# Scaling the TIMSS and PIRLS 2011 Achievement Data

Pierre Foy
Bradley Brossman
Joseph Galia

## Overview

The TIMSS and PIRLS assessments cover a wide range of topics in reading, mathematics, and science and, in the case of TIMSS, at two grade levels. Given this broad coverage in each assessment, a matrix-sampling booklet design (see Chapter 4 of the **PIRLS 2011 Assessment Framework** and Chapter 4 of **TIMSS 2011 Assessment Frameworks**) is used such that each student is administered only a subset of the entire PIRLS reading item pool or the TIMSS mathematics and science item pools. Given the complexities of the data collection and the need to have student scores on the entire assessments for analysis and reporting purposes, TIMSS and PIRLS rely on item response theory (IRT) scaling to describe student achievement on the assessments and to provide accurate measures of trends. As each student responded to only a part of the assessment item pool, the TIMSS and PIRLS scaling approach uses multiple imputation — or "plausible values" — methodology to obtain proficiency scores in reading (for PIRLS) and in mathematics and science (for TIMSS) for all students. To enhance the reliability of the student scores, the TIMSS and PIRLS scaling approach uses "conditioning", a process in which student responses to the items are combined with information about students' backgrounds.

This scaling section begins with a general description of the scaling approach and its use of plausible values. It then describes the concurrent calibration method used specifically to measure trends. Next, it explains how the proficiency scores are generated through the use of conditioning and describes the process of transforming the proficiency scores to place them on the metrics used to measure trends.

## The TIMSS and PIRLS Scaling Methodology

The IRT scaling approach used for TIMSS and PIRLS was developed originally by Educational Testing Service (ETS) for use in the U.S. National Assessment of Educational Progress (NAEP). It is based on psychometric models that were first used in the field of educational measurement in the 1950s and are now used extensively in large-scale surveys, test construction, and computer adaptive testing.

The analysis of the TIMSS and PIRLS assessment data utilized three distinct IRT models. All three models are "latent variable" models. Latent variable models describe the probability that a student will respond in a specific way to an item depending on the student's proficiency, which is an unobserved — or "latent" — trait, and various characteristics — or "parameters" — of the item.

The decision as to which IRT model to use depended upon the item type and the scoring procedure. The TIMSS and PIRLS assessments include both multiple choice and constructed response items. The multiple choice items were scored dichotomously as either correct or incorrect. Depending on the scoring guide, a constructed response item was scored either dichotomously, as correct or incorrect, or polytomously for partial credit. Accordingly, a three-parameter model was used for multiple choice items, and a two-parameter model was used for the constructed response items that were scored dichotomously. A partial credit model was used with the constructed response items that were scored polytomously.

## Proficiency Estimation Using Plausible Values

Most cognitive testing assesses the performance of individual students for the purposes of diagnosis, selection, or placement. Regardless of the measurement model used, whether classical test theory or item response theory, the accuracy of these measurements can be improved — that is, the amount of measurement error can be reduced — by increasing the number of items given to the individual. Thus, it is common to see achievement tests designed to provide information on individual students that contain more than 70 items. Since the uncertainty associated with estimates of individual student ability is negligible under these conditions, the distribution of student ability, or its joint distribution with other variables, can be approximated using each individual student's estimated ability.

For the estimation of proficiencies in large populations, more efficient estimates can be obtained from a matrix-sampling design such as that used in TIMSS and PIRLS. This design solicits relatively few responses from each sampled student while maintaining a wide range of content representation when responses are aggregated across all students. With this approach, the advantage of estimating population characteristics more efficiently is offset to some degree by the inability to make precise statements about individuals. Indeed, the uncertainty associated with individual student ability estimates becomes too large to be ignored.

Plausible values methodology was developed as a way to address this issue. Instead of first computing estimates of individual student abilities and then aggregating these to estimate population parameters, the plausible values approach with conditioning uses all available data — student responses to the items they were administered together with all background data — to estimate directly the characteristics of student populations and subpopulations. Although these directly estimated population characteristics could be used for reporting purposes, the plausible values approach generates multiple imputed scores (Rubin, 1987), called plausible values, from the estimated ability distributions and uses these in analyses and reporting. By conditioning on all the available background data while generating the plausible values, relationships between these background variables and the estimated proficiencies are appropriately accounted for in the plausible values. Because of this, analyses conducted using plausible values provide an accurate representation of these underlying relationships. A more detailed description of the technical details involved in the scaling can be found in **TIMSS and PIRLS 2011 Achievement Scaling Methodology**.

Plausible values are not intended to be estimates of individual student scores, but rather are imputed scores for like students — students with similar response patterns and background characteristics in the sampled population — that may be used to estimate population characteristics correctly. When the underlying model is correctly specified, plausible values provide consistent estimates of population characteristics, even though they are generally biased estimates of the proficiencies of the individuals with whom they are associated. Taking the average of the plausible values does not yield suitable estimates of individual student scores.

## Implementing the TIMSS and PIRLS Scaling Procedures

The application of IRT scaling and plausible values methodology to the data from the TIMSS and PIRLS assessments involves four major tasks: calibrating the achievement items (estimating model parameters for each item), creating principal components from the student questionnaire data for use in conditioning — the Learning to Read Survey data also are included for PIRLS, generating proficiency scores for reading, mathematics, and science, and placing these proficiency scores on the metrics used to report trend results from previous assessments. PIRLS and prePIRLS each have a single scale for overall reading, whereas TIMSS has separate scales for mathematics and science at both fourth and eighth grades. The scaling procedures also generate proficiency scores for the subdomains of the overall subjects: the purposes for reading and the processes of comprehension for PIRLS, and the content and cognitive domains of mathematics and science for TIMSS.

## Linking Assessments Cycles with Concurrent Calibration

The metric of the TIMSS reporting scales for overall mathematics and science at each grade level were originally established in TIMSS 1995 by setting the mean of the national average scores for all countries that participated in TIMSS 1995 to 500 and the standard deviation to 100. Similarly, the metric of the PIRLS reading scale was established in PIRLS 2001. To enable measurement of trends over time, achievement data from successive TIMSS and PIRLS assessments were transformed to these same metrics. This is done by concurrently scaling the data from each successive assessment with the data from the previous assessment—a process known as "concurrent calibration"—and applying linear transformations to place the results from each successive assessment on the same scale as the results from the previous assessment. This procedure enables TIMSS to measure trends across all five assessment cycles (1995, 1999, 2003, 2007, and 2011) and PIRLS to measure trends across its three cycles (2001, 2006, 2011).

The first step in linking the assessments for trend scaling is to estimate ("calibrate") the item parameters for the items in the current assessment through a concurrent calibration of the data from the current assessment and from the previous assessment. In 2011, the TIMSS concurrent calibration consisted of

combining achievement data from the 2011 and 2007 assessments, and the PIRLS concurrent calibration process combined the 2011 and 2006 PIRLS achievement data.

To link successive assessments, concurrent calibration relies in large part on the presence of "trend" items, items that are retained from one assessment to the next. The TIMSS assessment consists of 14 mathematics item blocks and 14 science item blocks at each grade. Six of the mathematics blocks and six of the science blocks consist of newly developed items. The remaining eight mathematics blocks and eight science blocks are carried forward from the previous TIMSS assessment and are the basis for linking the TIMSS assessments and maintaining trends over time. The PIRLS assessment consists of 5 literary and 5 informational passages and their items. Each successive assessment includes two newly developed literary passages and two newly developed informational passages in addition to three literary and three informational passages from the previous PIRLS assessment. Exhibits 1 through 5 list the number of items for concurrent calibration in the TIMSS and PIRLS assessment in 2007 and 2011 by item type and domain.

