Common Core State Standards for Mathematics*. Washington, DC: Authors.

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory* (3rd ed.). New York: McGraw-Hill.

Nye, C. D. & Drasgow, F. (2011). Assessing goodness of fit: Simple rules of thumb simply do not work. *Organizational Research Methods, 14*(3), 548–570.

R Development Core Team (2014). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from http://www.R-project.org

Reise, S. P., Horan, W. P., & Blanchard, J. J. (2011). The challenges of fitting an item response theory model to the Social Anhedonia Scale. *Journal of Personality Assessment, 93*(3), 213–224.

Revelle, W. (1979). Hierarchical cluster analysis and the internal structure of tests. *Multivariate Behavioral Research, 14*(1), 57–74.

Revelle, W. (2016). *psych: Procedures for personality and psychological research* (Version 1.6.6). Evanston, Illinois: Northwestern University. Retrieved from http://CRAN.R-project.org/package=psych

Schoen, R. C., LaVenia, M., Bauduin, C., & Farina, K. (2016). *Elementary mathematics student assessment: Measuring the performance of grade 1 and 2 students in counting, word problems, and computation in fall 2013* (Research Report No. 2016-03). Tallahassee, FL: Learning Systems Institute, Florida State University.

Schoen, R. C., LaVenia, M., Champagne, Z. M., & Farina, K. (2016). *Mathematics performance and cognition (MPAC) interview: Measuring grade 1 and 2 student achievement in number, operations, and equality in spring 2014* (Research Report No. 2016–01). Tallahassee, FL: Learning Systems Institute, Florida State University. doi:10.1725/fsu.1493238156

Schoen, R. C., Champagne, Z. M., Whitacre, I., & McCrackin, S. (Manuscript submitted for review). Comparing the frequency and variation of additive word problems in U.S. first-grade textbooks in the 1980s and the Common Core era. *Teachers College Record*.

Stigler, J. W., Fuson, K. C., Ham, M., & Kim, M. S. (1986). An analysis of addition and subtraction word problems in American and Soviet elementary mathematics textbooks. *Cognition and Instruction, 3*(3), 153–171.

Streiner, D. L. (2003) Starting at the beginning: An introduction to coefficient alpha and internal consistency. *Journal of Personality Assessment*, *80*(1), 99–103.

Zinbarg, R. E., Revelle, W., Yovel, I., & Li, W. (2005). Cronbach's α, Revelle's β, McDonald's ω_h: Their relations with each other and two alternative conceptualizations of reliability. *Psychometrika*, *70*(1), 123–133.

Appendix A—First Grade Test

School:

Teacher:

Student:

Student Mathematics Test
First Grade
August 2014

Sample <u>fill in the bubble</u> multiple-choice

What grade are you in?

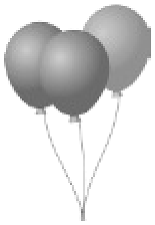
K	1	2	3	4
○	●	○	○	○

Sample <u>write in the box</u>

Write the number four in the box: $\boxed{4}$

[redacted]

[redacted]

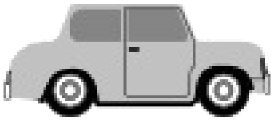


○ ○ ○ ○ ○

[redacted]

[redacted] [redacted] [redacted] [redacted] [redacted]

○ ○ ○ ○ ○



[redacted]

[redacted] [redacted] [redacted] [redacted] [redacted]

○ ○ ○ ○ ○

[redacted]

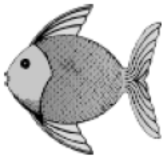
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
○	○	○	○	○

[redacted]

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
○	○	○	○	○

[redacted]

[redacted] ○ [redacted] ○ [redacted] ○ [redacted] ○ [redacted] ○



Appendix B—Second Grade Test

School:

Teacher:

Student:

Student Mathematics Test
Second Grade
August 2014

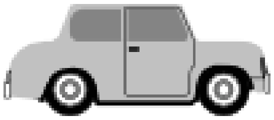
Sample <u>fill in the bubble</u> multiple-choice

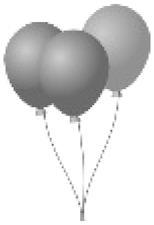
What grade are you in?

K	1	2	3	4
○	○	●	○	○

Sample <u>write in the box</u>

Write the number four in the box: $\boxed{4}$





[redacted]

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
○	○	○	○	○

[redacted]

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
○	○	○	○	○

[redacted]

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
○	○	○	○	○

[redacted]

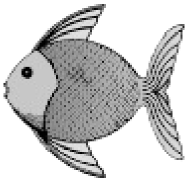
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
○	○	○	○	○

[redacted]

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
○	○	○	○	○

[redacted]

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
○	○	○	○	○



[redacted]

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
○	○	○	○	○

Appendix C—First Grade Administration Guide

Primary Grades Math Study:

Pretest Guidelines, Administration Instructions, and Student Information Sheet

First Grade

2014–2015

Measure development supported by the U.S. Department of Education, Institute of Education Sciences (IES) grant award # R305A120781.

Table of Contents

Pretest Guidelines 2

Overview 2

Pretest Testing Window..2

Materials..2

Test Booklets 2

Students to be Tested..2

Preparing for Testing..3

The first page of each test booklet has the following box for student information: 3

Manipulatives 3

Administering the Test 3

Accommodations..4

Testing in the Primary Grades..4

Testing Time Allocation..4

Submitting the Pre-test Materials 4

Pretest Administration Instructions – Grade 1 5

Pretest Student Information Sheet 12

Pretest Guidelines

Overview

The Primary Grades Math Study pre-test (hereafter, pretest) provides three sections of assessments: Counting, Word Problems, and Computation.

