Reporting Student Achievement in Mathematics and Science for TIMSS 1999 Benchmarking

Eugenio J. Gonzalez
Kelvin D. Gregory
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15.1 Overview
As described in earlier chapters, the Benchmarking study makes extensive use of imputed student proficiency scores to report achievement in mathematics and science, both in the subjects overall and in the separate content areas. This chapter describes the procedures followed in computing the major statistics used to summarize achievement in the TIMSS 1999 Benchmarking Reports (Mullis et al., 2001; Martin et al., 2001), including average scores based on plausible values, Bonferroni adjustments for multiple comparisons, international benchmarks of achievement, and profiles of relative performance in subject-matter areas.

15.2 Computing Average Student Achievement
The item response theory (IRT) scaling procedure described in chapter 13 yields five imputed scores or plausible values in mathematics and science and in each of their content areas for each student. Average mathematics or science scores for countries or Benchmarking jurisdictions were computed by first taking the mean for each of the five plausible values, and then taking the mean of the five plausible-value means, as follows: The average for each plausible value was computed as the weighted mean

\[
\bar{X}_{pl} = \frac{\sum_{i=1}^{N} W_{i,j} \cdot pvl_{ij}}{\sum_{j=1}^{N} W_{i,j}}
\]

where

\( \bar{X}_{pl} \) is the country or jurisdiction mean for plausible value \( l \)

\( pvl_{ij} \) is the \( l^{th} \) plausible value for the \( j^{th} \) student

---

1. This chapter is based on Gonzalez & Gregory (2000) from the TIMSS 1999 international technical report (Martin, Gregory, & Stemler, 2000).
$W^i_j$ is the weight associated with the $j^{th}$ student in class $i$, described in chapters 5 and 6.

$N$ is the number of students in the sample.

The country or jurisdiction average is the mean of the five plausible value means.

The international average for mathematics and science was computed by taking the mean of the country means for each of the five plausible values and averaging across these five international means, as follows: The international average for each plausible value was computed as the average of that plausible value for each country:

$$X_{pvl} = \frac{\sum_{k=1}^{N} X_{pvl,k}}{N}$$

where

$X_{pvl}$ is the international mean for plausible value $l$

$X_{pvl,k}$ is the $k^{th}$ country mean for plausible value $l$

and $N$ is the number of countries.

The international average was the average of these five international means. The international averages were based on all TIMSS 1999 countries. Data from Benchmarking jurisdictions were not included in the computation of international averages.

### 15.3 Achievement Differences Across Benchmarking Jurisdictions

The TIMSS 1999 Benchmarking Reports aim to provide fair and accurate comparisons of student achievement across the participating jurisdictions. Most of the exhibits summarize achievement using a statistic such as a mean or percentage, and each statistic is accompanied by its standard error, which is a measure of the uncertainty due to student sampling and the imputation process. In comparisons of performance across jurisdictions, standard errors were used to assess the statistical significance of the difference between the summary statistics.

The charts presented in the TIMSS 1999 Benchmarking Reports provide comparisons of average performance of a jurisdiction with that of the TIMSS 1999 countries as well as with other participating jurisdictions. The significance tests reported in these
charts include a Bonferroni adjustment for multiple comparisons. The Bonferroni adjustment is necessary because the probability of finding a difference that is an artifact of chance greatly increases as the number of simultaneous comparisons increases.

15.3.1 Bonferroni Adjustments in TIMSS

If repeated samples were taken from two populations with the same mean and variance, and in each one the hypothesis that the two means are significantly different at the $\alpha = .05$ level (i.e., with 95% confidence) was tested, then it would be expected that in about 5% of the comparisons significant differences would be found between the sample means even though no difference exists in the populations. The probability of finding significant differences when none exist (the so-called Type I error) is given by $\alpha$. Conversely, the probability of not making such an error is $1 - \alpha$, which in the case of a single test is .95. When $\alpha = .05$, comparing the means of three countries involves three tests (country A versus country B, country B versus country C, and country A versus country C). Since these are independent tests, the probability of avoiding a Type I error in any of the three is the product of the individual probabilities, which is $(1 - \alpha)(1 - \alpha)(1 - \alpha)$. With $\alpha = .05$, the overall probability of avoiding a Type I error is only .873. Stated differently, the probability of committing a Type I error rises from .05 for one comparisons to .127 with three comparisons, which is considerably less than the probability for a single test. As the number of tests increases, the probability of making a Type I error increases rapidly.

Several methods can be used to correct for the increased probability of a Type I error while making many simultaneous comparisons. Dunn (1961) developed a procedure that is appropriate for testing a set of a priori hypotheses while controlling the probability that the Type I error will occur. In this procedure, the value of $\alpha$ is adjusted to compensate for the increase in the probability of making the error (the Dunn-Bonferroni procedure for multiple a priori comparisons; Winer, Brown, and Michels, 1991).