**Exhibit 1: TIMSS 2011 Mathematics Items for Concurrent Calibration at the Fourth Grade**

| Item Type | Points | Items Released in 2007 | | Items Common in 2007 and 2011 | | Items Introduced in 2011 | | Total | |
|---|---|---|---|---|---|---|---|---|---|
| | | Items | Points | Items | Points | Items | Points | Items | Points |
| Multiple Choice | 1 | 36 | 36 | 58 | 58 | 35 | 35 | 129 | 129 |
| Constructed Response | 1 | 35 | 35 | 37 | 37 | 36 | 36 | 108 | 108 |
| | 2 | 3 | 6 | 8 | 16 | 1 | 2 | 12 | 24 |
| **Total** | | **74** | **77** | **103** | **111** | **72** | **73** | **249** | **261** |

**TIMSS 2011 Mathematics Items by Content and Cognitive Domains for Concurrent Calibration at the Fourth Grade**

| Mathematics Content Domains | Items Released in 2007 | | Items Common in 2007 and 2011 | | Items Introduced in 2011 | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Items | Points | Items | Points | Items | Points | Items | Points |
| Number | 38 | 40 | 52 | 55 | 36 | 37 | 126 | 132 |
| Geometric Shapes and Measures | 24 | 24 | 36 | 40 | 25 | 25 | 85 | 89 |
| Data Display | 12 | 13 | 15 | 16 | 11 | 11 | 38 | 40 |
| **Total** | **74** | **77** | **103** | **111** | **72** | **73** | **249** | **261** |
| **Mathematics Cognitive Domains** | **Items Released in 2007** | | **Items Common in 2007 and 2011** | | **Items Introduced in 2011** | | **Total** | |
| | Items | Points | Items | Points | Items | Points | Items | Points |
| Knowing | 24 | 24 | 44 | 47 | 26 | 26 | 94 | 97 |
| Applying | 30 | 31 | 40 | 43 | 31 | 31 | 101 | 105 |
| Reasoning | 20 | 22 | 19 | 21 | 15 | 16 | 54 | 59 |
| **Total** | **74** | **77** | **103** | **111** | **72** | **73** | **249** | **261** |

**Exhibit 2: TIMSS 2011 Science Items for Concurrent Calibration at the Fourth Grade**

| Item Type | Points | Items Released in 2007 | | Items Common in 2007 and 2011 | | Items Introduced in 2011 | | Total | |
|---|---|---|---|---|---|---|---|---|---|
| | | Items | Points | Items | Points | Items | Points | Items | Points |
| Multiple Choice | 1 | 35 | 35 | 54 | 54 | 36 | 36 | 125 | 125 |
| Constructed Response | 1 | 29 | 29 | 32 | 32 | 33 | 33 | 94 | 94 |
| | 2 | 7 | 14 | 12 | 24 | 1 | 2 | 20 | 40 |
| **Total** | | **71** | **78** | **98** | **110** | **70** | **71** | **239** | **259** |

**TIMSS 2011 Science Items by Content and Cognitive Domains for Concurrent Calibration at the Fourth Grade**

| Science Content Domains | Items Released in 2007 | | Items Common in 2007 and 2011 | | Items Introduced in 2011 | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Items | Points | Items | Points | Items | Points | Items | Points |
| Life Science | 29 | 33 | 42 | 48 | 32 | 33 | 103 | 114 |
| Physical Science | 26 | 27 | 37 | 38 | 24 | 24 | 87 | 89 |
| Earth Science | 16 | 18 | 19 | 24 | 14 | 14 | 49 | 56 |
| **Total** | **71** | **78** | **98** | **110** | **70** | **71** | **239** | **259** |
| **Science Cognitive Domains** | **Items Released in 2007** | | **Items Common in 2007 and 2011** | | **Items Introduced in 2011** | | **Total** | |
| | Items | Points | Items | Points | Items | Points | Items | Points |
| Knowing | 25 | 29 | 41 | 47 | 27 | 28 | 93 | 104 |
| Applying | 28 | 29 | 40 | 44 | 31 | 31 | 99 | 104 |
| Reasoning | 18 | 20 | 17 | 19 | 12 | 12 | 47 | 51 |
| **Total** | **71** | **78** | **98** | **110** | **70** | **71** | **239** | **259** |

**Exhibit 3: TIMSS 2011 Mathematics Items for Concurrent Calibration at the Eighth Grade**

| Item Type | Points | Items Released in 2007 | | Items Common in 2007 and 2011 | | Items Introduced in 2011 | | Total | |
|---|---|---|---|---|---|---|---|---|---|
| | | Items | Points | Items | Points | Items | Points | Items | Points |
| Multiple Choice | 1 | 50 | 50 | 66 | 66 | 52 | 52 | 168 | 168 |
| Constructed Response | 1 | 27 | 27 | 45 | 45 | 37 | 37 | 109 | 109 |
| | 2 | 11 | 22 | 13 | 26 | 2 | 4 | 26 | 52 |
| **Total** | | **88** | **99** | **124** | **137** | **91** | **93** | **303** | **329** |

**TIMSS 2011 Mathematics Items by Content and Cognitive Domains for Concurrent Calibration at the Eighth Grade**

| Mathematics Content Domains | Items Released in 2007 | | Items Common in 2007 and 2011 | | Items Introduced in 2011 | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Items | Points | Items | Points | Items | Points | Items | Points |
| Number | 32 | 37 | 30 | 34 | 31 | 32 | 93 | 103 |
| Algebra | 17 | 18 | 46 | 51 | 23 | 24 | 86 | 93 |
| Geometry | 22 | 23 | 24 | 26 | 18 | 18 | 64 | 67 |
| Data and chance | 17 | 21 | 24 | 26 | 19 | 19 | 60 | 66 |
| **Total** | **88** | **99** | **124** | **137** | **91** | **93** | **303** | **329** |
| **Mathematics Cognitive Domains** | **Items Released in 2007** | | **Items Common in 2007 and 2011** | | **Items Introduced in 2011** | | **Total** | |
| | **Items** | **Points** | **Items** | **Points** | **Items** | **Points** | **Items** | **Points** |
| Knowing | 28 | 28 | 52 | 54 | 27 | 27 | 107 | 109 |
| Applying | 45 | 50 | 42 | 48 | 42 | 43 | 129 | 141 |
| Reasoning | 15 | 21 | 30 | 35 | 22 | 23 | 67 | 79 |
| **Total** | **88** | **99** | **124** | **137** | **91** | **93** | **303** | **329** |

**Exhibit 4: TIMSS 2011 Science Items for Concurrent Calibration at the Eighth Grade**

| Item Type | Points | Items Released in 2007 | | Items Common in 2007 and 2011 | | Items Introduced in 2011 | | Total | |
|---|---|---|---|---|---|---|---|---|---|
| | | Items | Points | Items | Points | Items | Points | Items | Points |
| Multiple Choice | 1 | 44 | 44 | 60 | 60 | 49 | 49 | 153 | 153 |
| Constructed Response | 1 | 33 | 33 | 53 | 53 | 37 | 37 | 123 | 123 |
| | 2 | 9 | 18 | 12 | 24 | 5 | 10 | 26 | 52 |
| **Total** | | **86** | **95** | **125** | **137** | **91** | **96** | **302** | **328** |

**TIMSS 2011 Science Items by Content and Cognitive Domains for Concurrent Calibration at the Eighth Grade**

| Science Content Domains | Items Released in 2007 | | Items Common in 2007 and 2011 | | Items Introduced in 2011 | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Items | Points | Items | Points | Items | Points | Items | Points |
| Biology | 28 | 34 | 46 | 51 | 33 | 36 | 107 | 121 |
| Chemistry | 16 | 18 | 25 | 27 | 19 | 20 | 60 | 65 |
| Physics | 22 | 23 | 33 | 36 | 21 | 21 | 76 | 80 |
| Earth Science | 20 | 20 | 21 | 23 | 18 | 19 | 59 | 62 |
| **Total** | **86** | **95** | **125** | **137** | **91** | **96** | **302** | **328** |
| **Science Cognitive Domains** | **Items Released in 2007** | | **Items Common in 2007 and 2011** | | **Items Introduced in 2011** | | **Total** | |
| | **Items** | **Points** | **Items** | **Points** | **Items** | **Points** | **Items** | **Points** |
| Knowing | 36 | 37 | 43 | 45 | 30 | 31 | 109 | 113 |
| Applying | 30 | 33 | 58 | 67 | 33 | 35 | 121 | 135 |
| Reasoning | 20 | 25 | 24 | 25 | 28 | 30 | 72 | 80 |
| **Total** | **86** | **95** | **125** | **137** | **91** | **96** | **302** | **328** |