The following guidelines provide information on the protocol for administering the pretest. Throughout this document a second-person voice is used; the intended reader is the classroom teacher. We assume that the classroom teacher will administer the pretest, but administration by other school personnel (such as a paraprofessional or even a substitute teacher) is permissible, provided the pretest protocol is followed as detailed below.

Pretest Testing Window

Please identify your locale in the table below for the applicable testing window.

Local Education Agency	Testing Window
District A	August 18–August 29, 2014
District B	August 11–August 22, 2014

Materials

The following materials are required for testing:

- Primary Grades Math Study Pretest Guidelines and Administration Instructions (provided)
- A test booklet for each student (provided)
- At least one sharpened pencil for each student

Test Booklets

Test booklets are consumable and students mark their answers directly in the test booklets. Should you need additional testing materials, please contact Amanda Tazaz (atazaz@lsi.fsu.edu). Remember that these materials are to remain at the school site until the testing window has ended. The materials must be stored in a secure, access-restricted location at all times.

Students To Be Tested

The pretest for the Primary Grades Math Study will be administered to all of the students in your classroom. On the pretest student information sheet (p. 12 of this document), please list all students in your classroom and indicate those for whom you have signed consent form in the table as requested.

Preparing for Testing

The first page of each test booklet has the following box for student information:

School:

Teacher:

Student:

Before the testing session, the classroom teacher must enter this information (school name, teacher name, student name, and student grade level) on a test booklet for each student to be tested. (Please do not leave this information for students to enter.)

The pretest for Primary Grades Math Study may be administered to students on either an individual or a group basis. Please adhere to the following guidelines:

1. Ensure all students have testing materials (i.e., a test booklet and a sharpened pencil).
2. Ensure that students and prelabeled test booklets are properly paired (i.e., that each student receives the test booklet that has his or her name written on it).
3. Provide students with a comfortable testing environment.
4. Adhere to the pretest guidelines and administration instructions.
5. Permit no talking or communication between students during testing.
6. Permit students to use mathematics manipulatives during the pretest.

Manipulatives

If students would ordinarily be permitted to use manipulatives in your classroom to solve math problems, then they should also be permitted to do so for the pretest.

Administering the Test

The testing conditions for the pretest should be consistent with the testing conditions for other student assessments administered in the classroom. For example, students should space out the desks or use student “privacy folders” if that is what they would usually do.

Avoid reading problems or answering student questions in a way that may offer clues to the correct answer. Student responses should reflect their current math knowledge. Effort to ensure that the test questions are clearly presented and that students understand how they are to mark their answers is therefore important, but great care should be taken to not lead students to the correct answer. To ensure that the students’ test responses are valid, appropriate procedures must be followed during the pretest. These procedures include:

- Administration of the appropriate test level (Grade 1 pretest for grade 1 students, etc.)
- Adherence to the pretest guidelines and administration instructions in order to provide a standardized testing protocol across classrooms
- Maintenance of test security

Accommodations

Students with special academic plans (e.g., IEP, 504, ELL) may receive whatever accommodations are specified in their plans, at the teacher's discretion.

Testing in the Primary Grades

Because children at this age level vary in their familiarity with whole-group testing procedures, the following recommendations are provided to facilitate a smooth testing procedure and minimize student frustration:

- Ensure students understand the testing instructions.
- Monitor students to ensure they are completing the correct questions.
- Provide students with sufficient time to answer the questions.

Testing Time Allocation

Administration of the pretest should take approximately 45 minutes. This is not a timed test, and students should be allowed adequate time to answer the test questions.

Submitting the Pretest Materials

Upon conclusion of testing, repack the test booklets in the original packaging. Please be sure to include the pretest guidelines, administration instructions, and completed student information sheet in the package. All unused test booklets should be repacked for return to project personnel. A Primary Grades Math Study representative will coordinate with your school to set a date to retrieve the testing materials from you. The target period of pickup will be the week of September 2.

If you have questions about this process, contact atazaz@lsi.fsu.edu.

Pretest Administration Instructions—Grade 1

[The boxes contain the script that you will read to the student.]

Your class is about to take a short math assessment. You will need a pencil.

Verify that every student has a pencil.

I will now pass out the assessments. The assessments are already labeled with your names. When you receive the assessment, keep it face up, and do not turn any pages; we will all begin at the same time after I go over the instructions.

Ensure that students and prelabeled test booklets are properly paired (i.e., that each student receives the test booklet that has his or her name written on it).

The first page of the assessment gives the instructions and provides samples of how you will mark your answers.

For some problems you will fill in the bubble beneath (below) the answer choice you think is correct. These are multiple-choice problems where you need to choose one answer from the list of possible answers.

Look at the first example.
It asks: ‘What grade are you in?’ The correct answer choice is 1. Notice how the bubble beneath (below) the 1 has been shaded in for you. For some problems, you are going to mark your answer choices the same way, by shading in the bubble beneath (below) the answer choice you think is correct.

For some problems, you will write the answer that you think is correct in a box.

Look at the second example. It says: "Write the number four in the box." The correct answer is written for you in the box. For some problems, you are going to write your answer the same way, by writing the answer you think is correct in a box.

If you are not sure which answer is correct, mark the answer that you think is best. Make sure you mark an answer for every question.

I will read all of the problems to you. Please do not say any answers out loud. You will answer all of the questions by writing on your paper.

You may underline words in the problems if you find that helpful. Also, feel free to use the white space on the paper to work out your answers.