The TIMSS 1999 International Reports contain multiple-comparison exhibits that show the statistical significance of the differences between all possible combinations of the 38 participating countries. There were $(38*37)/2 = 703$ possible differences. In the Bonferroni procedure the significance level ($\alpha$) of a statistical test is adjusted by establishing the number of comparisons that are
planned and then looking up the appropriate quantile from the normal distribution. In choosing the adjustment of the significance level for TIMSS, it was necessary to decide how the multiple comparison exhibits would most likely be used. A very conservative approach would be to adjust the significance level to compensate for all of the 703 possible comparisons among the 38 countries concerned. This risks an error of a different kind, however, that of concluding that a difference in sample means is not significant when in fact there is a difference in the population means (i.e., Type II error).

Most users of the multiple comparison exhibits in the international reports are likely to be interested in comparing a single country with all other countries, rather than in making all possible between-country comparisons at once; the more realistic approach of using the number of countries (minus one) to adjust the significance level was therefore adopted for the international reports. This meant that the number of simultaneous comparisons to be adjusted for was 37 instead of 703. The critical value for a 95% significance test adjusted for 37 simultaneous comparisons is 3.2049, from the appropriate quantiles from the normal (Gaussian) distribution.

In the multiple comparison exhibits of the TIMSS 1999 Benchmarking Reports (Martin et al., 2001; Mullis et al., 2001), it was decided to keep the same Bonferroni correction as in the international reports so that between-country significance tests in both sets of reports would have the same results. This decision was taken despite the fact that Benchmarking exhibits that included all 38 TIMSS countries as well as the 27 Benchmarking participants had more comparisons (65) than exhibits in the international reports, which involved just the 38 countries. Consequently, exhibits with all 65 comparisons, which are confined to the first chapter in each Benchmarking report, present significance tests that are slightly less conservative than they would otherwise be.

15.3.2 Standard Error of the Difference

Mean proficiencies were considered significantly different if the absolute difference between them, divided by the standard error of the difference, was greater than the Bonferroni-adjusted critical value. For differences between countries or Benchmarking
jurisdictions, which can be considered as independent samples, the standard error of the difference in means was computed as the square root of the sum of the squared standard errors of each mean:

$$se_{\text{diff}} = \sqrt{se_j^2 + se_2^2}$$

where $se_j$ and $se_2$ are the standard errors of the means. Exhibits 15.1 and 15.2 show the means and standard errors for mathematics and science used in the calculation of statistical significance for countries and Benchmarking jurisdictions, respectively.

**Exhibit 15.1** Means and Standard Errors for Multiple-Comparisons Exhibits-Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Math</th>
<th>Science</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.E.</td>
</tr>
<tr>
<td>United States</td>
<td>501.633</td>
<td>3.971</td>
</tr>
<tr>
<td>Australia</td>
<td>525.080</td>
<td>4.840</td>
</tr>
<tr>
<td>Belgium (Flemish)</td>
<td>557.958</td>
<td>3.291</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>510.591</td>
<td>5.850</td>
</tr>
<tr>
<td>Canada</td>
<td>530.753</td>
<td>2.460</td>
</tr>
<tr>
<td>Chile</td>
<td>392.494</td>
<td>4.364</td>
</tr>
<tr>
<td>Chinese Taipei</td>
<td>585.117</td>
<td>4.033</td>
</tr>
<tr>
<td>Cyprus</td>
<td>476.382</td>
<td>1.792</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>519.874</td>
<td>4.176</td>
</tr>
<tr>
<td>England</td>
<td>496.330</td>
<td>4.150</td>
</tr>
<tr>
<td>Finland</td>
<td>520.452</td>
<td>2.743</td>
</tr>
<tr>
<td>Hong Kong, SAR</td>
<td>582.056</td>
<td>4.280</td>
</tr>
<tr>
<td>Hungary</td>
<td>531.601</td>
<td>3.674</td>
</tr>
<tr>
<td>Indonesia</td>
<td>403.070</td>
<td>4.896</td>
</tr>
<tr>
<td>Iran, Islamic Rep.</td>
<td>422.148</td>
<td>3.397</td>
</tr>
<tr>
<td>Israel</td>
<td>466.336</td>
<td>3.932</td>
</tr>
<tr>
<td>Italy</td>
<td>479.479</td>
<td>3.829</td>
</tr>
<tr>
<td>Japan</td>
<td>578.604</td>
<td>1.654</td>
</tr>
<tr>
<td>Jordan</td>
<td>427.664</td>
<td>3.592</td>
</tr>
<tr>
<td>Korea, Rep. of</td>
<td>587.152</td>
<td>1.969</td>
</tr>
<tr>
<td>Latvia (LSS)</td>
<td>505.059</td>
<td>3.435</td>
</tr>
<tr>
<td>Lithuania</td>
<td>481.567</td>
<td>4.281</td>
</tr>
<tr>
<td>Macedonia, Rep.</td>
<td>446.604</td>
<td>4.224</td>
</tr>
<tr>
<td>Malaysia</td>
<td>519.256</td>
<td>4.354</td>
</tr>
<tr>
<td>Moldova</td>
<td>469.231</td>
<td>3.883</td>
</tr>
<tr>
<td>Morocco</td>
<td>336.597</td>
<td>2.573</td>
</tr>
<tr>
<td>Netherlands</td>
<td>539.875</td>
<td>7.147</td>
</tr>
<tr>
<td>New Zealand</td>
<td>490.967</td>
<td>5.178</td>
</tr>
<tr>
<td>Philippines</td>
<td>344.905</td>
<td>5.979</td>
</tr>
<tr>
<td>Romania</td>
<td>472.440</td>
<td>5.787</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>526.023</td>
<td>5.935</td>
</tr>
<tr>
<td>Singapore</td>
<td>604.393</td>
<td>6.259</td>
</tr>
<tr>
<td>Slovak Republic</td>
<td>533.953</td>
<td>3.959</td>
</tr>
<tr>
<td>Slovenia</td>
<td>530.113</td>
<td>2.777</td>
</tr>
<tr>
<td>South Africa</td>
<td>274.503</td>
<td>6.815</td>
</tr>
<tr>
<td>Thailand</td>
<td>467.377</td>
<td>5.088</td>
</tr>
<tr>
<td>Tunisia</td>
<td>447.925</td>
<td>2.430</td>
</tr>
<tr>
<td>Turkey</td>
<td>428.606</td>
<td>4.343</td>
</tr>
</tbody>
</table>
### Exhibit 15.2  Means and Standard Errors for Multiple-Comparisons Exhibits -States and Districts