**Exhibit 5: PIRLS 2011 Items for Concurrent Calibration**

| Item Type | Points | Items Released in 2006 | | Items Common in 2006 and 2011 | | Items Introduced in 2011 | | Total | |
|---|---|---|---|---|---|---|---|---|---|
| | | Items | Points | Items | Points | Items | Points | Items | Points |
| Multiple Choice | 1 | 22 | 22 | 41 | 41 | 33 | 33 | 96 | 96 |
| Constructed Response | 1 | 16 | 16 | 12 | 12 | 16 | 16 | 44 | 44 |
| | 2 | 9 | 18 | 19 | 38 | 8 | 16 | 36 | 72 |
| | 3 | 3 | 9 | 3 | 9 | 3 | 9 | 9 | 27 |
| **Total** | | **50** | **65** | **75** | **100** | **60** | **74** | **185** | **239** |

**PIRLS 2011 Items by Purposes and Processes for Concurrent Calibration**

| Purposes for Reading | Items Released in 2006 | | Items Common in 2006 and 2011 | | Items Introduced in 2011 | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Items | Points | Items | Points | Items | Points | Items | Points |
| Literary Experience | 25 | 33 | 39 | 51 | 33 | 39 | 97 | 123 |
| Acquire and Use Information | 25 | 32 | 36 | 49 | 27 | 35 | 88 | 116 |
| **Total** | **50** | **65** | **75** | **100** | **60** | **74** | **185** | **239** |
| **Processes of Comprehension** | **Items Released in 2006** | | **Items Common in 2006 and 2011** | | **Items Introduced in 2011** | | **Total** | |
| | Items | Points | Items | Points | Items | Points | Items | Points |
| Retrieving and Straightforward Inferencing | 29 | 33 | 45 | 50 | 34 | 37 | 108 | 120 |
| Interpreting, Integrating and Evaluating | 21 | 32 | 30 | 50 | 26 | 37 | 77 | 119 |
| **Total** | **50** | **65** | **75** | **100** | **60** | **74** | **185** | **239** |

**prePIRLS 2011 Items for Calibration**

| Item Type | Points | Total | | Purposes for Reading | | | | Processes of Comprehension | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Literary Experience | | Acquire and Use Information | | Retrieving and Straightforward Inferencing | | Interpret, Integrate and Evaluate | |
| | | Items | Points | Items | Points | Items | Points | Items | Points | Items | Points |
| Multiple Choice | 1 | 56 | 56 | 30 | 30 | 26 | 26 | 23 | 23 | 33 | 33 |
| Constructed Response | 1 | 56 | 56 | 28 | 28 | 28 | 28 | 31 | 31 | 25 | 25 |
| | 2 | 9 | 18 | 4 | 8 | 5 | 10 | 3 | 6 | 6 | 12 |
| | 3 | 1 | 3 | 0 | 0 | 1 | 3 | 0 | 0 | 1 | 3 |
| **Total** | | **122** | **133** | **62** | **66** | **60** | **67** | **57** | **60** | **65** | **73** |

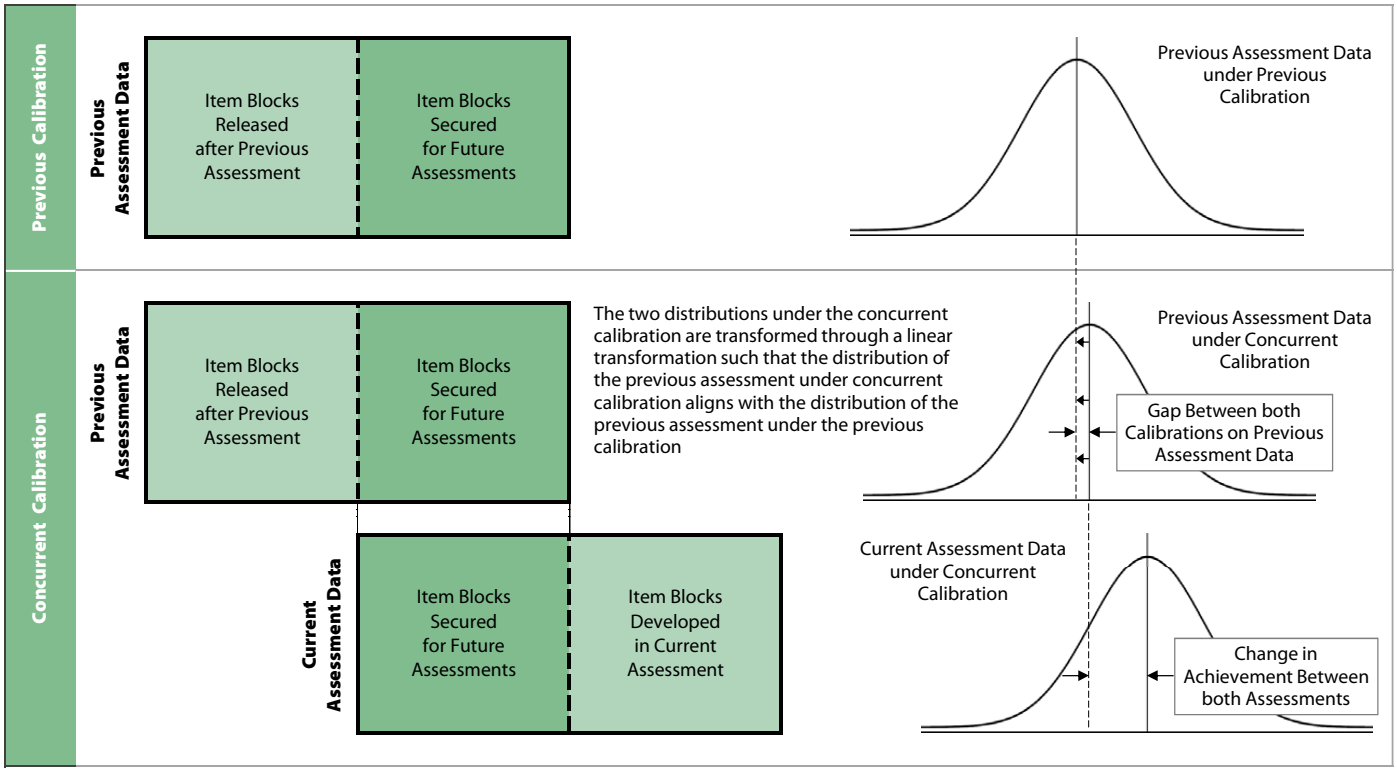
In concurrent calibration, item parameters for the current assessment are estimated based on the data from both the current and previous assessments, recognizing that some items are common to both. It is then possible to estimate the latent ability distributions of students in both assessments using the item parameters from the concurrent calibration. The difference between these two distributions is the change in achievement between the previous and current assessments.

The next step is to find a linear transformation that transforms the distribution of the previous assessment data from this concurrent calibration to match the distribution of these same data under the calibration that was done in the previous assessment. The final step entails applying this linear transformation to the current assessment data scaled using the concurrent calibration. This places the current assessment data on the trend scale.

Exhibit 6 illustrates how the concurrent calibration approach is applied in the context of TIMSS and PIRLS trend scaling. The gap between both calibrations on the previous assessment data is typically small and arises from slight differences in the item parameter estimations, which are due primarily to the previous assessment data being calibrated with other assessment data in the two calibrations. The linear transformation removes this gap by shifting the two distributions from the concurrent calibration such that the distribution of the previous assessment data from the concurrent calibration aligns with the distribution of the previous assessment data from the previous calibration,[1] while preserving the gap between the previous and current assessment data under the concurrent calibration. This latter gap is the change in achievement between the previous and current assessments that TIMSS and PIRLS set out to measure as trend.

1 The degree of fit, after transformation, between the two ability distributions of the previous assessment data is a measure of the linkage error introduced by the trend scaling procedure.

**Exhibit 6: Concurrent Calibration Model Used for TIMSS and PIRLS**




*Calibrating the TIMSS and PIRLS 2011 Assessment Data*

Item calibration was conducted by the TIMSS & PIRLS International Study Center using the commercially-available Parscale software (Muraki & Bock, 1991) and included data from the previous assessment (PIRLS 2006 for PIRLS and TIMSS 2007 for TIMSS) and data from the 2011 assessment for countries that participated in both assessment cycles. The calibration used all available item response data from each country's student samples and from both current and previous assessments. All student samples were weighted so that each country contributed equally to the item calibration. Exhibits 7 through 9 show sample sizes for scaling the TIMSS and PIRLS 2011 data.