Are there any questions?

Address any questions.

If there are no more questions, turn to the page with the stars.

Pause; check to ensure all students are on the correct page.

[redacted]

I am going to read the problem one more time: [redacted]

When you finish, put your pencil down.

Pause and wait for all students to complete the item.

Turn to the page with the dog at the top.

Pause; check to ensure all students are on the correct page.

[redacted]

I am going to read the problem one more time: [redacted]

When you finish, put your pencil down.

Pause and wait for all students to complete the item.

Turn to the page with the frog at the top.

Pause; check to ensure all students are on the correct page.

[redacted]

I am going to read the problem one more time. [redacted]

When you finish, put your pencil down.

Pause and wait for all students to complete the item.

Turn to the page with the bicycle at the top.

Pause; check to ensure all students are on the correct page.

[redacted]

I am going to read the problem one more time: [redacted]

When you are finished, put your pencil down.

Turn to the page with the balloons at the top.

Pause; check to ensure all students are on the correct page.

[redacted]

Shade in the circle below the answer you think is correct.

I am going to read the problem one more time: [redacted]

Shade in the circle below the answer you think is correct.

When you are finished, put your pencil down.

Pause and wait for all students to complete the item.

Turn to the page with the book at the top.

Pause; check to ensure all students are on the correct page.

[redacted]

Shade in the circle below the answer you think is correct.

I am going to read the problem one more time: [redacted]

Shade in the circle below the answer you think is correct.

When you are finished, put your pencil down.

Pause and wait for all students to complete the item.

Turn to the page with the car at the top.

Pause; check to ensure all students are on the correct page.

[redacted]

Shade in the circle below the answer you think is correct.

I am going to read the problem one more time: [redacted]

Shade in the circle below the answer you think is correct.

When you are finished, put your pencil down.

Pause and wait for all students to complete the item.

Turn to the page with the movie ticket at the top.

Pause; check to ensure all students are on the correct page.

[redacted]

Shade in the circle below the answer you think is correct.

I am going to read the problem one more time: [redacted]

Shade in the circle below the answer you think is correct.

When you are finished, put your pencil down.

Pause and wait for all students to complete the item.

Turn to the page with the soccer ball at the top.

Pause; check to ensure all students are on the correct page.

[redacted]

Shade in the circle below the answer you think is correct.

I am going to read the problem one more time: [redacted]

Shade in the circle below the answer you think is correct.

When you are finished, put your pencil down.

Pause and wait for all students to complete the item.

Turn to the page with the smiley face at the top.

Pause; check to ensure all students are on the correct page.

[redacted]

Shade in the circle below the answer you think is correct.

I am going to read the problem one more time: [redacted]

Shade in the circle below the answer you think is correct.

When you are finished, put your pencil down.

Pause and wait for all students to complete the item.

Turn to the page with the fish at the top.

Pause; check to ensure all students are on the correct page.

Please complete the following problems on this page and the next page. Please write the correct answer in the box. When I say "begin'" you can start answering the questions. Any questions?

Address any questions.

BEGIN.

Circulate as students work on the problems.
Provide students with ample time to complete the problems. Once you see that students have completed the problems, please end the assessment.

END.

Collect all testing materials.

Test Student Information Sheet

INSTRUCTION: Please enter the information at the top of this form and provide the following information for all students in your class. For each student, provide his or her unique district ID #, first and last name, indication of whether a completed pretest is enclosed, and any other relevant notes. Notes are optional; all other information is required.

School Name:		**Testing Date:**	
Teacher Name:		**Testing Start Time:**	
Grade Level(s):		**Testing End Time:**	
Were mathematics manipulatives used by students during the pretest? (circle one)			YES or NO

Student's District ID #	Student's first name	Student's last name	Student's nickname (if any)	Completed pretest enclosed (circle one)	ELL or testing accommodations?	Notes
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		

Student's District ID #	Student's first name	Student's last name	Student's nickname (if any)	Completed pretest enclosed (circle one)	ELL or testing accommodations?	Notes
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		

Appendix D—Second Grade Administration Guide

Primary Grades Math Study:

Pretest Guidelines, Administration Instructions, and Student Information Sheet

Second Grade

2014–2015

Measure development supported by the U.S. Department of Education, Institute of Education Sciences (IES) grant award # R305A120781.

Table of Contents

Pretest Guidelines 2
Overview 2
Pretest Testing Window 2
Materials 2
Test Booklets 2
Students to be Tested 2
Preparing for Testing 3
The first page of each test booklet has the following box for student information: 3
Manipulatives 3
Administering the Test 3
Accommodations 4
Testing in the Primary Grades 4
Testing Time Allocation 4
Submitting the Pre-test Materials 4
Pretest Administration Instructions—Grade 2 5
Pretest Student Information Sheet 12

Pretest Guidelines

Overview

The Primary Grades Math Study pretest (hereafter, pretest) provides three sections of assessments: Counting, Word Problems, and Computation.

The following guidelines provide information on the protocol for administering the pretest. Throughout this document a second-person voice is used; the intended reader is the classroom teacher. We assume that the classroom teacher will administer the pretest, but administration by for other school personnel (such as a paraprofessional or even a substitute teacher) is permissible, providing the pretest protocol is followed as detailed below.

Pretest Testing Window

Please identify your locale in the table below for the applicable testing window.