<table>
<thead>
<tr>
<th>States</th>
<th>Math</th>
<th>Science</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.E.</td>
<td>Mean</td>
<td>SE</td>
</tr>
<tr>
<td>Idaho</td>
<td>494.886</td>
<td>7.385</td>
<td>526.368</td>
<td>6.585</td>
</tr>
<tr>
<td>Illinois</td>
<td>509.478</td>
<td>6.730</td>
<td>520.515</td>
<td>6.546</td>
</tr>
<tr>
<td>Indiana</td>
<td>514.626</td>
<td>7.186</td>
<td>534.202</td>
<td>6.973</td>
</tr>
<tr>
<td>Maryland</td>
<td>494.610</td>
<td>6.245</td>
<td>506.110</td>
<td>7.689</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>513.469</td>
<td>5.938</td>
<td>533.194</td>
<td>7.363</td>
</tr>
<tr>
<td>Michigan</td>
<td>516.630</td>
<td>7.452</td>
<td>544.142</td>
<td>8.624</td>
</tr>
<tr>
<td>Missouri</td>
<td>489.731</td>
<td>5.314</td>
<td>522.826</td>
<td>6.486</td>
</tr>
<tr>
<td>North Carolina</td>
<td>495.218</td>
<td>7.026</td>
<td>507.792</td>
<td>6.544</td>
</tr>
<tr>
<td>Oregon</td>
<td>514.110</td>
<td>5.953</td>
<td>536.094</td>
<td>6.051</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>507.452</td>
<td>6.299</td>
<td>528.951</td>
<td>6.475</td>
</tr>
<tr>
<td>South Carolina</td>
<td>501.610</td>
<td>7.393</td>
<td>510.958</td>
<td>6.693</td>
</tr>
<tr>
<td>Texas</td>
<td>516.445</td>
<td>9.066</td>
<td>508.698</td>
<td>10.427</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Districts and Consortia</th>
<th>Math</th>
<th>Science</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Academy School Dist. #20, CO</td>
<td>528.464</td>
<td>1.828</td>
<td>558.742</td>
<td>2.116</td>
</tr>
<tr>
<td>Chicago Public Schools, IL</td>
<td>462.500</td>
<td>6.102</td>
<td>449.447</td>
<td>9.505</td>
</tr>
<tr>
<td>Delaware Science Coalition, DE</td>
<td>479.483</td>
<td>8.928</td>
<td>500.446</td>
<td>8.379</td>
</tr>
<tr>
<td>First in the World Consort., IL</td>
<td>559.633</td>
<td>5.775</td>
<td>565.461</td>
<td>5.255</td>
</tr>
<tr>
<td>Fremont/LincolnWestSide PS, NE</td>
<td>488.142</td>
<td>8.215</td>
<td>511.302</td>
<td>5.780</td>
</tr>
<tr>
<td>Guilford County, NC</td>
<td>513.565</td>
<td>7.705</td>
<td>533.780</td>
<td>7.063</td>
</tr>
<tr>
<td>Jersey City Public Schools, NJ</td>
<td>474.814</td>
<td>8.610</td>
<td>439.666</td>
<td>9.756</td>
</tr>
<tr>
<td>Miami-Dade County PS, FL</td>
<td>421.330</td>
<td>9.449</td>
<td>425.956</td>
<td>10.937</td>
</tr>
<tr>
<td>Michigan Invitational Group, MI</td>
<td>531.748</td>
<td>5.815</td>
<td>563.495</td>
<td>6.246</td>
</tr>
<tr>
<td>Montgomery County, MD</td>
<td>537.370</td>
<td>3.548</td>
<td>531.480</td>
<td>4.252</td>
</tr>
<tr>
<td>Naperville Sch. Dist. #203, IL</td>
<td>569.172</td>
<td>2.835</td>
<td>583.727</td>
<td>4.092</td>
</tr>
<tr>
<td>Project SMART Consortium, OH</td>
<td>520.593</td>
<td>7.507</td>
<td>539.223</td>
<td>8.370</td>
</tr>
<tr>
<td>Rochester City Sch. Dist., NY</td>
<td>444.404</td>
<td>6.462</td>
<td>451.669</td>
<td>7.372</td>
</tr>
<tr>
<td>SW Math/Sci. Collaborative, PA</td>
<td>516.719</td>
<td>7.547</td>
<td>543.249</td>
<td>7.429</td>
</tr>
</tbody>
</table>