**Exhibit 7: TIMSS 2011 Sample Sizes for Scaling the Fourth Grade Data**

| Country | Concurrent Calibration | | Proficiency Estimation | |
|---|---|---|---|---|
| | 2011 | 2007 | 2011 | 2007 |
| Armenia | — | — | 5,146 | — |
| Australia | 6,146 | 4,108 | 6,146 | 4,108 |
| Austria | 4,668 | 4,859 | 4,668 | 4,859 |
| Azerbaijan | — | — | 4,882 | — |
| Bahrain | — | — | 4,083 | — |
| Belgium (Flemish) | — | — | 4,849 | — |
| Chile | — | — | 5,585 | — |
| Chinese Taipei | 4,284 | 4,131 | 4,284 | 4,131 |
| Croatia | — | — | 4,584 | — |
| Czech Republic | 4,578 | 4,235 | 4,578 | 4,235 |
| Denmark | 3,987 | 3,519 | 3,987 | 3,519 |
| England | 3,397 | 4,316 | 3,397 | 4,316 |
| Finland | — | — | 4,638 | — |
| Georgia | 4,799 | 4,108 | 4,799 | 4,108 |
| Germany | 3,995 | 5,200 | 3,995 | 5,200 |
| Hong Kong SAR | 3,957 | 3,791 | 3,957 | 3,791 |
| Hungary | 5,204 | 4,048 | 5,204 | 4,048 |
| Iran, Islamic Rep. of | 5,760 | 3,833 | 5,760 | 3,833 |
| Ireland | — | — | 4,560 | — |
| Italy | 4,200 | 4,470 | 4,200 | 4,470 |
| Japan | 4,411 | 4,487 | 4,411 | 4,487 |
| Kazakhstan | — | — | 4,382 | — |
| Korea, Rep. of | — | — | 4,334 | — |
| Kuwait | — | — | 4,142 | — |
| Lithuania | 4,688 | 3,980 | 4,688 | 3,980 |
| Malta | — | — | 3,607 | — |
| Morocco | — | — | 7,841 | — |
| Netherlands | 3,229 | 3,349 | 3,229 | 3,349 |
| New Zealand | 5,572 | 4,940 | 5,572 | 4,940 |
| Northern Ireland | — | — | 3,571 | — |
| Norway | 3,121 | 4,108 | 3,121 | 4,108 |
| Oman | — | — | 10,411 | — |
| Poland | — | — | 5,027 | — |
| Portugal | — | — | 4,042 | — |
| Qatar | — | — | 4,117 | — |
| Romania | — | — | 4,673 | — |
| Russian Federation | 4,467 | 4,464 | 4,467 | 4,464 |
| Saudi Arabia | — | — | 4,515 | — |
| Serbia | — | — | 4,379 | — |
| Singapore | 6,368 | 5,041 | 6,368 | 5,041 |
| Slovak Republic | 5,616 | 4,963 | 5,616 | 4,963 |

**Exhibit 7: TIMSS 2011 Sample Sizes for Scaling the Fourth Grade Data (Continued)**

| Country | Concurrent Calibration | | Proficiency Estimation | |
|---|---|---|---|---|
| | 2011 | 2007 | 2011 | 2007 |
| Slovenia | 4,492 | 4,351 | 4,492 | 4,351 |
| Spain | — | — | 4,183 | — |
| Sweden | 4,663 | 4,676 | 4,663 | 4,676 |
| Thailand | — | — | 4,448 | — |
| Tunisia | 4,912 | 4,134 | 4,912 | 4,134 |
| Turkey | — | — | 7,479 | — |
| United Arab Emirates | — | — | 14,720 | — |
| United States | 12,569 | 7,896 | 12,569 | 7,896 |
| Yemen | — | — | 8,058 | — |
| **Sixth Grade Participants** | | | | |
| Botswana | — | — | 4,198 | — |
| Honduras | — | — | 3,919 | — |
| Yemen | — | — | 4,929 | — |
| **Benchmarking Participants** | | | | |
| Alberta, Canada | — | — | 3,645 | — |
| Ontario, Canada | — | — | 4,570 | — |
| Quebec, Canada | — | — | 4,235 | — |
| Abu Dhabi, UAE | — | — | 4,164 | — |
| Dubai, UAE | — | — | 6,151 | — |
| Florida, US | — | — | 2,661 | — |
| North Carolina, US | — | — | 1,792 | — |
| **TOTAL** | **119,083** | **107,007** | **301,603** | **107,007** |

**Exhibit 8: TIMSS 2011 Sample Sizes for Scaling the Eighth Grade Data**

| Country | Item Calibration | | Proficiency Estimation | |
|---|---|---|---|---|
| | 2011 | 2007 | 2011 | 2007 |
| Armenia | — | — | 5,846 | — |
| Australia | 7,556 | 4,069 | 7,556 | 4,069 |
| Bahrain | 4,640 | 4,230 | 4,640 | 4,230 |
| Chile | — | — | 5,835 | — |
| Chinese Taipei | 5,042 | 4,046 | 5,042 | 4,046 |
| England | 3,842 | 4,025 | 3,842 | 4,025 |
| Finland | — | — | 4,266 | — |
| Georgia | 4,563 | 4,178 | 4,563 | 4,178 |
| Ghana | — | — | 7,323 | — |
| Hong Kong SAR | 4,015 | 3,470 | 4,015 | 3,470 |
| Hungary | 5,178 | 4,111 | 5,178 | 4,111 |
| Indonesia | 5,795 | 4,203 | 5,795 | 4,203 |
| Iran, Islamic Rep. of | 6,029 | 3,981 | 6,029 | 3,981 |
| Israel | — | — | 4,699 | — |
| Italy | 3,979 | 4,408 | 3,979 | 4,408 |
| Japan | 4,414 | 4,312 | 4,414 | 4,312 |
| Jordan | 7,694 | 5,251 | 7,694 | 5,251 |
| Kazakhstan | — | — | 4,390 | — |
| Korea, Rep. of | 5,166 | 4,240 | 5,166 | 4,240 |
| Lebanon | 3,974 | 3,786 | 3,974 | 3,786 |
| Lithuania | 4,747 | 3,991 | 4,747 | 3,991 |
| Macedonia, Rep. of | — | — | 4,062 | — |
| Malaysia | 5,733 | 4,466 | 5,733 | 4,466 |
| Morocco | — | — | 8,986 | — |
| New Zealand | — | — | 5,336 | — |
| Norway | 3,862 | 4,627 | 3,862 | 4,627 |
| Oman | 9,542 | 4,752 | 9,542 | 4,752 |
| Palestinian Nat'l Auth. | 7,812 | 4,378 | 7,812 | 4,378 |
| Qatar | — | — | 4,422 | — |
| Romania | 5,523 | 4,198 | 5,523 | 4,198 |
| Russian Federation | 4,893 | 4,472 | 4,893 | 4,472 |
| Saudi Arabia | — | — | 4,344 | — |
| Singapore | 5,927 | 4,599 | 5,927 | 4,599 |
| Slovenia | 4,415 | 4,043 | 4,415 | 4,043 |
| Sweden | 5,573 | 5,215 | 5,573 | 5,215 |
| Syrian Arab Republic | 4,413 | 4,650 | 4,413 | 4,650 |
| Thailand | 6,124 | 5,412 | 6,124 | 5,412 |
| Tunisia | 5,128 | 4,080 | 5,128 | 4,080 |
| Turkey | — | — | 6,928 | — |
| Ukraine | 3,378 | 4,424 | 3,378 | 4,424 |
| United Arab Emirates | — | — | 14,089 | — |
| United States | 10,477 | 7,377 | 10,477 | 7,377 |