Local Education Agency	Testing Window
District A	August 18–August 29, 2014
District B	August 11–August 22, 2014

Materials

The following materials are required for testing:

- Primary Grades Math Study Pretest Guidelines and Administration Instructions (provided)
- A test booklet for each student (provided)
- At least one sharpened pencil for each student

Test Booklets

Test booklets are consumable and students mark their answers directly in the test booklets. Should you need additional testing materials, please contact Amanda Tazaz (atazaz@lsi.fsu.edu). Remember that these materials are to remain at the school site until the testing window has ended. The materials must be stored in a secure, access-restricted location at all times.

Students To Be Tested

The pretest for the Primary Grades Math Study will be administered to all of the students in your classroom. On the pretest student information sheet (p. 12 of this document), please list all students in your classroom and indicate those students for whom you have received signed consent forms in the table as requested.

Preparing for Testing

The first page of each test booklet has the following box for student information:

School:

Teacher:

Student:

Before the testing session, the classroom teacher must enter this information (school name, teacher name, student name, and student grade level) on a test booklet for each student to be tested. (Please do not leave this information for students to enter.)

The pretest for Primary Grades Math Study may be administered to students on either an individual or a group basis. Please adhere to the following guidelines:

1. Ensure all students have testing materials (i.e., test booklet and a sharpened pencil).
2. Ensure that students and prelabeled test booklets are properly paired (i.e., that each student receives the test booklet that has his or her name written on it).
3. Provide students with a comfortable testing environment.
4. Adhere to the pretest guidelines and administration instructions.
5. Permit no talking or communication between students during testing.
6. Permit students to use mathematics manipulatives during the pretest.

Manipulatives

If students would ordinarily be permitted to use manipulatives in your classroom to solve math problems, then they should also be permitted to do so for the pretest.

Administering the Test

The testing conditions for the pretest should be consistent with the testing conditions for other student assessments administered in the classroom. For example, students should space out the desks or use student "privacy folders" if that is what they would usually do.

Avoid reading problems or answering student questions in a way that may offer clues to the correct answer. Student responses should reflect their current math knowledge. Effort to ensure that the test questions are clearly presented and that students understand how they are to mark their answers is important, but great care should be taken to not lead students to the correct answer. To ensure that the students' test responses are valid, appropriate procedures must be followed during the pretest. These procedures include:

- Administration of the appropriate test level (Grade 2 pre-test for Grade 2 students, etc.)
- Adherence to the pretest guidelines and administration instructions in order to provide a standardized testing protocol across classrooms
- Maintenance of test security

Accommodations

Students with special academic plans (e.g., IEP, 504, ELL) may receive whatever accommodations are specified in their plans, at the teacher's discretion.

Testing in the Primary Grades

Because children at this age level vary in their familiarity with whole-group testing procedures, the following recommendations are provided to facilitate a smooth testing procedure and minimize student frustration:

- Ensure students understand the testing instructions.
- Monitor students to ensure they are completing the correct questions.
- Provide students with sufficient time to answer the questions.

Testing Time Allocation

Administration of the pretest should take approximately 45 minutes. This is not a timed test, and students should be allowed adequate time to answer the test questions.

Submitting the Pretest Materials

Upon conclusion of testing, repack the test booklets in the original packaging. Please be sure to include the pretest guidelines, administration instructions, and completed student information sheet in the package. All unused test booklets should be repacked for return to project personnel. A Primary Grades Math Study representative will coordinate with your school to set a date to retrieve the testing materials from you. The target period of pickup will be the week of September 2.

If you have questions about this process, contact Amanda Tazaz via email (atazaz@lsi.fsu.edu).

Pretest Administration Instructions—Grade 2

[The boxes contain the script that you will read to the student.]

Your class is about to take a short math assessment. You will need a pencil.

Verify that every students has a pencil.

I will now pass out the assessments. The assessments are already labeled with your names. When you receive the assessment, keep it face up, and do not turn any pages; we will all begin at the same time after I go over the instructions.

Ensure that students and prelabeled test booklets are properly paired (i.e., that each student receives the test booklet that has his or her name written on it).

The first page of the assessment gives the instructions and provides samples of how you will mark your answers.

For some problems you will fill in the bubble beneath (below) the answer choice you think is correct. These are multiple-choice problems where you need to choose one answer from the list of possible answers.

Look at the first example.
It asks: ‘What grade are you in?’ The correct answer choice is 2. Notice how the bubble beneath (below) the 2 has been shaded in for you. For some problems, you are going to mark your answer choices the same way, by shading in the bubble beneath (below) the answer choice you think is correct.

For some problems, you will write the answer that you think is correct in a box.

Look at the second example. It says: "Write the number four in the box." The correct answer is written for you in the box. For some problems, you are going to write your answer the same way, by writing the answer you think is correct in a box.

If you are not sure which answer is correct, mark the answer that you think is best. Make sure you mark an answer for every question.

I will read all of the problems to you. Please do not say any answers out loud. You will answer all of the questions by writing on your paper.

You may underline words in the problems if you find that helpful. Also, feel free to use the white space on the assessment to work out your answers.

Are there any questions?

Address any questions.

Turn to the page with the dog at the top.

Pause; check to ensure all students are on the correct page.

[redacted]

I am going to read the problem one more time: [redacted]

When you finish, put your pencil down.

Pause and wait for all students to complete the item.

Turn to the page with the car at the top.

Pause; check to ensure all students are on the correct page.

[redacted]

I am going to read the problem one more time: [redacted]

Write it in the box.

When you finish, put your pencil down.

Pause and wait for all students to complete the item.

Turn to the page with the smiley face at the top.

Pause; check to ensure all students are on the correct page.

[redacted]

I am going to read the problem one more time: [redacted]

Write it in the box.

When you finish, put your pencil down.

Pause and wait for all students to complete the item.