### 15.4 Comparing Achievement with the International Mean

Many of the data exhibits in the TIMSS 1999 International Reports show countries’ and jurisdictions’ mean achievement compared with the international mean. Since this resulted in 38 simultaneous comparisons, the critical value was adjusted to 3.2125 using the Dunn-Bonferroni procedure. In the Benchmarking Reports, the corresponding exhibits contained 40 comparisons (27 Benchmarking participants and 13 selected countries), but for consistency with the international reports, the critical value for 38 comparisons was used in Benchmarking exhibits also.
When comparing each country's mean with the international average, TIMSS took into account the fact that the country contributed to the international standard error. To correct for this contribution, TIMSS adjusted the standard error of the difference. The sampling component of the standard error of the difference for country \( j \) was

$$
S_{i dif, j} = \sqrt{\frac{((N - 1)^2 - 1) s_{j}^2 + \sum_{k=1}^{N} s_{k}^2}{N}}
$$

where

- \( s_{i dif, j} \) is the standard error of the difference due to sampling when country \( j \) is compared to the international mean.
- \( N \) is the number of countries.
- \( s_{j}^2 \) is the sampling standard error for country \( j \).
- \( s_{k}^2 \) is the sampling standard error for country \( k \).

The imputation component of the standard error was computed by taking the square root of the imputation variance calculated as follows:

$$
se_{i dif, j} = \sqrt{\frac{\text{Var}(d_{1}...d_{l}...d_{S})}{5}}
$$

where \( d_{i} \) is the difference between the international mean and the jurisdiction mean for plausible value \( l \).

Finally, the standard error of the difference was calculated as:

$$
se_{dif, j} = \sqrt{se_{i dif, j}^2 + se_{s dif, j}^2}.
$$

### 15.5 International Benchmarks of Achievement

In order to provide more information about student achievement, TIMSS identified four points on each of the mathematics and science scales for use as international benchmark as described in chapter 14. The top 10% benchmark was defined as the 90th percentile on the TIMSS scale, computed across all students in all participating countries, with countries weighted in proportion to the size of their eighth-grade population. This point on each scale (mathematics and science) is the point above which the top 10% of students in the 1999 TIMSS assessment scored. The upper quar-
ter benchmark is the 75th percentile on the scale, above which the top 25% of students scored. The median benchmark is the 50th percentile, above which the top half of students scored. Finally, the lower quarter benchmark is the 25th percentile, the point reached by the top 75% of students. Comparing the percentage of students in Benchmarking jurisdictions that reached the achievement levels defined by these international benchmarks was a very useful way of describing student performance at various points of the ability distribution.

### 15.5.1 Establishing the International Benchmarks of Achievement

In computing of the international benchmarks of achievement, each country was weighted to contribute as many students as there were students in the target population. In other words, each country’s contribution to setting the international benchmarks was proportional to the estimated population enrolled in the eighth grade. Exhibit 15.3 shows the contribution of each country to the estimation of the international benchmarks.
If all countries had the same distribution of student achievement, approximately 10% of students within each country would be above the 90th percentile in the international distribution, regardless of the country's population size. That this is not the case, and that countries vary considerably, is evident from the fact that 46% of students in Singapore reached the top 10% benchmark, compared to fewer than 1% in Tunisia, the Philippines, South Africa, and Morocco.
Because of the imputation technology used to derive the student achievement scores, the international benchmarks had to be computed once for each of the five plausible values, and the results averaged to arrive at the final figure. The standard errors presented in the exhibits are computed by taking into account the sampling design as well as the variance due to imputation. The international benchmarks are presented in Exhibit 15.4 and 15.5 for mathematics and science, respectively.

### Exhibit 15.4 International Benchmarks of Achievement for Eighth Grade—Mathematics

<table>
<thead>
<tr>
<th>Proficiency Score</th>
<th>25&lt;sup&gt;th&lt;/sup&gt; Percentile</th>
<th>50&lt;sup&gt;th&lt;/sup&gt; Percentile</th>
<th>75&lt;sup&gt;th&lt;/sup&gt; Percentile</th>
<th>90&lt;sup&gt;th&lt;/sup&gt; Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plausible Value 1</td>
<td>396.86</td>
<td>479.20</td>
<td>554.49</td>
<td>615.15</td>
</tr>
<tr>
<td>Plausible Value 2</td>
<td>395.76</td>
<td>478.79</td>
<td>554.74</td>
<td>615.37</td>
</tr>
<tr>
<td>Plausible Value 3</td>
<td>395.62</td>
<td>478.56</td>
<td>554.83</td>
<td>616.23</td>
</tr>
<tr>
<td>Plausible Value 4</td>
<td>394.57</td>
<td>478.09</td>
<td>554.03</td>
<td>615.02</td>
</tr>
<tr>
<td>Plausible Value 5</td>
<td>396.30</td>
<td>479.10</td>
<td>554.56</td>
<td>615.76</td>
</tr>
<tr>
<td>Mean Plausible Value</td>
<td>395.82</td>
<td>478.75</td>
<td>554.53</td>
<td>615.51</td>
</tr>
</tbody>
</table>