**Exhibit 8: TIMSS 2011 Sample Sizes for Scaling the Eighth Grade Data (Continued)**

| Country | Item Calibration | | Proficiency Estimation | |
|---|---|---|---|---|
| | 2011 | 2007 | 2011 | 2007 |
| **Ninth Grade Participants** | | | | |
| Botswana | — | — | 5,400 | — |
| Honduras | — | — | 4,418 | — |
| South Africa | — | — | 11,969 | — |
| **Benchmarking Participants** | | | | |
| Alberta, Canada | — | — | 4,799 | — |
| Ontario, Canada | — | — | 4,756 | — |
| Quebec, Canada | — | — | 6,149 | — |
| Abu Dhabi, UAE | — | — | 4,373 | — |
| Dubai, UAE | — | — | 5,571 | — |
| Alabama, US | — | — | 2,113 | — |
| California, US | — | — | 2,614 | — |
| Colorado, US | — | — | 2,167 | — |
| Connecticut, US | — | — | 2,099 | — |
| Florida, US | — | — | 1,712 | — |
| Indiana, US | — | — | 2,260 | — |
| Massachusetts, US | — | — | 2,075 | — |
| Minnesota, US | — | — | 2,500 | — |
| North Carolina, US | — | — | 2,103 | — |
| **TOTAL** | **159,434** | **128,994** | **307,038** | **128,994** |

**Exhibit 9: PIRLS 2011 Sample Sizes for Scaling**

| Country | Concurrent Calibration | | Proficiency Estimation | |
|---|---|---|---|---|
| | 2011 | 2006 | 2011 | 2006 |
| Australia | — | — | 6,126 | — |
| Austria | 4,670 | 5,067 | 4,670 | 5,067 |
| Azerbaijan | — | — | 4,881 | — |
| Belgium (French) | 3,727 | 4,552 | 3,727 | 4,552 |
| Bulgaria | 5,261 | 3,863 | 5,261 | 3,863 |
| Canada | — | — | 23,206 | — |
| Chinese Taipei | 4,293 | 4,589 | 4,293 | 4,589 |
| Colombia | — | — | 3,966 | — |
| Croatia | — | — | 4,587 | — |
| Czech Republic | — | — | 4,556 | — |
| Denmark | 4,594 | 4,001 | 4,594 | 4,001 |
| England | 3,927 | 4,036 | 3,927 | 4,036 |
| Finland | — | — | 4,640 | — |
| France | 4,438 | 4,404 | 4,438 | 4,404 |
| Georgia | 4,796 | 4,402 | 4,796 | 4,402 |
| Germany | 4,000 | 7,899 | 4,000 | 7,899 |
| Hong Kong SAR | 3,875 | 4,712 | 3,875 | 4,712 |
| Hungary | 5,204 | 4,068 | 5,204 | 4,068 |
| Indonesia | 4,791 | 4,774 | 4,791 | 4,774 |
| Iran, Islamic Rep. of | 5,758 | 5,411 | 5,758 | 5,411 |
| Ireland | — | — | 4,524 | — |
| Israel | — | — | 4,186 | — |
| Italy | 4,189 | 3,581 | 4,189 | 3,581 |
| Lithuania | 4,661 | 4,701 | 4,661 | 4,701 |
| Malta | — | — | 3,598 | — |
| Morocco | — | — | 7,805 | — |
| Netherlands | 3,995 | 4,156 | 3,995 | 4,156 |
| New Zealand | 5,644 | 6,256 | 5,644 | 6,256 |
| Northern Ireland | — | — | 3,586 | — |
| Norway | 3,190 | 3,837 | 3,190 | 3,837 |
| Oman | — | — | 10,394 | — |
| Poland | 5,005 | 4,854 | 5,005 | 4,854 |
| Portugal | — | — | 4,085 | — |
| Qatar | — | — | 4,120 | — |
| Romania | 4,665 | 4,273 | 4,665 | 4,273 |
| Russian Federation | 4,461 | 4,720 | 4,461 | 4,720 |
| Saudi Arabia | — | — | 4,507 | — |
| Singapore | 6,367 | 6,390 | 6,367 | 6,390 |
| Slovak Republic | 5,630 | 5,380 | 5,630 | 5,380 |
| Slovenia | 4,512 | 5,337 | 4,512 | 5,337 |
| Spain | 8,580 | 4,094 | 8,580 | 4,094 |

**Exhibit 9: PIRLS 2011 Sample Sizes for Scaling (Continued)**

| Country | Concurrent Calibration | | Proficiency Estimation | |
|---|---|---|---|---|
| | 2011 | 2006 | 2011 | 2006 |
| Sweden | 4,622 | 4,394 | 4,622 | 4,394 |
| Trinidad and Tobago | 3,948 | 3,951 | 3,948 | 3,951 |
| United Arab Emirates | — | — | 14,618 | — |
| United States | 12,726 | 5,190 | 12,726 | 5,190 |
| **Sixth Grade Participants** | | | | |
| Botswana | — | — | 4,197 | — |
| Honduras | — | — | 3,893 | — |
| Kuwait | — | — | 3,363 | — |
| Morocco | — | — | 7,183 | — |
| **Benchmarking Participants** | | | | |
| Alberta, Canada | — | — | 3,789 | — |
| Ontario, Canada | — | — | 4,561 | — |
| Quebec, Canada | — | — | 4,244 | — |
| Maltese - Malta | — | — | 3,548 | — |
| Eng/Afr (5) - RSA | — | — | 3,515 | — |
| Andalusia, Spain | — | — | 4,333 | — |
| Abu Dhabi, UAE | — | — | 4,146 | — |
| Dubai, UAE | — | — | 6,061 | — |
| Florida, US | — | — | 2,598 | — |
| **TOTAL** | **141,529** | **132,892** | **310,345** | **132,892** |

**prePIRLS 2011 Sample Sizes for Scaling**

| Country | Item Calibration | Proficiency Estimation |
|---|---|---|
| Botswana | 4,393 | 4,393 |
| Colombia | 3,964 | 3,964 |
| South Africa | 15,744 | 15,744 |
| **TOTAL** | **24,101** | **24,101** |

The item parameters estimated from these concurrent calibrations, based on the countries that have participated in both the previous and current assessments, were used to estimate student proficiency for all countries and benchmarking entities participating in the current assessment. These item parameters were also used to estimate student proficiency in the mathematics and science content and cognitive domains for TIMSS and for the reading purposes and comprehension processes for PIRLS. For tables displaying the item parameters, readers are referred to **TIMSS 2011 Item Parameters from Concurrent Calibration** and **PIRLS 2011 Item Parameters from Concurrent Calibration.**

## Treatment of Omitted and Not-Reached Responses

Given the matrix-sampling design used by TIMSS and PIRLS, whereby a student is administered only a sample of the assessment blocks (two mathematics and two science blocks in TIMSS and two reading passages in PIRLS) most items are missing by design for each student. However, missing data could also occur because a student does not answer an item, which can occur when the student does not know the answer, omits the item by mistake, or does not have sufficient time to attempt the item. An item is considered "not reached" when — within part 1 or part 2 of a booklet[2] — the item itself and the item immediately preceding it are not answered, and there are no other items completed in the remainder of that part of the booklet.

Not-reached items are treated differently in estimating item parameters and in generating student proficiency scores. In estimating the values of the item parameters, items in the assessment booklets that are considered not to have been reached by students are treated as if they have not been administered. This approach is considered optimal for parameter estimation. However, not-reached items are always considered as incorrect responses when student proficiency scores are generated.

## Evaluating Fit of IRT Models to the TIMSS and PIRLS Assessment Data

After the item calibrations are completed, checks were performed to verify that the item parameters obtained from Parscale adequately reproduce the observed distribution of student responses across the proficiency continuum. The fit of the IRT models to the TIMSS and PIRLS assessment data is examined by comparing the item response function curves generated using the item parameters estimated from the data with the empirical item response functions calculated from the latent abilities estimated for each student that responded to the item. When the empirical results for an item fall near the fitted curves, the IRT model fits the data well and provides an accurate and reliable measurement of the underlying proficiency scale. Graphical plots of these response function curves are called item characteristic curves (ICC).

Each plot in Exhibits 10 and 11 shows the empirical and fitted item response functions for a dichotomous item. In the plot, the horizontal axis represents the proficiency scale, and the vertical axis represents the probability of a correct response. The fitted curve based on the estimated item parameters is shown as a solid line. Empirical results are represented by circles. The empirical results are

2 The TIMSS and PIRLS assessment booklets consist of two parts, with a break in between.

obtained by first dividing the proficiency scale into intervals of equal size and then counting the number of students responding to the item whose estimated latent abilities (EAP scores) from Parscale fall in each interval. Then the proportion of students in each interval that responded correctly to the item is calculated. In the exhibits, the center of each circle represents this empirical proportion of correct responses. The size of each circle is proportional to the number of students contributing to the estimation of the empirical proportion correct.