Turn to the page with the balloons at the top.

Pause; check to ensure all students are on the correct page.

[redacted]

I am going to read the problem one more time. [redacted]

Write it in the box.

When you finish, put your pencil down.

Pause and wait for all students to complete the item.

Turn to the page with the movie ticket at the top.

Pause; check to ensure all students are on the correct page.

[redacted]

Shade in the circle below the answer you think is correct.

I am going to read the problem one more time: [redacted]

When you are finished, put your pencil down.

Pause and wait for all students to complete the item.

Turn to the page with the soccer ball at the top.

Pause; check to ensure all students are on the correct page.

[redacted]

Shade in the circle below the answer you think is correct.

I am going to read the problem one more time: [redacted]

Shade in the circle below the answer you think is correct.

When you are finished, put your pencil down.

Pause and wait for all students to complete the item.

Turn to the page with the zebra at the top.

Pause; check to ensure all students are on the correct page.

[redacted]

Shade in the circle below the answer you think is correct.

I am going to read the problem one more time: [redacted]

Shade in the circle below the answer you think is correct.

When you are finished, put your pencil down at the top.

Pause and wait for all students to complete the item.

Turn to the page with the pencil at the top.

Pause; check to ensure all students are on the correct page.

[redacted]

[redacted]

Shade in the circle below the answer you think is correct.

[redacted]

Shade in the circle below the answer you think is correct.

When you are finished, put your pencil down.

Pause and wait for all students to complete the item.

Turn to the page with the book at the top.

Pause; check to ensure all students are on the correct page.

[redacted]

Shade in the circle below the answer you think is correct.

I am going to read the problem one more time: [redacted]

When you are finished, put your pencil down.

Pause and wait for all students to complete the item.

Turn to the page with the frog at the top.

Pause; check to ensure all students are on the correct page.

[redacted]

Shade in the circle below the answer you think is correct.

I am going to read the problem one more time: [redacted]

When you are finished, put your pencil down.

Pause and wait for all students to complete the item.

Turn to the page with the fish at the top.

Pause; check to ensure all students are on the correct page.

[redacted]

Shade in the circle below the answer you think is correct.

I am going to read the problem one more time: [redacted]

When you are finished, put your pencil down.

Pause and wait for all students to complete the item.

Turn to the page with the bicycle at the top.

Pause; check to ensure all students are on the correct page.

Please complete the following problems on this page and the next page. Please write the correct answer in the box. When I say “begin,” you can start answering the questions. Any questions?

Address any questions.

BEGIN.

Circulate as students work on the problems.

Provide students with ample time to complete the problems. Once you see that all students have completed the problems please end the assessment.

END.

Collect all testing materials.

Test Student Information Sheet

INSTRUCTION: Please enter the information at the top of this form and provide the following information for every student in your class. For each student, provide his or her unique district ID #, first and last name, indication of whether a completed pretest is enclosed, and any other relevant notes. Notes are optional; all other information is required.

School Name:		**Testing Date:**	
Teacher Name:		**Testing Start Time:**	
Grade Level(s):		**Testing End Time:**	
Were mathematics manipulatives used by students during the pretest? (circle one)			YES or NO

Student's District ID #	**Student's first name**	**Student's last name**	**Student's nickname (if any)**	**Completed pretest enclosed (circle one)**	**ELL or testing accommodations?**	**Notes**
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		

Student's District ID #	Student's first name	Student's last name	Student's nickname (if any)	Completed pretest enclosed (circle one)	ELL or testing accommodations?	Notes
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		
				YES or NO		

Appendix E—Distributions of Number of Items Answered Correctly Within Each Factor

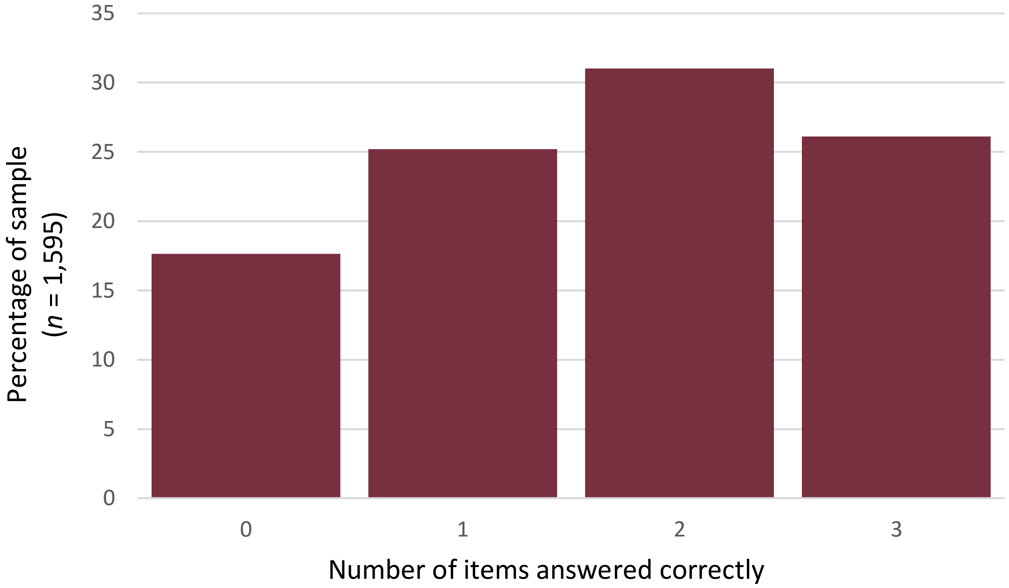


Figure 12. Distribution of the number of items individual students in the grade 1 sample answered correctly within the Counting factor.