### Exhibit 15.5 International Benchmarks of Achievement for Eighth Grade—Science

<table>
<thead>
<tr>
<th>Proficiency Score</th>
<th>25&lt;sup&gt;th&lt;/sup&gt; Percentile</th>
<th>50&lt;sup&gt;th&lt;/sup&gt; Percentile</th>
<th>75&lt;sup&gt;th&lt;/sup&gt; Percentile</th>
<th>90&lt;sup&gt;th&lt;/sup&gt; Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plausible Value 1</td>
<td>409.03</td>
<td>487.76</td>
<td>558.66</td>
<td>617.01</td>
</tr>
<tr>
<td>Plausible Value 2</td>
<td>409.87</td>
<td>487.61</td>
<td>557.60</td>
<td>615.88</td>
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<tr>
<td>Plausible Value 3</td>
<td>410.38</td>
<td>488.04</td>
<td>557.27</td>
<td>616.12</td>
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<tr>
<td>Plausible Value 4</td>
<td>410.05</td>
<td>487.54</td>
<td>557.47</td>
<td>615.82</td>
</tr>
<tr>
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<td>410.87</td>
<td>487.59</td>
<td>557.79</td>
<td>615.88</td>
</tr>
<tr>
<td>Mean Plausible Value</td>
<td>410.04</td>
<td>487.71</td>
<td>557.76</td>
<td>616.14</td>
</tr>
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</table>
**Exhibit 15.6 Percentages of Students Reaching TIMSS 1999 International Benchmarks of Mathematics Achievement**

<table>
<thead>
<tr>
<th>States, Districts and Consortia</th>
<th>Top 10%</th>
<th>Upper Quarter</th>
<th>Median</th>
<th>Lower Quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connecticut</td>
<td>11 (2.5)</td>
<td>31 (3.9)</td>
<td>67 (4.4)</td>
<td>91 (1.9)</td>
</tr>
<tr>
<td>Idaho</td>
<td>5 (1.1)</td>
<td>24 (2.9)</td>
<td>61 (3.5)</td>
<td>88 (2.2)</td>
</tr>
<tr>
<td>Illinois</td>
<td>10 (1.6)</td>
<td>29 (2.9)</td>
<td>65 (3.3)</td>
<td>92 (1.5)</td>
</tr>
<tr>
<td>Indiana †</td>
<td>9 (1.9)</td>
<td>30 (3.9)</td>
<td>69 (3.6)</td>
<td>94 (1.2)</td>
</tr>
<tr>
<td>Maryland</td>
<td>8 (1.4)</td>
<td>27 (2.5)</td>
<td>57 (3.2)</td>
<td>87 (2.0)</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>10 (1.6)</td>
<td>31 (2.6)</td>
<td>68 (3.0)</td>
<td>92 (1.6)</td>
</tr>
<tr>
<td>Michigan</td>
<td>10 (2.0)</td>
<td>33 (3.7)</td>
<td>70 (3.3)</td>
<td>92 (1.7)</td>
</tr>
<tr>
<td>Missouri</td>
<td>4 (0.9)</td>
<td>20 (2.4)</td>
<td>58 (2.9)</td>
<td>89 (1.5)</td>
</tr>
<tr>
<td>North Carolina</td>
<td>7 (1.6)</td>
<td>25 (3.1)</td>
<td>57 (3.3)</td>
<td>88 (2.0)</td>
</tr>
<tr>
<td>Oregon</td>
<td>10 (1.8)</td>
<td>32 (2.8)</td>
<td>69 (2.8)</td>
<td>91 (1.4)</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>9 (1.3)</td>
<td>28 (2.6)</td>
<td>65 (3.0)</td>
<td>91 (1.8)</td>
</tr>
<tr>
<td>South Carolina</td>
<td>10 (2.0)</td>
<td>30 (3.2)</td>
<td>60 (3.5)</td>
<td>88 (1.8)</td>
</tr>
<tr>
<td>Texas</td>
<td>13 (2.2)</td>
<td>37 (3.8)</td>
<td>66 (4.3)</td>
<td>90 (2.1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>States, Districts and Consortia</th>
<th>Top 10%</th>
<th>Upper Quarter</th>
<th>Median</th>
<th>Lower Quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academy School Dist. #20, CO</td>
<td>12 (0.8)</td>
<td>38 (1.5)</td>
<td>75 (1.5)</td>
<td>95 (0.7)</td>
</tr>
<tr>
<td>Chicago Public Schools, IL</td>
<td>2 (0.9)</td>
<td>12 (1.7)</td>
<td>41 (4.3)</td>
<td>81 (2.5)</td>
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<tr>
<td>Delaware Science Coalition, DE</td>
<td>5 (1.8)</td>
<td>22 (4.1)</td>
<td>51 (4.5)</td>
<td>83 (2.4)</td>
</tr>
<tr>
<td>First in the World Consort., IL</td>
<td>22 (3.2)</td>
<td>56 (3.3)</td>
<td>87 (2.1)</td>
<td>98 (0.6)</td>
</tr>
<tr>
<td>Fremont/Lincoln/WestSide PS, NE</td>
<td>6 (2.3)</td>
<td>23 (4.1)</td>
<td>58 (4.0)</td>
<td>84 (2.7)</td>
</tr>
<tr>
<td>Guilford County, NC †</td>
<td>10 (2.2)</td>
<td>33 (3.5)</td>
<td>66 (4.1)</td>
<td>91 (1.6)</td>
</tr>
<tr>
<td>Jersey City Public Schools, NJ</td>
<td>6 (1.9)</td>
<td>17 (3.4)</td>
<td>48 (3.9)</td>
<td>82 (2.9)</td>
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<tr>
<td>Miami-Dade County PS, FL</td>
<td>2 (0.9)</td>
<td>9 (2.4)</td>
<td>29 (3.6)</td>
<td>61 (3.5)</td>
</tr>
<tr>
<td>Michigan Invitational Group, MI</td>
<td>12 (2.4)</td>
<td>39 (3.4)</td>
<td>77 (3.0)</td>
<td>96 (1.3)</td>
</tr>
<tr>
<td>Montgomery County, MD †</td>
<td>17 (2.2)</td>
<td>45 (1.8)</td>
<td>77 (1.4)</td>
<td>95 (1.1)</td>
</tr>
<tr>
<td>Naperville Sch. Dist. #203, IL</td>
<td>24 (1.7)</td>
<td>59 (2.2)</td>
<td>91 (1.1)</td>
<td>99 (0.4)</td>
</tr>
<tr>
<td>Project SMART Consortium, OH</td>
<td>11 (2.9)</td>
<td>34 (4.7)</td>
<td>70 (3.1)</td>
<td>95 (1.0)</td>
</tr>
<tr>
<td>Rochester City Sch. Dist., NY</td>
<td>2 (0.9)</td>
<td>9 (2.5)</td>
<td>32 (3.2)</td>
<td>73 (2.9)</td>
</tr>
<tr>
<td>SW Math/Sci. Collaborative, PA</td>
<td>11 (2.7)</td>
<td>32 (3.9)</td>
<td>68 (3.1)</td>
<td>93 (1.6)</td>
</tr>
</tbody>
</table>