**Exhibit 10: Example of Item Response Function for a Dichotomous Multiple Choice Item from the TIMSS 2011 Eighth Grade Mathematics Assessment**

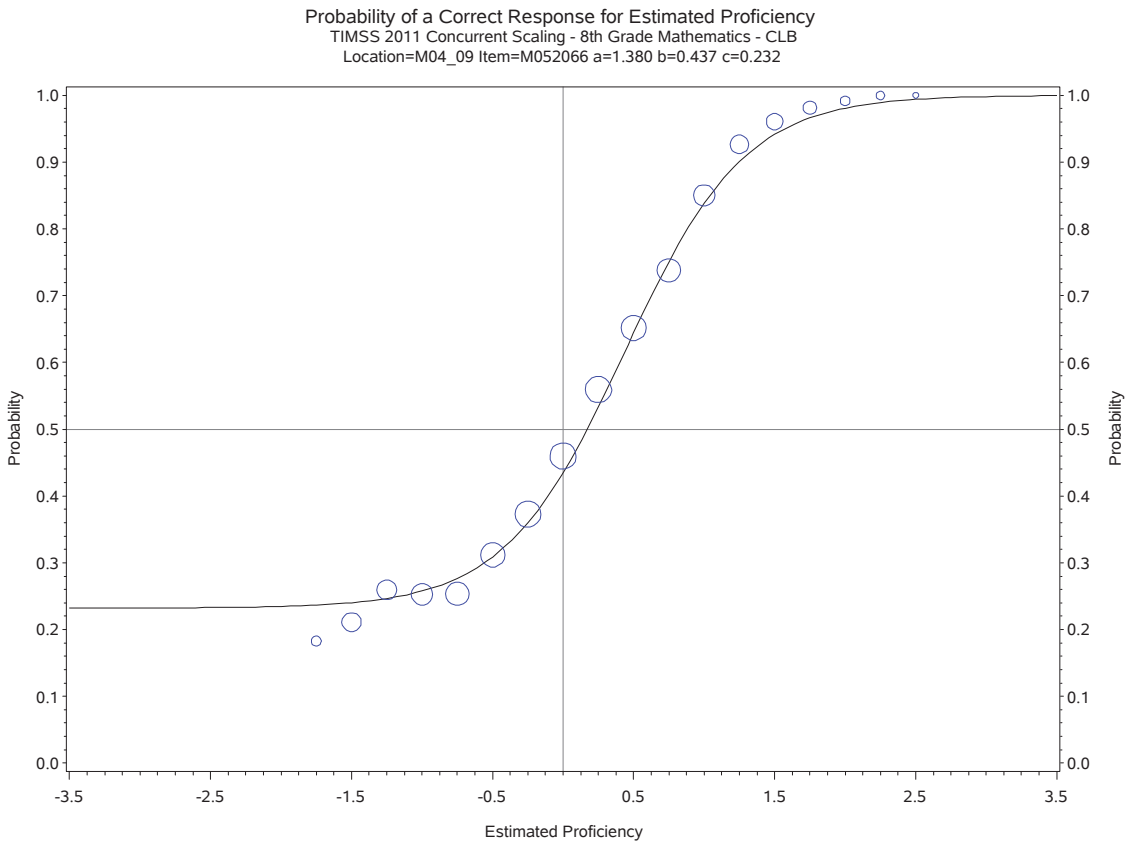
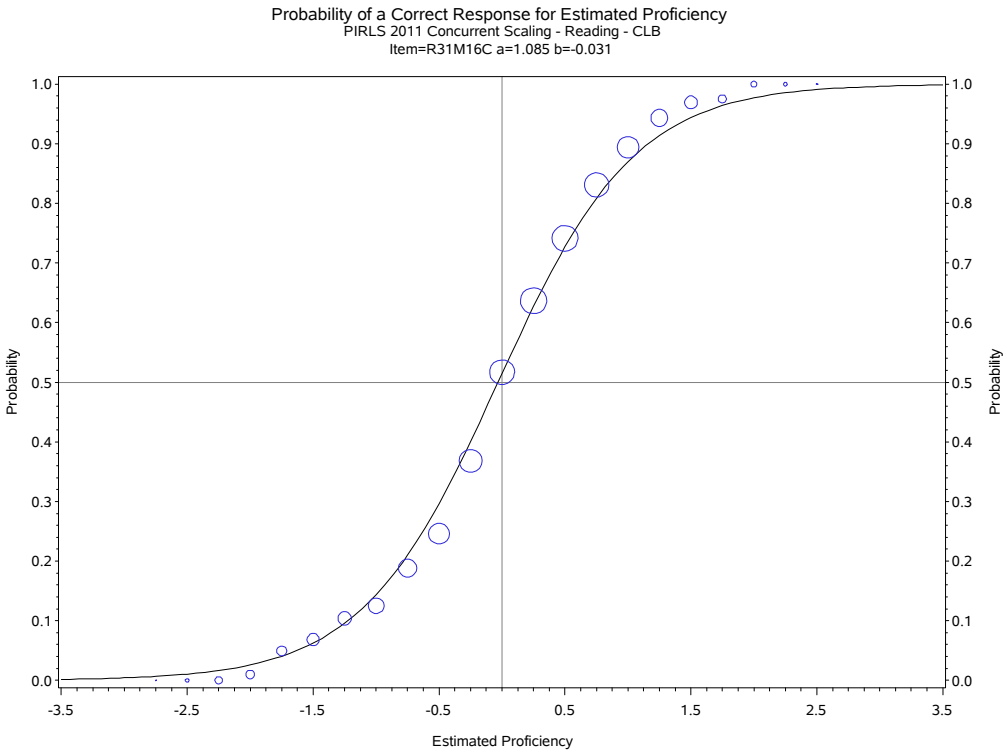
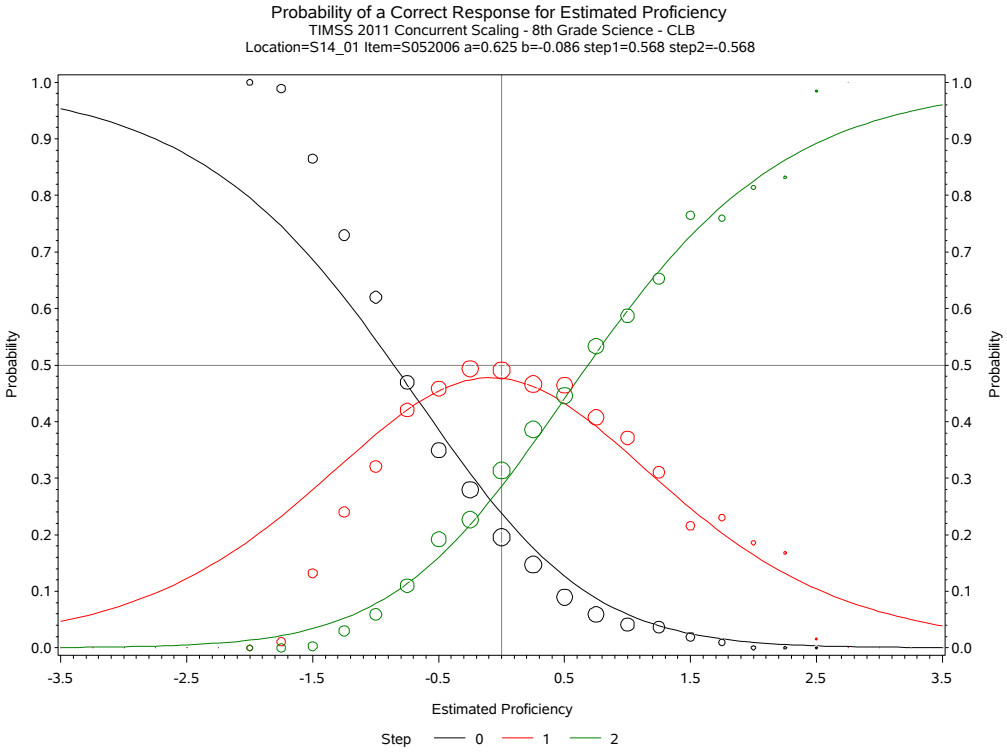



**Exhibit 11: Example of Item Response Function for a Dichotomous Constructed Response Item from PIRLS 2011**




The plot in Exhibits 12 shows the empirical and fitted item response functions for polytomous items. Similar to the dichotomous item plots, the horizontal axis represents the proficiency scale, but in this example the vertical axis represents the probability of having a response in a given response category. The fitted curves based on the estimated item parameters are shown as solid lines and again the empirical results are represented by circles. The interpretation of the circles is the same as in Exhibit10 and Exhibit 11. The curve starting at the top left of the chart plots the probability of a score of zero on the item. This probability decreases as proficiency increases. The bell-shaped curve shows the probability of a score of one point—partial credit, starting low for low-ability students, reaching a maximum for medium-ability students, and decreasing for high-ability students. The curve ending at the top right corner of the chart shows the probability of a score of two points—full credit, starting low for low-ability students and increasing as proficiency increases.