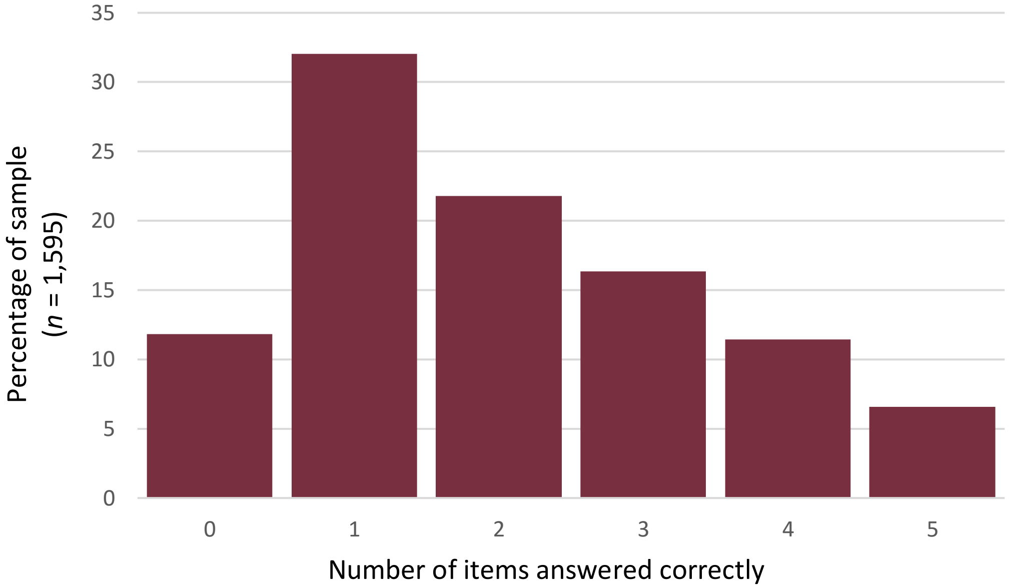


Figure 13. Distribution of the number of items individual students in the grade 1 sample answered correctly within the Word Problems factor.

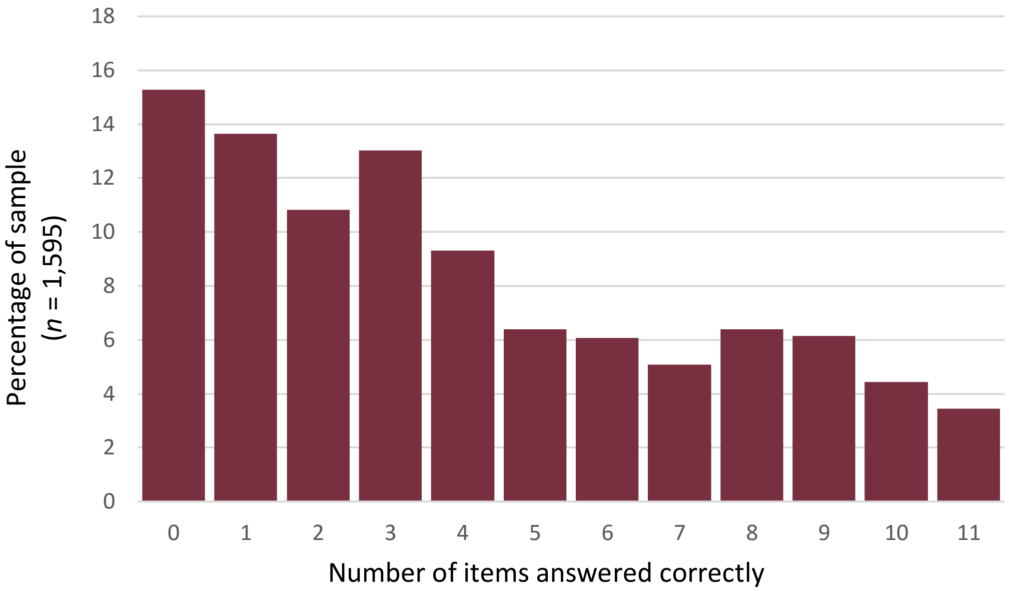


Figure 14. Distribution of the number of items individual students in the grade 1 sample answered correctly within the Computation factor.