Top 10% Benchmark (90th Percentile) 616
Upper Quarter Benchmark (75th Percentile) 555
Median Benchmark (50th Percentile) 479
Lower Quarter Benchmark (25th Percentile) 396

States in italics did not fully satisfy guidelines for sample participation rates (see Appendix A for details).
† Met guidelines for sample participation rates only after replacement schools were included (see Exhibit A.6).
1 National Defined Population covers less than 90 percent of National Desired Population (see Exhibit A.3).
( ) Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.
Exhibit 15.7 Percentages of Students Reaching TIMSS 1999 International Benchmarks of Science Achievement

<table>
<thead>
<tr>
<th>States</th>
<th>Top 10%</th>
<th>Upper Quarter</th>
<th>Median</th>
<th>Lower Quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connecticut</td>
<td>17 (3.0)</td>
<td>39 (4.4)</td>
<td>69 (4.6)</td>
<td>90 (2.5)</td>
</tr>
<tr>
<td>Idaho</td>
<td>13 (1.8)</td>
<td>37 (3.2)</td>
<td>70 (3.3)</td>
<td>91 (1.8)</td>
</tr>
<tr>
<td>Illinois</td>
<td>14 (1.9)</td>
<td>36 (3.0)</td>
<td>66 (3.0)</td>
<td>88 (1.5)</td>
</tr>
<tr>
<td>Indiana</td>
<td>18 (2.5)</td>
<td>41 (3.6)</td>
<td>72 (2.8)</td>
<td>92 (1.4)</td>
</tr>
<tr>
<td>Maryland</td>
<td>12 (1.3)</td>
<td>31 (3.0)</td>
<td>59 (3.5)</td>
<td>84 (2.5)</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>17 (2.4)</td>
<td>40 (3.0)</td>
<td>71 (3.4)</td>
<td>92 (1.7)</td>
</tr>
<tr>
<td>Michigan</td>
<td>22 (2.6)</td>
<td>47 (3.6)</td>
<td>75 (3.4)</td>
<td>91 (2.2)</td>
</tr>
<tr>
<td>Missouri</td>
<td>14 (2.3)</td>
<td>36 (3.0)</td>
<td>67 (2.8)</td>
<td>89 (1.8)</td>
</tr>
<tr>
<td>North Carolina</td>
<td>11 (1.4)</td>
<td>30 (2.9)</td>
<td>60 (3.4)</td>
<td>85 (2.1)</td>
</tr>
<tr>
<td>Oregon</td>
<td>19 (2.3)</td>
<td>43 (2.7)</td>
<td>73 (2.6)</td>
<td>91 (1.9)</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>15 (1.5)</td>
<td>38 (2.5)</td>
<td>70 (3.2)</td>
<td>91 (1.6)</td>
</tr>
<tr>
<td>South Carolina</td>
<td>13 (1.8)</td>
<td>34 (2.7)</td>
<td>60 (3.4)</td>
<td>85 (1.7)</td>
</tr>
<tr>
<td>Texas</td>
<td>15 (2.1)</td>
<td>35 (3.6)</td>
<td>61 (4.5)</td>
<td>83 (3.3)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Districts and Consortia</th>
<th>Top 10%</th>
<th>Upper Quarter</th>
<th>Median</th>
<th>Lower Quarter</th>
</tr>
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<tr>
<td>Academy School Dist. #20, CO</td>
<td>23 (1.6)</td>
<td>52 (1.5)</td>
<td>84 (1.2)</td>
<td>97 (0.6)</td>
</tr>
<tr>
<td>Chicago Public Schools, IL</td>
<td>3 (1.1)</td>
<td>11 (2.4)</td>
<td>34 (3.9)</td>
<td>67 (3.8)</td>
</tr>
<tr>
<td>Delaware Science Coalition, DE</td>
<td>10 (1.8)</td>
<td>29 (4.0)</td>
<td>56 (4.2)</td>
<td>83 (2.1)</td>
</tr>
<tr>
<td>First in the World Consort., IL</td>
<td>27 (3.7)</td>
<td>54 (3.6)</td>
<td>85 (2.0)</td>
<td>97 (0.9)</td>
</tr>
<tr>
<td>Fremont/Lincoln/WestSide PS, NE</td>
<td>11 (1.7)</td>
<td>32 (3.1)</td>
<td>63 (3.2)</td>
<td>86 (2.1)</td>
</tr>
<tr>
<td>Guilford County, NC</td>
<td>19 (2.5)</td>
<td>43 (3.6)</td>
<td>69 (3.5)</td>
<td>90 (2.0)</td>
</tr>
<tr>
<td>Jersey City Public Schools, NJ</td>
<td>3 (1.5)</td>
<td>11 (3.1)</td>
<td>31 (3.6)</td>
<td>64 (3.5)</td>
</tr>
<tr>
<td>Miami-Dade County PS, FL</td>
<td>4 (1.4)</td>
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</tr>