**Exhibit 12: Example of Item Response Function for a Polytomous Constructed Response Item from TIMSS 2011 Eighth Grade Science Assessment**




## Variables for Conditioning the TIMSS and PIRLS Assessment Data

Conditioning is the practice of using all available students' background information to improve the reliability of the estimated student proficiency scores. Because there are so many student background variables that could be used in conditioning, the TIMSS & PIRLS International Study Center follows the practice established by NAEP and followed by other large-scale studies of using principal components analysis to reduce the number of variables while explaining most of their common variance. Principal components for the TIMSS and PIRLS student background variables (and parent background variables for PIRLS) were constructed as follows:

- For categorical variables (questions with a small number of fixed response options), a "dummy coded" variable was created for each response option, with a value of one if the option is chosen and zero otherwise. If a student omitted or was not administered a particular question, all dummy coded variables associated with that question were assigned the value zero.

- Background variables with numerous response options (such as year of birth) were recoded using criterion scaling.[3] This was done by replacing the response option with the mean interim achievement score of all students choosing that option. Criterion scaling maximizes the correlation between the scaled variable and achievement. For PIRLS, the interim achievement score was the overall reading EAP (expected a-priori) achievement score produced from the item calibration. For TIMSS, the interim achievement score was the average of the mathematics and science EAP scores produced from the item calibrations.

- Separately for each country, all the dummy-coded and criterion-scaled variables were included in a principal components analysis. Those principal components accounting for 90 percent of the variance of the background variables were retained for use as conditioning variables.[4] Because the principal components analysis was performed separately for each country, different numbers of principal components were required to account for 90% of the common variance in each country's background variables.

In addition to the principal components, student gender (dummy coded), the language of the test (dummy coded), an indicator of the classroom in the school to which a student belongs (criterion scaled), and an optional country-specific variable (dummy coded) were included as primary conditioning variables, thereby accounting for most of the variance between students and preserving the between- and within-classrooms variance structure in the scaling model. For information on principle components conditioning, readers are referred to **TIMSS 2011 Conditioning Models for Concurrent Calibration** and **PIRLS 2011 Conditioning Models for Concurrent Calibration.**

## Generating IRT Proficiency Scores for the TIMSS and PIRLS Assessment Data

Educational Testing Service's MGROUP program (Sheehan, 1985) was used to generate the IRT proficiency scores. This program takes as input the students' responses to the items they were given, the item parameters estimated at the calibration stage, and the conditioning variables, and generates as output the plausible values that represent student proficiency. A useful feature of MGROUP is its ability to perform multi-dimensional scaling using the responses to all items across the proficiency scales and the correlations among the scales to

3 The process of generating criterion-scaled variables is described in Beaton (1969).

4 The number of principal components retained is limited to no more than 5% of a country's student sample size, thereby reducing the percentage of variance accounted for, to avoid over-specification of the conditioning model.

improve the reliability of each individual scale. TIMSS capitalizes on this feature to simultaneously estimate overall mathematics and overall science proficiency scales using a two-dimensional MGROUP run.

The multi-dimensional scaling feature of MGROUP also was used to generate proficiency scores for the TIMSS and PIRLS 2011 subdomains. For PIRLS, a two-dimensional analysis using the item parameters estimated for the overall reading scale and the same conditioning variables, generated proficiency scores for the literary and informational purposes for reading. A second two-dimensional analysis generated proficiency scores for two processes of comprehension: retrieval and simple inferencing and interpreting and integrating. For TIMSS, multidimensional analyses using the item parameters estimated for the overall mathematics and overall science scales and the same conditioning variables were used in the estimation of proficiency scores for the mathematics and science content and cognitive domains. At fourth grade, the content domain scaling used a three-dimensional model to estimate proficiency scores for the three content domains in both mathematics and science. At eighth grade, the content domain scaling required a four-dimensional model because of the four content domains in each subject. A series of three-dimensional models were used for scaling the three cognitive domains in mathematics and science at fourth and eighth grades.

In addition to generating plausible values on the overall reading, mathematics, and science scales for the 2011 assessment data, the item parameters estimated at the calibration stage also were used to generate plausible values for the previous assessments (PIRLS 2006 and TIMSS 2007) for the countries included in the concurrent calibration. These additional plausible values were used to establish the linear transformation necessary to place the 2011 assessment data on the appropriate trend scales.

## Transforming the Overall Scores to Measure Trends

To provide results for the 2011 assessments that are comparable to results from previous assessments, the 2011 proficiency scores (plausible values) — for overall mathematics and overall science in TIMSS and overall reading in PIRLS — has to be transformed to the TIMSS and PIRLS achievement scales used for measuring trends. This was accomplished through two successive linear transformations as part of the concurrent calibration approach.

For TIMSS, the first step was to transform the means and standard deviations of the mathematics and science 2007 scores produced in 2011—

the plausible values from the TIMSS 2007 assessment data based on the 2011 concurrent item calibrations—to match the means and standard deviations of the scores reported in the TIMSS 2007 assessment—the plausible values produced in 2007 using the 2007 item calibrations—by applying the appropriate linear transformations. These linear transformations were given by:

$$PV^{\star}_{k,i} = A_{k,i} + B_{k,i} \times PV_{k,i}$$

where

$PV_{k,i}$ is plausible value $i$ of scale $k$ prior to transformation;

$PV^{\star}_{k,i}$ is plausible value $i$ of scale $k$ after transformation; and

$A_{k,i}$ and $B_{k,i}$ are the linear transformation constants.

The linear transformation constants were obtained by first computing the international means and standard deviations of the proficiency scores for the overall mathematics and science scales using the plausible values produced in 2007 based on the 2007 item calibrations for the trend countries. Next, the same calculations were done using the plausible values from the TIMSS 2007 assessment data based on the 2011 item calibrations for the same set of countries. The linear transformation constants were defined as:

$$B_{k,i} = \sigma_{k,i} / \sigma^{\star}_{k,i}$$

$$A_{k,i} = \mu_{k,i} - B_{k,i} \cdot \mu^{\star}_{k,i}$$

where

$\mu_{k,i}$ is the international mean of scale $k$ based on plausible value $i$ released in the 2007 assessment;

$\mu^{\star}_{k,i}$ is the international mean of scale $k$ based on plausible value $i$ from the 2007 assessment based on the 2011 concurrent calibration;

$\sigma_{k,i}$ is the international standard deviation of scale $k$ based on plausible value $i$ released in the 2007 assessment;

$\sigma^{*}_{k,i}$ is the international standard deviation of scale $k$ based on plausible value $i$ from the 2007 assessment based on the 2011 concurrent calibration.

There are five sets of transformation constants for each scale, one for each plausible value.

A similar procedure was followed to place the PIRLS 2011 data on the PIRLS achievement scale.