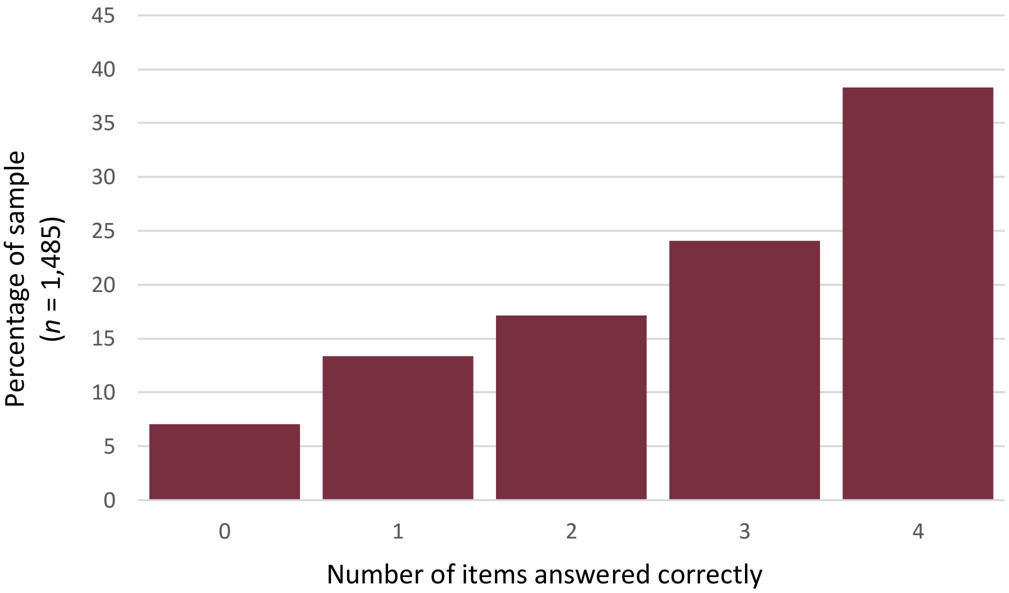


Figure 15. Distribution of the number of items individual students in the grade 2 sample answered correctly within the Counting factor.

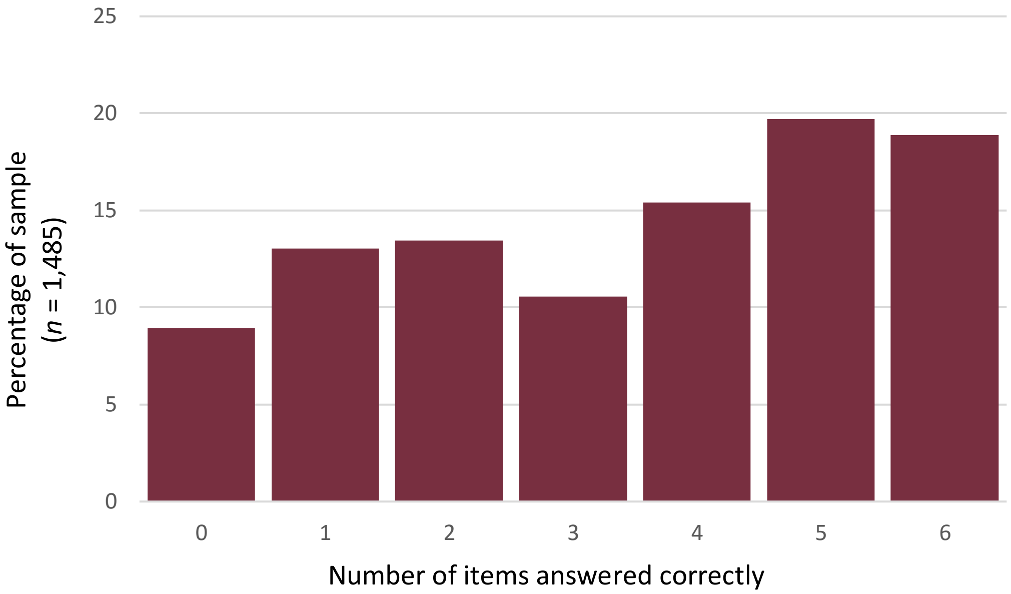


Figure 16. Distribution of the number of items individual students in the grade 2 sample answered correctly within the Word Problems factor.

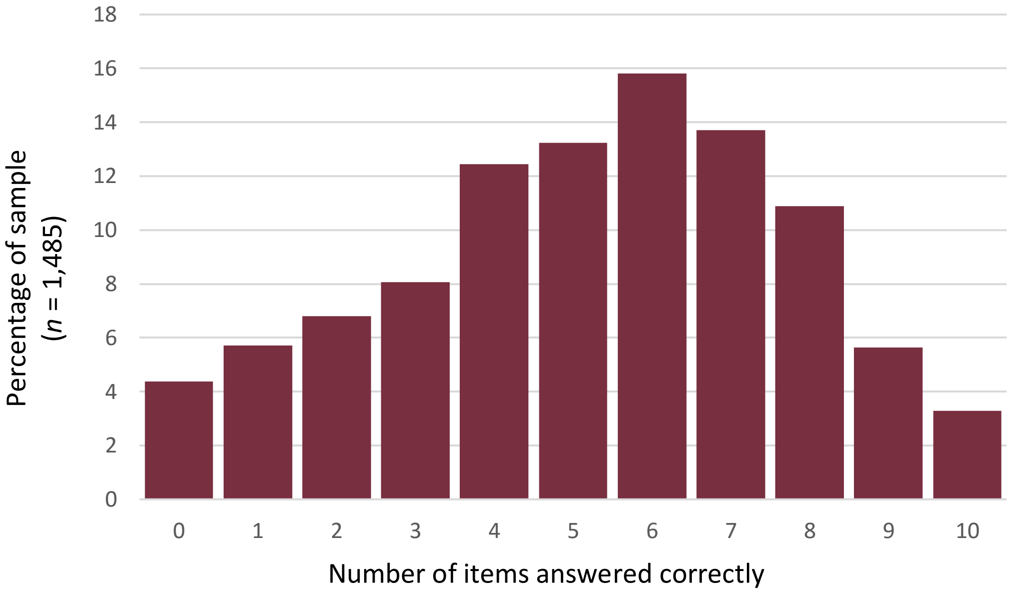


Figure 17. Distribution of the number of items individual students in the grade 2 sample answered correctly within the Computation factor.