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<td>25 (3.1)</td>
<td>54 (3.0)</td>
<td>84 (2.1)</td>
<td>96 (1.1)</td>
</tr>
<tr>
<td>Montgomery County, MD</td>
<td>17 (1.1)</td>
<td>40 (2.5)</td>
<td>70 (2.3)</td>
<td>91 (1.3)</td>
</tr>
<tr>
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</tr>
<tr>
<td>Rochester City Sch. Dist., NY</td>
<td>3 (1.3)</td>
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<td>33 (3.7)</td>
<td>68 (3.0)</td>
</tr>
<tr>
<td>SW Math/Sci. Collaborative, PA</td>
<td>19 (3.1)</td>
<td>45 (3.6)</td>
<td>75 (3.5)</td>
<td>94 (1.7)</td>
</tr>
</tbody>
</table>

Top 10% Benchmark (90th Percentile) 616
Upper Quarter Benchmark (75th Percentile) 558
Median Benchmark (50th Percentile) 488
Lower Quarter Benchmark (25th Percentile) 410

States in italics did not fully satisfy guidelines for sample participation rates (see Appendix A for details).
† Met guidelines for sample participation rates only after replacement schools were included (see Exhibit A.6).
‡ National Defined Population covers less than 90 percent of National Desired Population (see Exhibit A.3).
Standard errors appear in parentheses. Because results are rounded to the nearest whole number, some totals may appear inconsistent.
15.5.2 Reporting Student Achievement at the International Benchmarks

To compare student performance at the international benchmarks, TIMSS computed the percentage of students in each Benchmarking jurisdiction reaching each international benchmark. These percentages and their standard errors are presented in Exhibit 15.6 for mathematics and in Exhibit 15.7 for science.

15.6 Reporting Gender Differences

TIMSS reported gender differences in student achievement in mathematics and science overall, as well as in content areas. Gender differences in countries and Benchmarking jurisdictions were presented in an exhibit showing mean achievement for males and females, the differences between them, and an accompanying graph indicating whether the difference was statistically significant. The significance test was adjusted for multiple comparisons, based on the number of countries presented.

Because in most countries males and females attend the same schools, the two samples cannot be treated as independent for the purpose of statistical tests. Accordingly, TIMSS used a jackknife procedure applicable to correlated samples for estimating the standard error of the male-female difference. This involves computing the differences between boys and girls once for each of the 75 replicate samples, and five more times, once for each plausible value, as described in chapter 11.

15.7 Relative Performance by Content Areas

In addition to performance in mathematics and science overall, it was of interest to see how Benchmarking participants and countries performed on the content areas relative to performance on the subject overall. Five content areas in mathematics and six in science were used in this analysis. Relative performance on the content areas was examined separately for the two subjects. The average across content area scores was computed for each jurisdiction, and then performance in each content area was shown as the difference between that average and the overall average. Confidence intervals were estimated for each difference.