**Exhibit 13: TIMSS 2011 Linear Transformation Constants for Achievement Scores at the Fourth Grade**

| Overall Mathematics | TIMSS 2007 Published Scores | | TIMSS 2007 Re-scaled Scores | | $A_{k,i}$ | $B_{k,i}$ |
|---|---|---|---|---|---|---|
| | Mean | Standard Deviation | Mean | Standard Deviation | | |
| PV1 | 509.77881 | 98.27104 | −0.06956 | 1.04438 | 516.32438 | 94.09515 |
| PV2 | 509.88650 | 98.20761 | −0.06919 | 1.04119 | 516.41272 | 94.32281 |
| PV3 | 510.18829 | 97.68089 | −0.06890 | 1.04833 | 516.60847 | 93.17783 |
| PV4 | 509.74968 | 98.39131 | −0.06850 | 1.04637 | 516.19085 | 94.03151 |
| PV5 | 509.65364 | 97.92636 | −0.06738 | 1.04057 | 515.99456 | 94.10840 |

| Overall Science | TIMSS 2007 Published Scores | | TIMSS 2007 Re-scaled Scores | | $A_{k,i}$ | $B_{k,i}$ |
|---|---|---|---|---|---|---|
| | Mean | Standard Deviation | Mean | Standard Deviation | | |
| PV1 | 514.12943 | 98.38115 | −0.03563 | 1.02478 | 517.54968 | 96.00185 |
| PV2 | 512.58575 | 98.91409 | −0.03307 | 1.02325 | 515.78221 | 96.66627 |
| PV3 | 512.54643 | 99.45460 | −0.03887 | 1.02803 | 516.30725 | 96.74254 |
| PV4 | 512.38909 | 99.01887 | −0.03413 | 1.02356 | 515.69084 | 96.73934 |
| PV5 | 513.82328 | 98.76119 | −0.03446 | 1.02502 | 517.14339 | 96.35051 |

**Exhibit 14: TIMSS 2011 Linear Transformation Constants for Achievement Scores at the Eighth Grade**

| Overall Mathematics | TIMSS 2007 Published Scores | | TIMSS 2007 Re-scaled Scores | | $A_{k,i}$ | $B_{k,i}$ |
|---|---|---|---|---|---|---|
| | Mean | Standard Deviation | Mean | Standard Deviation | | |
| PV1 | 475.80051 | 107.64135 | –0.01142 | 0.96338 | 477.07673 | 111.73350 |
| PV2 | 475.97536 | 108.81902 | –0.01089 | 0.96367 | 477.20509 | 112.92135 |
| PV3 | 475.94282 | 109.27775 | –0.01081 | 0.96505 | 477.16649 | 113.23526 |
| PV4 | 475.57437 | 109.20680 | –0.01066 | 0.96339 | 476.78226 | 113.35697 |
| PV5 | 476.45363 | 108.67854 | –0.00876 | 0.96132 | 477.44342 | 113.05174 |

| Overall Science | TIMSS 2007 Published Scores | | TIMSS 2007 Re-scaled Scores | | $A_{k,i}$ | $B_{k,i}$ |
|---|---|---|---|---|---|---|
| | Mean | Standard Deviation | Mean | Standard Deviation | | |
| PV1 | 490.88722 | 96.54763 | 0.03863 | 0.88485 | 486.67236 | 109.11153 |
| PV2 | 490.92138 | 96.43260 | 0.04036 | 0.88639 | 486.53078 | 108.79288 |
| PV3 | 491.45942 | 95.64552 | 0.03630 | 0.88714 | 487.54619 | 107.81349 |
| PV4 | 490.65845 | 96.92482 | 0.03857 | 0.88705 | 486.44385 | 109.26640 |
| PV5 | 491.32917 | 96.12894 | 0.03831 | 0.88560 | 487.17122 | 108.54636 |

**Exhibit 15: PIRLS 2011 Linear Transformation Constants for Achievement Scores**

| Overall Reading | PIRLS 2006 Published Scores | | PIRLS 2006 Re-scaled Scores | | $A_{k,i}$ | $B_{k,i}$ |
|---|---|---|---|---|---|---|
| | Mean | Standard Deviation | Mean | Standard Deviation | | |
| PV1 | 520.81919 | 84.44586 | -0.02328 | 0.99551 | 522.79397 | 84.82715 |
| PV2 | 520.38923 | 84.77937 | -0.02210 | 0.99177 | 522.27862 | 85.48312 |
| PV3 | 520.36103 | 84.64243 | -0.02120 | 0.99447 | 522.16518 | 85.11339 |
| PV4 | 520.37738 | 84.80857 | -0.02043 | 0.99393 | 522.12030 | 85.32680 |
| PV5 | 520.47872 | 84.75365 | -0.01999 | 0.99338 | 522.18452 | 85.31838 |

**prePIRLS 2011 Linear Transformation Constants for Achievement Scores**

| Overall Reading | Mean | Standard Deviation | $A_{k,i}$ | $B_{k,i}$ |
|---|---|---|---|---|
| PV1 | -1.80607 | 1.33534 | 635.25174 | 74.88718 |
| PV2 | -1.80799 | 1.32898 | 636.04363 | 75.24582 |
| PV3 | -1.81168 | 1.33073 | 636.14203 | 75.14673 |
| PV4 | -1.81160 | 1.33838 | 635.35764 | 74.71704 |
| PV5 | -1.80606 | 1.34337 | 634.44267 | 74.43989 |

Once these linear transformation constants were established, they were applied to the overall proficiency scores — reading for PIRLS and mathematics and science for TIMSS — for all participating countries and benchmarking participants. This provided student achievement scores for the 2011 TIMSS and PIRLS assessments that are directly comparable to the scores from all previous assessments.

The linear transformation constants for the overall scales also were applied to each of the subdomains. For PIRLS, the transformation constants for the overall reading scale were applied to the proficiency scores of the two purposes for reading and the two processes of comprehension. Likewise, the transformation constants for TIMSS mathematics were applied to the proficiency scores of the mathematics content domains and the cognitive domains, and the transformation constants for TIMSS science were applied to the proficiency scores of the science content domains and cognitive domains. In this approach to measuring trends, achievement changes over time are established in the context of achievement in each subject overall. Trends are not established separately for each content or cognitive domains; rather differential changes in performance in the domain are considered in the light of trends in the subject overall.

## Scaling the prePIRLS 2011 Achievement Data

prePIRLS is a reading assessment modeled on the same framework as PIRLS, and it is intended for populations of readers that would find the PIRLS assessment too challenging. In 2011, three countries took part in the first prePIRLS assessment; one of those countries, Colombia, chose to administer both the prePIRLS and PIRLS assessments to the same sample of students.

With prePIRLS in its first assessment cycle and with only three participating countries, a special scaling approach was required to make the best use of the limited data available. Because Colombia administered both PIRLS and prePIRLS to the same fourth grade students, it was possible to use the Colombian data as a link between the two assessments. Preliminary analyses based on scaling the PIRLS and prePIRLS data from Colombia together revealed a high latent correlation (0.91) between the two assessments. This was considered sufficient evidence of a single construct of reading achievement underlying both assessments to justify a combined scaling of PIRLS and prePIRLS together.

Much like the normal TIMSS and PIRLS scaling procedures, the prePIRLS

scaling approach involved the same four tasks of calibrating the achievement items, creating principal components, generating proficiency scores, and placing these proficiency scores on a new prePIRLS reading achievement scale. However, for prePIRLS the item calibration step involved a concurrent calibration of the prePIRLS data from its three countries (Botswana, Colombia, and South Africa) together with the PIRLS data from all of the PIRLS 2011 countries, including Colombia. In this concurrent calibration, the PIRLS items had item parameters fixed at the values previously estimated from the main PIRLS 2011 concurrent calibration. This linking was possible because the Colombian data included both PIRLS and prePIRLS achievement data for the same sample of students. Not only did this link the two assessments by placing the prePIRLS item parameters on the same scale as the PIRLS items, but also provided added robustness to the estimation of the prePIRLS item parameters.

The conditioning for prePIRLS was done in exactly the same way as for PIRLS, as was the estimation of proficiency scores using the MGROUP software. This included scores for overall reading, for the two purposes for reading, and the two processes of comprehension. Although the prePIRLS item calibration established a link between the PIRLS and prePIRLS scales, because this was done on the basis of data from just one country it was considered premature to use the PIRLS-prePIRLS link to establish the metric for the prePIRLS scale. Instead, the linear transformations to determine the prePIRLS reading metric were set to produce an average of 500 and standard deviation of 100 across the three participating countries. These same linear transformations also were applied to the purposes and processes subdomains.

## References


Muraki, E., & Bock, R.D. (1991). PARSCALE: Parameter scaling of rating data. Chicago, IL: Scientific Software, Inc.

Rubin, D.B. (1987). *Multiple imputation for nonresponse in surveys*. New York: John Wiley & Sons.

Sheehan, K.M. (1985). *M-Group: Estimation of group effects in multivariate models*. [Software Version 3.2] Princeton, NJ: Educational Testing Service.