Appendix F—Most Common Incorrect Response for Each Item

Table 18. Proportion of Grade 1 Student Responses by Item

		Correct response	Most frequent incorrect responses			
Item	Item description	Response (%)	Response (%)	Response (%)	Response (%)	Response (%)
Counting						
1	[redacted]	7 (.96)	6 (.02)	8 (.01)	10 (<.01)	1 (<.01)
2	[redacted]	9 (.78)	10 (.06)	8 (.03)	1 (.02)	7 (.02)
3	[redacted]	13 (.56)	15 (.08)	1 (.05)	31 (.04)	2 (.03)
4	[redacted]	16 (.32)	11 (.12)	10 (.07)	20 (.05)	12 (.04)
Word Problems						
5	[redacted]	7 (.78)	6 (.08)	1 (.06)	3 (.05)	4 (.03)
6	[redacted]	2 (.38)	6 (.28)	10 (.21)	8 (.07)	4 (.05)
7	[redacted]	4 (.32)	9 (.26)	14 (.24)	5 (.14)	DNS (.03)
8	[redacted]	6 (.20)	9 (.49)	12 (.19)	27 (.05)	3 (.04)
9	[redacted]	10 (.60)	7 (.14)	17 (.09)	24 (.07)	1 (.06)
10	[redacted]	7 (.36)	16 (.18)	25 (.15)	9 (.14)	6 (.14)
Computation						
11	[redacted]	11 (.66)	10 (.11)	6 (.04)	7 (.04)	9 (.02)
12	[redacted]	3 (.42)	9 (.30)	8 (.05)	6 (.04)	4 (.03)
13	[redacted]	14 (.47)	16 (.05)	13 (.05)	15 (.04)	9 (.04)
14	[redacted]	3 (.35)	17 (.26)	10 (.04)	7 (.04)	8 (.04)
15	[redacted]	15 (.43)	18 (.06)	14 (.06)	16 (.05)	10 (.05)
16	[redacted]	6 (.35)	12 (.24)	13 (.04)	7 (.04)	9 (.04)
17	[redacted]	6 (.29)	18 (.18)	7 (.07)	5 (.06)	16 (.04)
18	[redacted]	11 (.26)	19 (.20)	10 (.06)	12 (.05)	14 (.04)
19	[redacted]	10 (.32)	30 (.15)	9 (.05)	20 (.05)	11 (.04)
20	[redacted]	21 (.32)	20 (.10)	7 (.06)	17 (.05)	22 (.04)
21	[redacted]	25 (.29)	26 (.12)	24 (.05)	13 (.04)	7 (.03)
22	[redacted]	7 (.21)	23 (.14)	8 (.09)	6 (.05)	9 (.04)

Note. n = 1,595 valid grade 1 tests conducted. Items that remain in models after factor analysis are presented in boldface type. Only the four most common incorrect responses are displayed. Percentages may not sum to 100. Items that were not answered were recorded as "DNS" Item responses that were unclear were recorded as "UI."

Table 19. Proportion of Grade 2 Responses by Item

		Correct response	Most frequent incorrect responses			
Item	Item description	Response (%)	Response (%)	Response (%)	Response (%)	Response (%)
Counting						
1	[redacted]	15 (.87)	16 (.02)	14 (.01)	20 (.01)	51 (.01)
2	[redacted]	102 (.62)	100 (.07)	93 (.04)	101 (.04)	103 (.02)
3	[redacted]	49 (.69)	40 (.07)	14 (.04)	59 (.02)	51 (.02)
4	[redacted]	27 (.54)	26 (.07)	28 (.04)	47 (.03)	36 (.03)
Word Problems						
5	[redacted]	3 (.77)	7 (.08)	11 (.08)	4 (.05)	28 (.02)
6	[redacted]	13 (.62)	8 (.27)	3 (.07)	5 (.03)	DNS (.01)
7	[redacted]	6 (.67)	16 (.16)	11 (.10)	5 (.06)	DNS (.01)
8	[redacted]	24 (.52)	10 (.27)	16 (.10)	6 (.06)	4 (.04)
9	[redacted]	6 (.57)	40 (.17)	23 (.13)	7 (.07)	17 (.06)
10	[redacted]	4 (.48)	16 (.18)	25 (.15)	9 (.14)	6 (.14)
11	[redacted]	5 (.44)	60 (.16)	50 (.14)	10 (.13)	40 (.11)
Computation						
12	[redacted]	11 (.93)	10 (.02)	12 (.02)	9 (.01)	1 (<.01)
13	[redacted]	13 (.62)	12 (.09)	14 (.07)	25 (.05)	11 (.02)
14	[redacted]	26 (.67)	27 (.05)	25 (.05)	16 (.02)	24 (.02)
15	[redacted]	3 (.80)	17 (.08)	4 (.03)	2 (.02)	7 (.01)
16	[redacted]	20 (.74)	19 (.05)	4 (.04)	18 (.03)	21 (.03)
17	[redacted]	15 (.56)	14 (.07)	16 (.07)	29 (.07)	13 (.03)
18	[redacted]	16 (.55)	15 (.11)	17 (.07)	34 (.04)	14 (.03)
19	[redacted]	42 (.48)	41 (.05)	32 (.05)	36 (.04)	10 (.04)
20	[redacted]	35 (.22)	45 (.19)	85 (.06)	36 (.04)	40 (.03)
21	[redacted]	21 (.70)	20 (.06)	7 (.04)	22 (.03)	17 (.01)
22	[redacted]	50 (.44)	40 (.07)	41 (.07)	49 (.05)	51 (.04)
23	[redacted]	2 (.19)	1 (.09)	18 (.06)	11 (.06)	10 (.05)

Note. n = 1,485 valid grade 2 tests conducted. Items that remain in models after factor analysis are presented in boldface type. Only the four most common incorrect responses are displayed. Percentages may not sum to 100. Items that were not answered were recorded as "DNS". Item responses that were unclear were recorded as "UI".