In order to do this, TIMSS computed the vector of average proficiencies for each of the content areas on the test, and joined each vector to form a matrix called $R_{ks}$, where a row contained the average proficiency score for jurisdiction $k$ on scale $s$ for a specific subject. This $R_{ks}$ matrix had also a “zeroth” row and column. The elements in $r_{0k}$ contained the average of the elements on the $k^{th}$
row of the $R_{kj}$ matrix. These were the jurisdiction averages across the content areas. The elements in $r_{ij}$ contained the average of the elements of the $s^{th}$ column of the $R_{kj}$ matrix. These were the content area averages across all jurisdictions. The element $r_{j0}$ contained the overall average for the elements in vector $r_j$ or $r_{ks}$. Based on this information, the matrix $I_{ki}$ was constructed in which the elements are computed as

$$i_{ks} = r_{ks} + r_{j0} - r_{ks} - r_{k0}.$$ 

Each of these elements can be considered as the interaction between the performance of jurisdiction $k$ in content area $s$. A value of zero for an element $i_{ks}$ indicates a level of performance for jurisdiction $k$ in content area $s$ that would be expected given its performance in other content areas and its performance relative to other jurisdictions on that content area. A negative value for an element $i_{ks}$ indicates a performance for jurisdiction $k$ on content area $s$ lower than would be expected on the basis of the jurisdiction’s overall performance. A positive value for an element $i_{ks}$ indicates a better than expected performance for jurisdiction $k$ in the content areas. This procedure was applied to each of the five plausible values and the results were averaged.

To construct confidence intervals, the standard error for each content area in each jurisdiction first had to be estimated. These were then combined with a Bonferroni adjustment, based on the number of content areas. The imputation portion of the error was obtained from combining the results from the five calculations, one with each separate plausible value.

To compute the sampling portion of the standard error, the vector of average proficiency was computed for each of the jurisdiction replicates for each content area in the test. For each jurisdiction and each content area, 75 replicates were created. Each replicate was randomly reassigned to one of 75 sampling zones or replicates ($h$). These column vectors were then joined to form a new set of matrices each called $R_{hs}^k$, where a row contains the average proficiency for jurisdiction $k$ in content area $s$ for a specific subject, for the $h^{th}$ international set of replicates. Each of these $R_{hs}^k$ matrices has also a zero $0^{th}$ row and...

---

2. In countries and jurisdictions where there were fewer than 75 jackknife zones, 75 replicates were also created by assigning the overall mean to as many replicates as were necessary to have 75.
The elements in \( r_{k0}^h \) contain the average of the elements on the \( k^\text{th} \) row of the \( R^h_{ks} \) matrix. These are the jurisdiction averages across the content areas. The elements in \( r_{0s}^h \) contain the average of the elements of the \( s^\text{th} \) column of the \( R^h_{ks} \) matrix. These are the content area averages across all countries. The element \( r_{00}^h \) contains the overall average for the elements in vector \( r_{0j}^h \) or \( r_{k0}^h \). Based on this information the set of matrices \( R^h_{ks} \) were constructed, in which the elements were computed as

\[
i_{ks}^h = r_{ks}^h + r_{0s}^h - r_{k0}^h.
\]

The jackknife repeated replication (JRR) standard error is then given by the formula

\[
jse_{ks}^h = \sqrt{\frac{\sum_h (i_{ks}^h - i_{ks})^2}{n}}.
\]

The overall standard error was computed by combining the JRR and imputation variances. A relative performance was considered significantly different from the expected if the 95% confidence interval built around it did not include zero. The confidence interval for each of the \( i_{ks} \) elements was computed by adding to and subtracting from the \( i_{ks} \) element its corresponding standard error multiplied by the critical value for the number of comparisons.

The critical values were determined by adjusting the critical value for a two-tailed test, at the \( \alpha = .05 \) level of significance for multiple comparisons according the Dunn-Bonferroni procedure. The critical value for mathematics, with five content scales, was 2.5758, and for science, with six content scales, was 2.6383.

### 15.8 Percent Correct for Individual Items

To portray student achievement as fully as possible, the TIMSS 1999 Benchmarking Reports present many examples of the items used in the TIMSS 1999 tests, together with the percentage of students in each jurisdiction responding correctly to the item. These percentages were based on the total number of students tested on the items. Omitted and not-reached items were treated as incorrect. For multiple-choice items the percentage was the weighted percentage of students that answered the item correctly. For free-response items with more than one score level, it was the weighted percentage of students that achieved the highest score possible.
When the percent correct for example items was computed, student responses were classified in the following way. For multiple-choice items, a response to item \( j \) was classified as correct \((C_j)\) when the correct option was selected, incorrect \((W_j)\) when the incorrect option or no option was selected, invalid \((I_j)\) when two or more options were selected, not reached \((R_j)\) when it was assumed that the student stopped working on the test before reaching the question, and not administered \((A_j)\) when the question was not included in the student’s booklet or had been mistranslated or misprinted. For free-response items, student responses to item \( j \) were classified as correct \((C_j)\) when the maximum number of points was obtained, incorrect \((W_j)\) when the wrong answer or an answer not worth all the points in the question was given, invalid \((N_j)\) when the response was not legible or interpretable or was simply left blank, not reached \((R_j)\) when it was determined that the student stopped working on the test before reaching the question, and not administered \((A_j)\) when the question was not included in the student’s booklet or had been mistranslated or misprinted. The percent correct for an item \( (P_j) \) was computed as

\[
P_j = \frac{c_j}{c_j + w_j + i_j + r_j + n_j}
\]

where \( c_j, w_j, i_j, r_j \) and \( n_j \) are the weighted counts of the correct, wrong, invalid, not reached, and not interpretable responses to item \( j \), respectively.
References


